CABINET OF CURIOSITIES

Jacob's Wunderkammer

JACOB P. SAUNDERS

Self-published in Chicago for the amusement and edification of friends, family, & colleagues.

Artificial intelligence and Seymour Cray's elves were employed in the creation of this work. No elves were harmed.

www.jacobsaunders.com/cabinet

Rev 7.8

Das Kabinett

"Wunderkammern, or cabinets of curiosities, arose in mid-sixteenth-century Europe as repositories for all manner of wondrous and exotic objects. In essence these collections – combining specimens, diagrams, and illustrations from many disciplines; marking the intersection of science and superstition; and drawing on natural, manmade, and artificial worlds – can be seen as the precursors to museums."

Some years ago, I came across a Kickstarter campaign for something called a Mini Museum. I purchased one and was fascinated by all the items floating weightlessly trapped in glass-like acrylic, and by the historical sweep and scope of the artifacts. I could stare at it for ages trying to imagine the journey each had taken to get to me.

I ended up buying another, and another, and then found a sample of graphite from the world's first nuclear reactor embedded in acrylic Lucite. Because of my loose family connection to the Manhattan Project I thought it would be a cool addition, and that was the beginning of this collection.

Some of these things were inexpensive, others are priceless. Some are common, of others there are only a handful or even a single one. I have purchased objects at auctions, from other collectors, online, through social media, and from new friends. Sometimes I have hunted down a particular object for years, some I've discovered by happenstance. Packages have come from all corners of the world.

One day as I was standing in my office pondering the histories of these various little treasures and the many interrelationships between their stories, I realized that nobody other than I would have any idea what they were looking at. I decided to catalogue and document the items; you are looking at the result. Each chapter is chronological, but all are interdependent. If I have succeeded, the whole is more interesting than the sum of its parts.

I hope you enjoy browsing my Cabinet, I had fun creating it and learned many things.

Jacob

Many of the objects are very small, you can find most of them in the picture on the previous page. See how many you can spot!

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Misadventures with Atoms

Lucite with Graphite from First Nuclear Reaction, Manhattan Project, Chicago, 1942

A curious sight indeed would have greeted a visitor viewing preparations for this historic moment in 1942. In an abandoned squash court under the west grandstand of the University of Chicago's Stagg Field there lay a huge oblong pile of black graphite bricks and wooden timbers, covered on all sides but one by gray balloon material. Security regulations had forbidden the engineers from explaining to Goodyear what the Army wanted with a giant square balloon. In the freezing cold, workers and scientists had built the pile by stacking layers of the bricks, which had to be cut exactly to fit closely together, on top of a crude framing. Some were drilled with holes to fit lumps of uranium inside. Others were drilled to fit 14-foot rods. Workers cut lumber and machined bricks for the pile until their faces were so covered with graphite dust that they looked like coal miners. They sang together to pass the time during their 12-hour shifts, and afterwards it took them half an hour to remove the graphite dust from their skin. The dust also made the floor dangerously slippery. This was the Manhattan Project, the effort to build a bomb that would win the apocalyptic war that had engulfed the planet, operating at U of C under the fictional name "Metallurgical Laboratory" or "Met Lab", and this curious assemblage was Chicago Pile-1, the world's first nuclear reactor.

Over Christmas vacation in 1938, German physicists Lise Meitner and Otto Frisch had received puzzling scientific news in a private letter from nuclear chemist Otto Hahn. When bombarding uranium with neutrons, Hahn had made some surprising observations. Meitner and Frisch were able to provide an explanation for what he saw that would revolutionize the field: a uranium nucleus could split in half – or fission, as they called it. In 1933, Physicist Leo Szilard had conceived the idea of a nuclear chain reaction while waiting at a traffic light in London. He realized that if an element could be found that, when bombarded by one neutron, would release two neutrons, it could lead to a chain reaction releasing vast amounts of energy. The more atoms that split, the more energy they would release. The discovery at the dawn of World War II that uranium behaves thusly, and that its nucleus, when bombarded with a neutron, splits and releases two to three neutrons in turn, began the quest to prove experimentally that a nuclear chain reaction was possible.

August "Gus" Knuth was a millwright and carpenter, who helped construct Chicago Pile-1 and was present when it went critical.

Much of the research was being conducted in Nazi Germany, and Szilard drafted a confidential letter to U.S. President Franklin D. Roosevelt, explaining the possibility of nuclear weapons, warning of a German nuclear weapon project, and encouraging the development of a program that could result in their creation. The Nazis could not be allowed to develop this super-weapon first. He approached his old friend and collaborator Albert Einstein in August 1939, and convinced him to sign the letter, lending his prestige to the proposal. The Einstein–Szilard letter resulted in U.S. government funding of research into nuclear chain reactions, initiated at once by Leo Szilard and Italian physicist Enrico Fermi at Columbia University.

Daily the pile grew, brick by brick. What the outsider would not have understood – but what the men and women who would operate it certainly did – was how dangerous this pile of wood and bricks really was. The timbers supported a lattice structure that contained over six tons of pure uranium metal, along with 34 more tons of uranium oxide. The 400 tons of black bricks in the assembly were graphite, placed there to serve as moderators; the bricks in two of every three layers had a nodule of uranium inside each of them. The presence of so much "moderating" material might have sounded comforting until one learned that the moderators were there to increase the amount of fission produced by the uranium. The only things preventing a chain reaction from growing within the pile were a series of cadmium control rods inserted into the pile's side to absorb the free neutrons emitted by the uranium.

Chicago Historical Society

Tests on the early afternoon of December 1 indicated the experiment was close to being ready. By that evening, the scientists were convinced that if they withdrew the cadmium control rods the fission chain reaction in the pile would be self-sustaining. Unlike most reactors that have been built since, this first one had no radiation shielding and no cooling system of any kind. Fermi was convinced that his calculations were reliable enough to rule out a runaway chain reaction or an explosion, but the gamble remained in conducting a possibly catastrophic experiment in one of the most densely populated areas of the nation. When asked what he would do if anything went wrong, he replied, "I will walk away – leisurely".

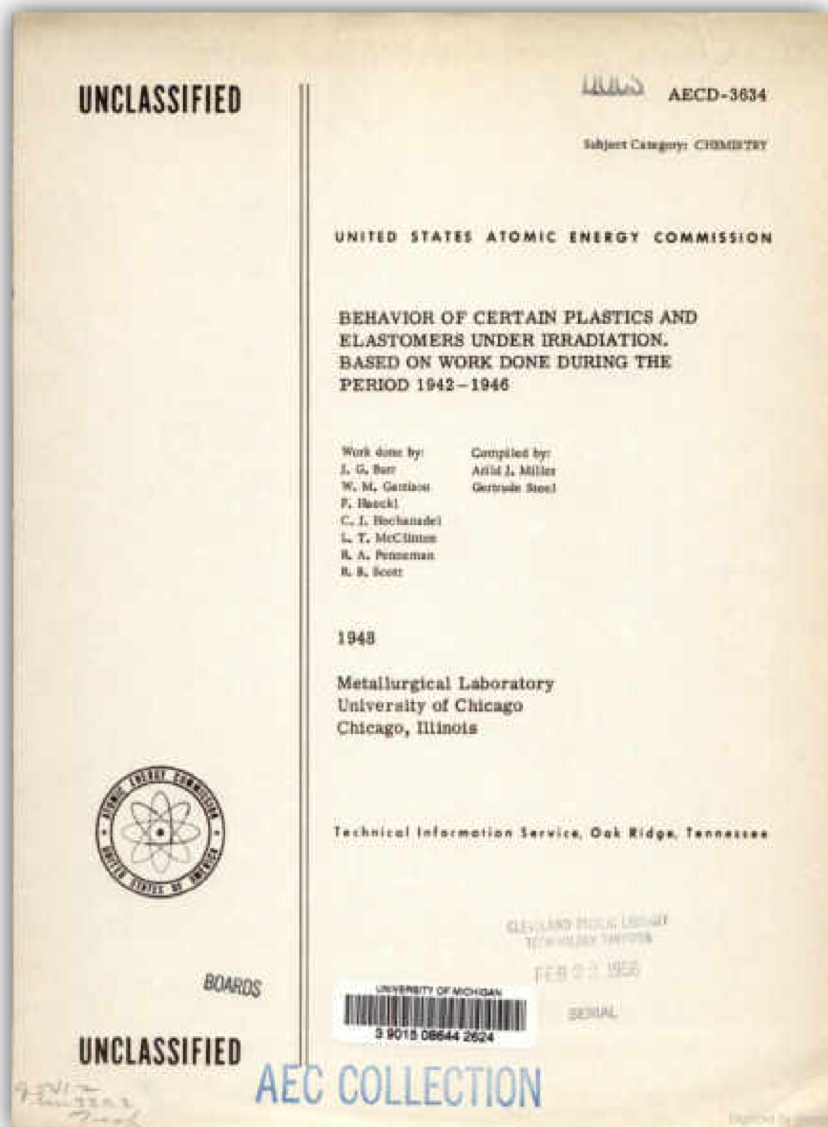
The next morning, 49 scientists, led by Fermi, crowded onto a balcony where squash spectators had once stood. Fermi and some of the others huddled around an instrument console; from there they could operate one set of control rods. The only person on the floor of the squash court was George Weil, the man who would physically withdraw the final control rod. If the reaction threatened to grow out of control he could re-insert his control rod, and an automatic control rod would also insert itself if the reaction reached a certain level.

In case of emergency, such as Weil becoming incapacitated or failure of the automatic control rod, another man stood on the balcony with an improbable nuclear safety device: an axe. If needed, he would cut a rope that ran up to the balcony, releasing another control rod into the pile. The last line of defense consisted of a "liquid-control squad" that stood on a platform, ready to flood the pile with a cadmium-salt solution.

Some signatures on the straw are still faintly visible.

The rods were removed one by one. At first you could hear the sound of the neutron counter, clickety-clack, clickety-clack. All eyes turned to the array of instruments indicating the pace of the reaction within the pile. The clicks came more and more rapidly, and after a while they began to merge into a roar. One of the scientists continued to call out the neutron count over a speaker system. After Fermi completed one final calculation, his face broke into a broad smile, he raised his hand, and announced "the reaction is self-sustaining." Quiet applause rippled through the room. For the first time in history, humans had unleashed and controlled the power of the sun. The reactor was generating about half a watt, barely enough to power a small light bulb. After 28 minutes of operation, Fermi ordered the emergency control rod replaced. The neutron counter abruptly slowed; the chain reaction was over. Eugene Wigner broke out a bottle of Bertolli Chianti he had been saving for the occasion. The scientists drank it out of paper cups and afterwards they all signed the straw wrapping.

A few hours later, Arthur Compton, the director of the Met Lab, called his boss Jim Conant. No code had been prearranged so they had to make one up on the spot. Compton told Conant "The Italian navigator has landed in the New in the New World". "How were the natives?" asked Conant. "Very friendly" was the reply.



UNCLASSIFIED

AECD-3634

Subject Category: CHEMISTRY

UNITED STATES ATOMIC ENERGY COMMISSION

BEHAVIOR OF CERTAIN PLASTICS AND ELASTOMERS UNDER IRRADIATION. BASED ON WORK DONE DURING THE PERIOD 1942–1946

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Compiled by:
Arild J. Miller
Gertrude Stoel

1948

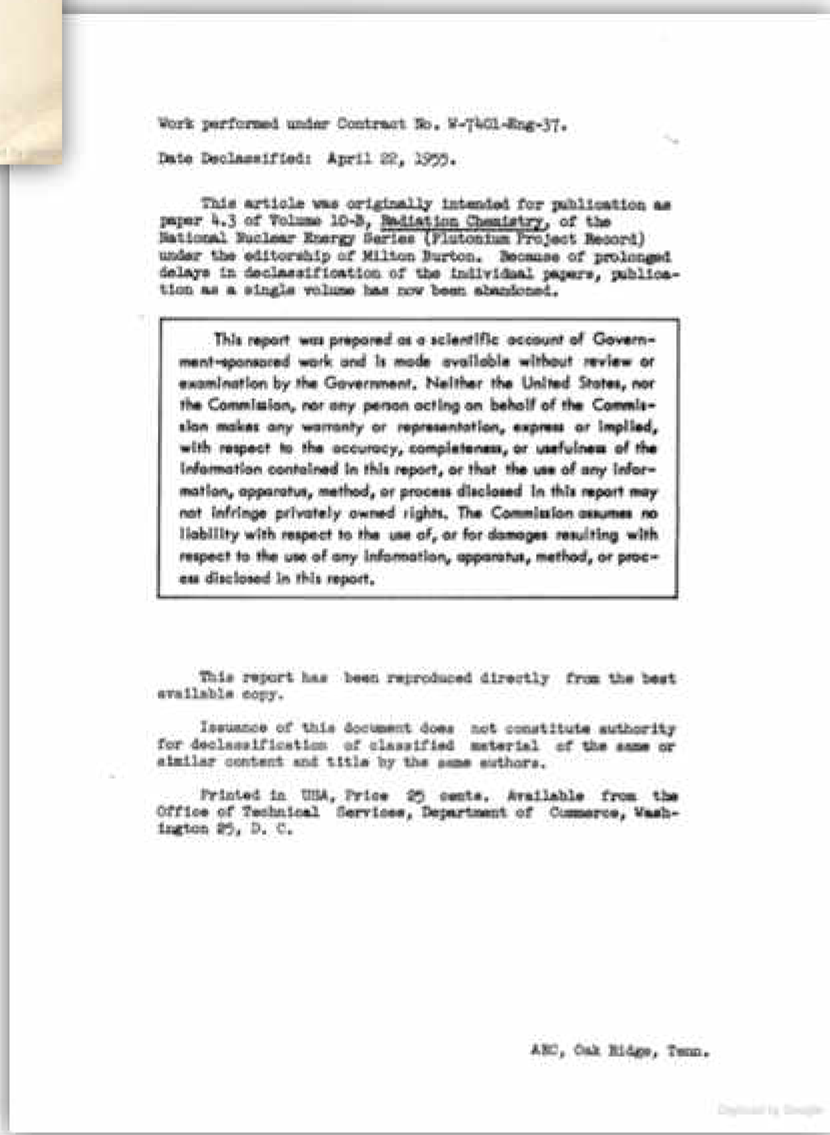
Metallurgical Laboratory
University of Chicago
Chicago, Illinois

Technical Information Service, Oak Ridge, Tennessee

UNCLASSIFIED

My great uncle Arild "Spike" Miller spent part of a year studying nuclear fission in Copenhagen with Niels Bohr, and went on to work on the Manhattan Project in Chicago in chemistry Section C-II and later for the Tennessee Eastman Corporation at the Y-12 Plant at Oak Ridge, studying among other things the effect of radiation on plastics. He never spoke of his work as far as I know, but after the war compiled the paper shown here.

Compiled by:
Arild J. Miller



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Date Declassified: April 22, 1955.

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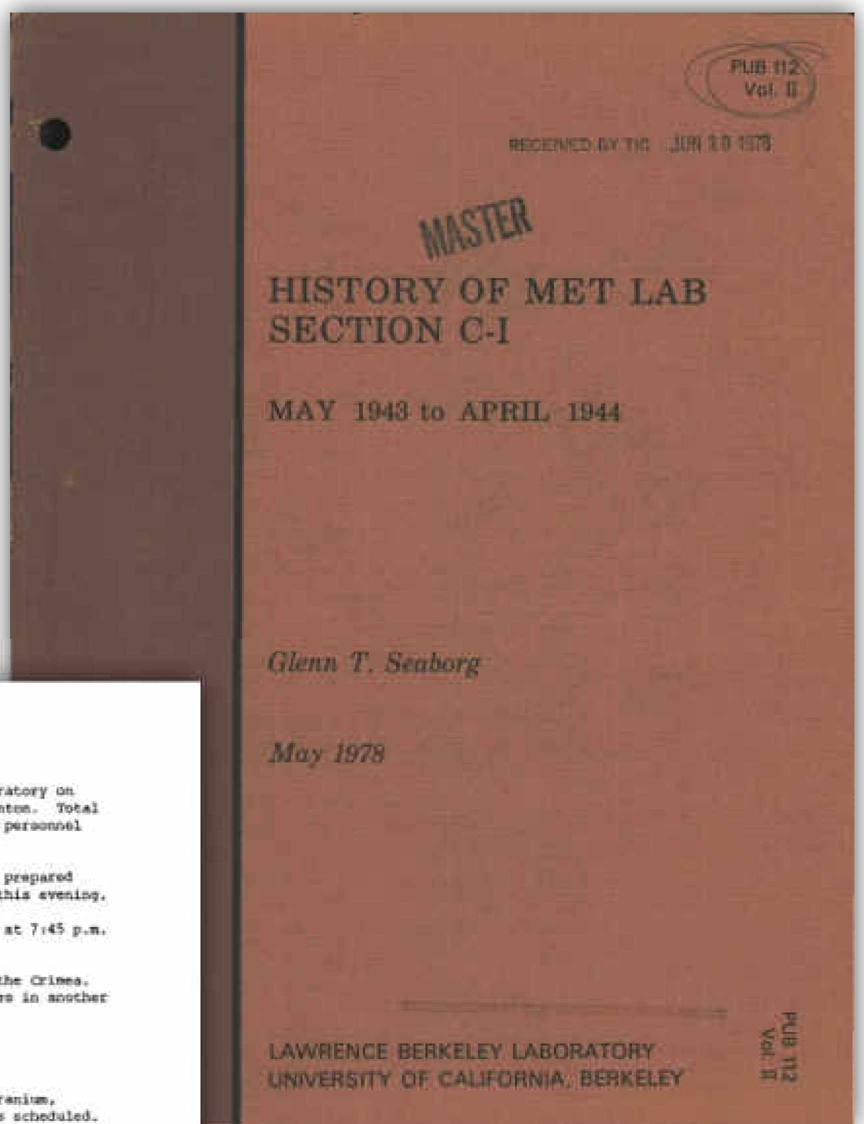
AEC, Oak Ridge, Tenn.

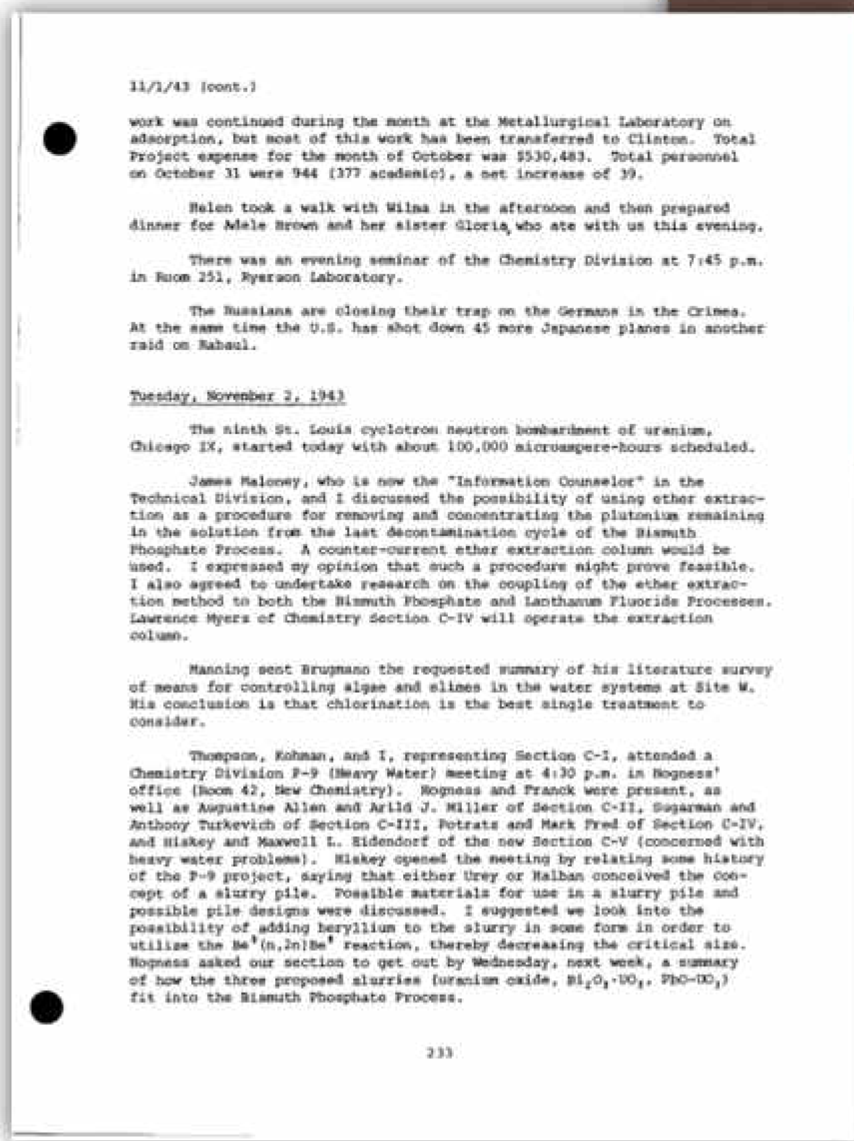
Like many of the scientists and engineers who worked on the Manhattan Project, Arild struggled with the perils and benefits of developing a nuclear bomb, and he believed science and religion are not mutually exclusive.

His wife – my great aunt – Jean Saunders Miller also worked on the project in an administrative role, and told me a great story once while we were having a glass of wine in Cinque Terre. Apparently when they were drawing cooling water, they kept getting fish in the system and they had to send frogmen to secretly install grates to keep the fish from getting stuck in the nuclear reactor. CP-1 was not water cooled so it couldn't have been Lake Michigan, perhaps this was CP-IX. Or the story could be apocryphal.

After the war, Arild and Jean moved to Yellow Springs, Ohio, and back to his alma mater in Northfield, WI. In 1957, the family traveled around Europe in a VW camper. In 1960 the family moved to Appleton, Wisconsin, where Arild joined the faculty of the Institute of Paper Chemistry until his retirement, and subsequent death in 1998.

The paper shown on this page is a history of the "Metallurgical Laboratory" and mentions him in the context of heavy water issues, just after a comment about algae and slime in the supply.





11/1/43 (cont.)

work was continued during the month at the Metallurgical Laboratory on adsorption, but most of this work has been transferred to Clinton. Total Project expense for the month of October was $530,483. Total personnel on October 31 were 944 (377 academic), a net increase of 39.

Helen took a walk with Wilma in the afternoon and then prepared dinner for Adele Brown and her sister Gloria, who ate with us this evening.

There was an evening seminar of the Chemistry Division at 7:45 p.m. in Room 251, Ryerson Laboratory.

The Russians are closing their trap on the Germans in the Crimea. At the same time the U.S. has shot down 45 more Japanese planes in another raid on Rabaul.

Tuesday, November 2, 1943

The ninth St. Louis cyclotron neutron bombardment of uranium, Chicago IX, started today with about 100,000 microampere-hours scheduled.

James Maloney, who is now the "Information Counselor" in the Technical Division, and I discussed the possibility of using ether extraction as a procedure for removing and concentrating the plutonium remaining in the solution from the last decontamination cycle of the Bismuth Phosphate Process. A counter-current ether extraction column would be used. I expressed my opinion that such a procedure might prove feasible. I also agreed to undertake research on the coupling of the ether extraction method to both the Bismuth Phosphate and Lanthanum Fluoride Processes. Lawrence Myers of Chemistry Section C-IV will operate the extraction column.

Manning sent Brugmann the requested summary of his literature survey of means for controlling algae and slimes in the water systems at Site W. His conclusion is that chlorination is the best single treatment to consider.

Thompson, Kohman, and I, representing Section C-I, attended a Chemistry Division P-9 (Heavy Water) meeting at 4:30 p.m. in Hogness' office (Room 42, New Chemistry). Hogness and Franck were present, as well as Augustine Allen and Arild J. Miller of Section C-II, Sugarman and Anthony Turkevich of Section C-III, Potratz and Mark Fred of Section C-IV, and Hiskey and Maxwell L. Eidendorf of the new Section C-V (concerned with heavy water problems). Hiskey opened the meeting by relating some history of the P-9 project, saying that either Urey or Halban conceived the concept of a slurry pile. Possible materials for use in a slurry pile and possible pile designs were discussed. I suggested we look into the possibility of adding beryllium to the slurry in some form in order to utilize the $Be^9(n,2n)Be^8$ reaction, thereby decreasing the critical size. Hogness asked our section to get out by Wednesday, next week, a summary of how the three proposed slurries (uranium oxide, $Bi_2O_3 \cdot UO_3$, $PbO-UO_3$) fit into the Bismuth Phosphate Process.

233

This Lucite puck contains a piece of graphite from that first chain reaction under the old stadium. It was the first Lucite embedded artifact I purchased after my earliest Mini Museums, and formed the seed of my collection.

Manhattan Project Plutonium Recovery Building Shield Window Fragment, 1944

Unfortunately, naturally occurring uranium does not have the right amount of the fissile isotope, known as uranium-235, needed to set off an explosive nuclear reaction. To make it suitable for use in a weapon, the amount of U-235 in uranium must be increased through a process of "enrichment", or isotope separation. Plutonium can be used instead of uranium to make an atomic weapon, but can only be made in a nuclear reactor. After the initial success of a sustained chain reaction, the Manhattan Project needed to rapidly achieve a series of breakthroughs to produce these materials.

Two potential types of weapon were designed, one of them a simpler model triggered by internal gun, which used uranium, and a more complex design involving the implosion of a hollow plutonium sphere using shaped explosives. The former design was used for the bomb known as "Little Boy" which would be dropped on Hiroshima, the latter for the first test of an atomic bomb and for the "Fat Man" device dropped on Nagasaki.

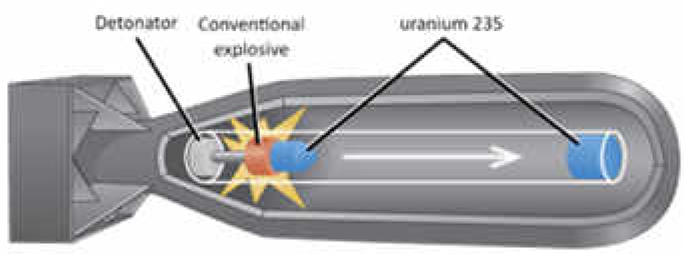
Massive facilities were quickly built to concoct the necessary ingredients for these bombs. The enormous Manhattan Project grew to involve over one hundred thousand scientists, engineers, technicians, and construction workers at more than 30 sites across the United States, including well-known locations such as Oak Ridge, Los Alamos, Trinity, and Hanford in southern Washington state. The B Reactor, located on a remote corner of the Hanford site, produced the plutonium needed for the first test detonation and for "Fat Man", the bomb ended World War II.

B Reactor.

This artifact is a fragment of a leaded glass shield window installed in Hanford's T Plant (221-T) Plutonium Recovery Building, the first and largest of two production bismuth-phosphate chemical separations plants used to extract plutonium (Pu-239) from fuel rods irradiated in B Reactor. The glass was sold during a government surplus auction in the late 1980s as part of the long decommissioning process.

The yellow color of the glass is due to a high concentration of lead-oxide (up to 70%), which blocks blue and near-UV spectral frequencies, and also gives the glass its protective qualities.

Uranium Bomb - Gun Type

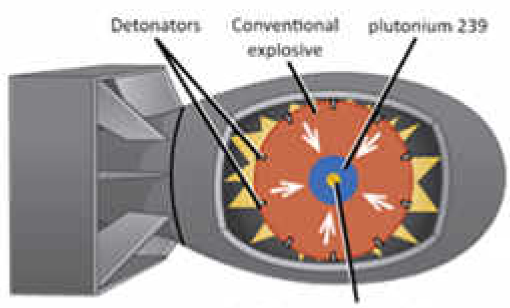


One piece of uranium is fired into another

Plutonium recovery.

This fragment of glass comes from Mini Museum.

Plutonium Bomb - Implosion



A shell of high explosives crushes a plutonium core

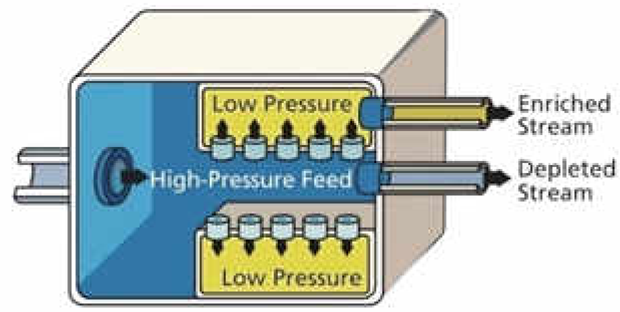
OpenStax / CC BY 4.0 / Modified

Hard Hat Shaped Lucite with Brick from Oak Ridge K-25 Building, 1944

K-25 was the codename given by the Manhattan Project to the program to produce enriched uranium for "Little Boy" using a method known as gaseous diffusion. Originally the codename for the product, over time it came to refer to the project, the production facility located at the Clinton Engineer Works (CEW) in Oak Ridge, Tennessee, the main building, and ultimately the site.

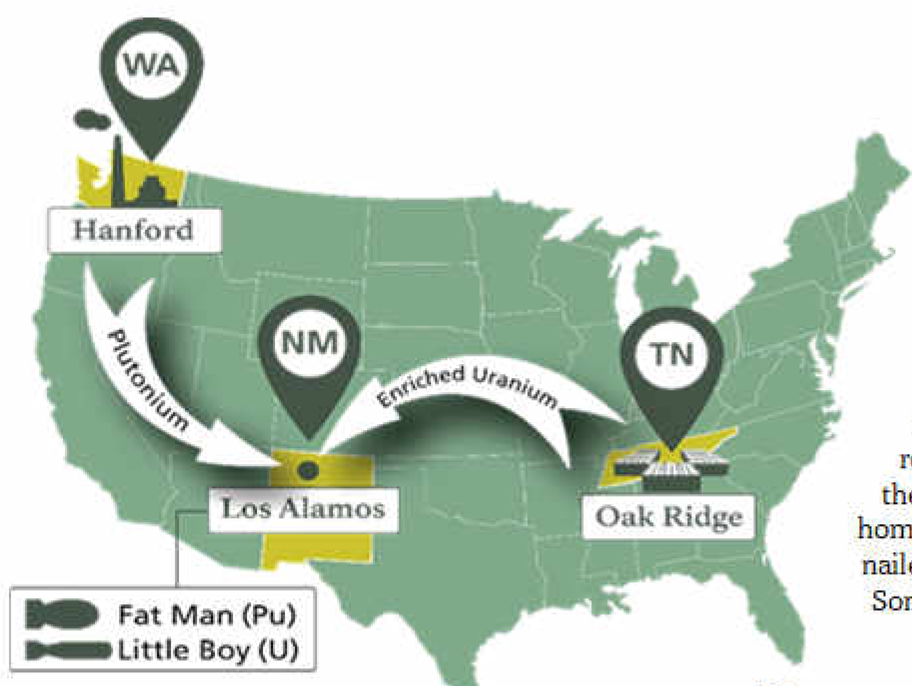
When it was built in 1944, the four-story K-25 plant was the world's largest building, comprising over 5,264,000 square feet of floor space and a volume of 97,500,000 cubic feet. This was even larger than the recently completed Pentagon. At the height of construction, over 25,000 workers were employed on the sprawling job site.

Out of several methods of isotope separation, the most promising but also the most challenging at the time was gaseous diffusion. Graham's law states that the rate of effusion of a gas is inversely proportional to the square root of its molecular mass, so in a box containing a semi-permeable membrane and a mixture of two gases, the lighter molecules will pass out of the container more rapidly than the heavier molecules. The gas leaving the container is somewhat enriched in the lighter molecules, while the residual gas is somewhat depleted. The idea was that such boxes could be formed into a cascade of pumps and membranes, with each successive stage containing a slightly more enriched mixture. Uranium hexafluoride, a highly corrosive substance, was the only known compound of uranium sufficiently volatile to be used in the process.



NRC / CC BY-SA 2.0

In November 1942 the military approved the construction of a 600-stage gaseous diffusion plant. In December 1942, the Manhattan Project contracted M. W. Kellogg to design, build and operate such a full-scale production plant. Unusually, the contract did not require any guarantees from Kellogg that it could actually accomplish the task. For security reasons, the Army had Kellogg establish a wholly owned subsidiary, the Kellex Corporation, so the project could be kept separate from other company work.



Sites for the plant were considered in the Tennessee Valley, two in the Chicago area, one near the Shasta Dam in California, and in Washington state, where the Hanford site was eventually established. The most promising was about 12 miles west of Knoxville, Tennessee. Over 1,000 families lived on the site on farms or in the hamlets of Elza, Robertsville, and Scarboro. The first that most heard about their eviction was when a representative visited to inform them that their land was being acquired. Some returned home from work to find an eviction notice nailed to their door or to a tree in the yard. Some were given just two weeks to leave.

Typical K-25 "withdrawal alley".

For some it was the third time that they had been evicted by the government, having previously been evicted for the Great Smoky Mountains National Park in the 1920s and the TVA's Norris Dam in the 1930s. Many expected that, like the TVA, the Army would provide assistance to help them relocate; but unlike the TVA, the Army had no mission to improve the area or the lot of the local people, and no funds for the purpose. Tires were in short supply in wartime America, and moving vehicles were hard to find. Some residents had to leave possessions behind.

The CEW – built where they had lived – produced the enriched uranium used in the bombing of Hiroshima, as well as the first examples of reactor-produced plutonium.

Today, uranium isotope separation is usually done by the more energy-efficient ultra-centrifuge process, developed in the Soviet Union after World War II by Soviet and captured German engineers working in detention. Production of enriched uranium at the K-25 site ended in 1964, and gaseous diffusion finally ceased on the site on 27 August 1985. Since 2020, the K-25 site is being redeveloped in part into a general aviation airport to service the city of Oak Ridge. Several small private nuclear facilities are also planned on the site.

This artifact was purchased from the widow of Gary Wayne Young, Jr., a Rigging Engineer and Lift Planner at Oak Ridge National Laboratory.

On the reverse:
"Built in 1944 as part of the Manhattan Project, K-25 and its workers will always be remembered."

The largest building in the world.

Lucite with Trinitite from First Nuclear Explosion, 1945

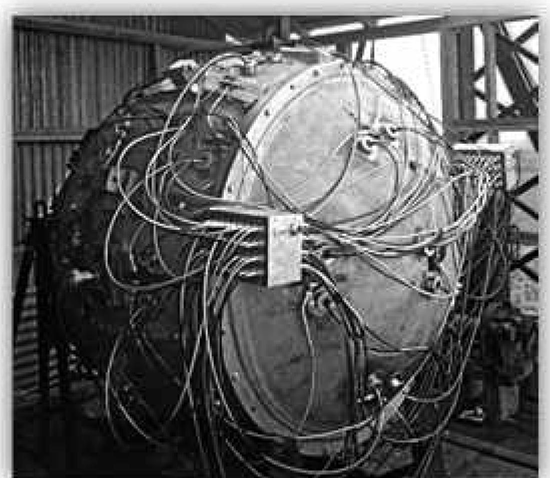
The efforts of the Manhattan Project finally came to fruition in 1945. After three years of research and experimentation, the world's first nuclear device, the "Gadget", was successfully detonated in the New Mexico desert. The test was conducted at the Alamogordo Bombing and Gunnery Range, 230 miles south of Los Alamos. The site, located in the Jornada Del Muerto Desert, was chosen for its isolation, flat ground, and lack of windy conditions. J. Robert Oppenheimer, Director of the Los Alamos Laboratory during the Manhattan Project, called the site "Trinity", a reference to a poem by John Donne. The name stuck and became the site's official code name.

The nuclear device detonated at Trinity, nicknamed "Gadget", was shaped like a large steel globe. Like the Fat Man bomb dropped on Nagasaki, it was a plutonium implosion device.

Though more complex, plutonium implosion devices are more efficient and powerful than gun-type uranium bombs like the Little Boy bomb detonated over Hiroshima. Plutonium implosion devices use conventional explosives around a central plutonium mass to quickly squeeze and consolidate the plutonium, increasing the pressure and density of the substance. An increased density allows plutonium-239 to reach its critical mass, firing neutrons and allowing the fission chain reaction to proceed. To detonate the device, the explosives were ignited, releasing a shock wave that compressed the fissile material and led to its explosion.

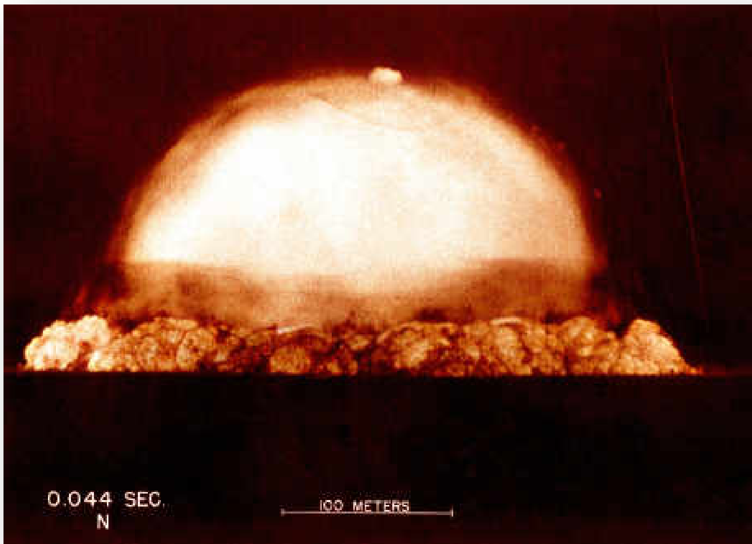
Closeup.

Despite the hundreds of man-hours spent preparing for this moment, many were still unsure that the bomb would detonate the way it was designed to. The Army Public Relations Department prepared somber explanations in the event of disaster. On July 16, a thunderstorm delayed the test, which was initially scheduled for 4:00 AM. Hubbard's team determined that optimal weather conditions would only be present between 5:00 and 6:00 AM. Groves famously told Hubbard that "I will hang you" if he was incorrect. Luckily for Hubbard, the weather did clear. The complex array of cables, wires, switches, and detonators all worked in unison, and at 5:29:45, Gadget detonated with 21 kilotons of force, slightly more than the Little Boy bomb later dropped on Hiroshima. It was an explosion of energy unlike any the world had ever seen.



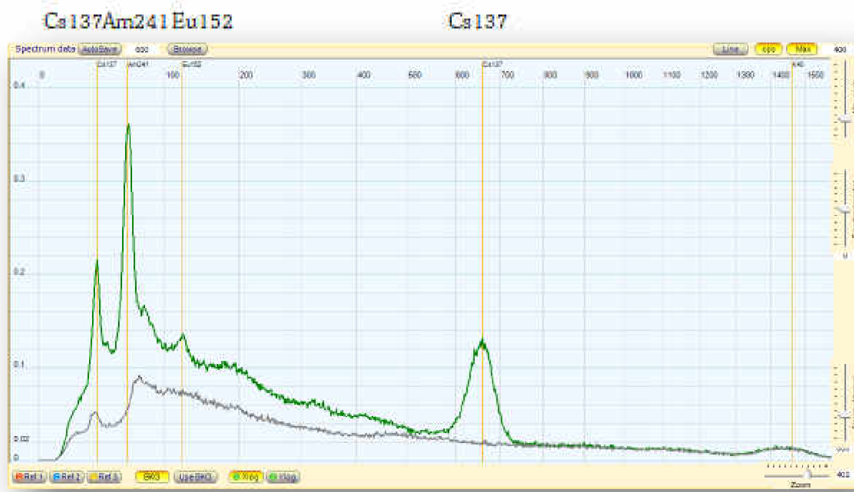
The "Gadget".

Brigadier General Thomas F. Farrell was bewildered by how "the whole country was lighted by a searing light with the intensity many times that of the midday sun. It was golden, purple, violet, gray and blue. It lighted every peak, crevasse, and ridge of the nearby mountain range with a clarity and beauty that cannot be described but must be seen to be imagined. It was that beauty the great poets dream about but describe most poorly and inadequately". J. Robert Oppenheimer came close to capturing the moment, quoting the Bhagavad Gita: "Now I am become death, destroyer of worlds."



Trinitite is the glassy residue that was left on the desert floor after the Trinity test. The glass is primarily composed of arkosic sand composed of quartz grains and feldspar, and was first academically described in American Mineralogist in 1948. It is usually a light green, although red trinitite was also found in one section of the blast site, and rare pieces of black trinitite also formed. It is mildly radioactive but safe to handle. Pieces of the material may still be found at the Trinity site, although most of it was bulldozed and buried by the United States Atomic Energy Commission in 1953.

The mineral was formed by sand which was drawn up inside the fireball itself and then rained down in a liquid form. Contained within the glass are melted bits of the bomb itself and its support structures, and various radionuclides formed during the detonation. Trinitite itself is marvelously complex, and besides glasses of varying composition also contains unmelted quartz grains. Air transport of the melted material led to the formation of spheres and dumbbell shaped particles. Similar glasses are formed during all ground level nuclear detonations and contain forensic information that can be used to identify the atomic device.



From the gamma spectra in the image above, the presence of the isotopes cesium-137, americium-241, and europium-152 is clearly visible. The americium and the cesium in particular give rise to evident photo-peaks. The presence of these isotopes is the characteristic "signature" of authentic trinitite. Let's look at their origin.

Cesium-137 is a radioactive isotope of the alkali metal cesium which is formed primarily as a by-product of nuclear fission. The nuclear bomb that exploded in the Trinity test started with plutonium-239 as its fissile material.

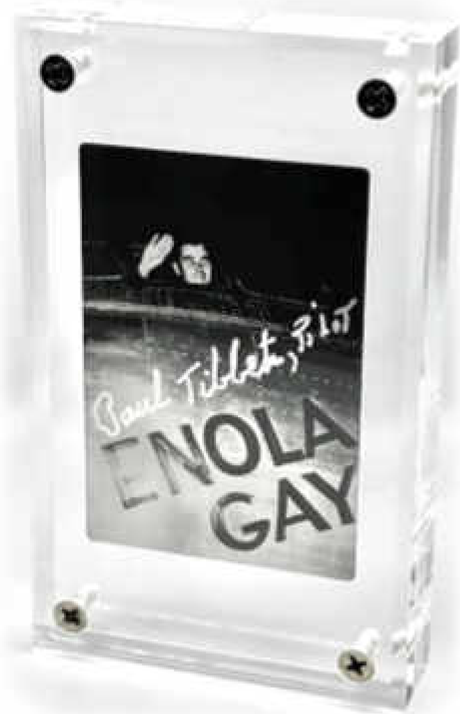
During the fission process the "father" nucleus, in this case plutonium-239, is split and produces two lighter nuclei of around half atomic number. Cesium 137 is one of these, and it is also the product of the beta decay of other fission isotopes such as xenon-137 and iodine-137. Cesium-137 has half-life of about 30 years and produces gamma emission at 662 KeV and 32 KeV.

The americium-241 is the product of the beta decay of plutonium-241, in turn obtained from the plutonium-239 fuel by double neutron capture. The half-life of this isotope is 432 years. This isotope produces strong alpha emission and gamma emission at 60 KeV.

Europium-152 was obtained by neutron activation of the stable europium-151 and europium-153 isotopes already present in the soil of the detonation site. Its half-life is 13.5 years.

This obelisk marks the site of the first nuclear explosion.

Signed Col. Paul Tibbets Enola Gay B-29 Data Plate, 1945



1945 would be the final year of World War II. After Germany surrendered on May 8, the Allies turned their full attention to the Pacific and began to prepare for a costly invasion of the Japanese mainland. In preparation, a firebombing campaign engulfed 67 Japanese cities in maelstroms of flame. Entire neighborhoods were reduced to ashes, tens of thousands of civilians perished. Still, Japan refused to surrender, despite having no chance of winning.

Reverse of the plate.

By July, the Manhattan Project had produced atomic bombs of both designs contemplated: “Fat Man”, a plutonium implosion-type nuclear weapon; and “Little Boy”, an enriched uranium gun-type fission weapon. The Allies called for the unconditional surrender of the Imperial Japanese armed forces in the Potsdam Declaration on July 26, the alternative being “prompt and utter destruction”. Japan ignored the ultimatum.

Little Boy on trailer cradle in pit on Tinian island, before being loaded into Enola Gay's bomb bay.

I visited Enola Gay at the Smithsonian's Udvar-Hazy Center.

On August 6, a B-29 bomber dropped “Little Boy” over the Japanese city of Hiroshima. The explosion immediately killed an estimated 80,000 people; tens of thousands more would later die of radiation exposure.

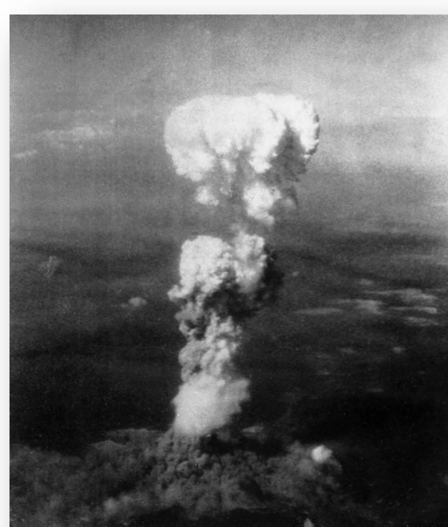
Three days later, a second B-29 dropped the plutonium implosion weapon on Nagasaki, killing an estimated 40,000 people. Emperor Hirohito announced his country’s unconditional surrender on August 15, citing the power of “a new and most cruel bomb.”

Col. Tibbets wearing his Distinguished Service Cross after the mission.

Paul Warfield Tibbets Jr. was the founding commander of the 509th Composite Group, the Twentieth Air Force’s atomic striking force, and led the Hiroshima bombing raid in a specialized Silverplate version of the B-29 Superfortress known as the Enola Gay (named after his mother) when it dropped Little Boy.

“Prompt and utter destruction”.

This artifact is a “reproduction” (pretend) data plate, obtained by the seller from a retired Vietnam war veteran who attended an event on June 22, 2002, at which Brigadier General Tibbets signed it.



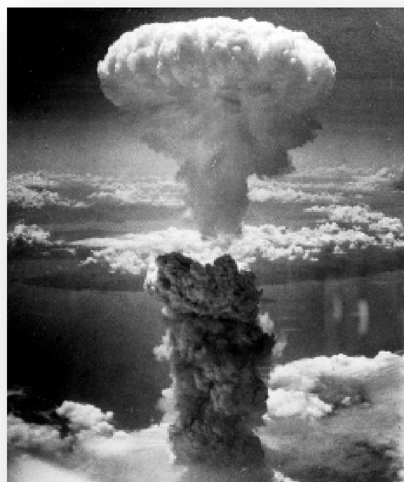
Nagasaki Atomic Bomb “Kawara” Roof Tile, 1945

Closeup.

The second and (so far) last atomic bomb ever dropped in anger was the plutonium implosion weapon of the type “Fat Man”, which was detonated at an altitude of 1,650 ft over the Japanese city of Nagasaki on August 9, 1945. It had a yield of approximately 21 kilotons, about 40% more powerful than Little Boy.

This roof piece was recovered next to the Urakami Cathedral, now an atomic bomb memorial site, in Nagasaki in 1980. The tile survived the 5,000 degrees of the detonation, leaving black boiling dots on the surface.

Urakami (Immaculate Conception) Cathedral



These dots are the result of the glaze which boiled instantly, and are a distinctive characteristic of an atomic bomb.

There is a similar tile fragment from Hiroshima in my collection.

Bomb victim Sumiteru Taniguchi's back injuries, 1946

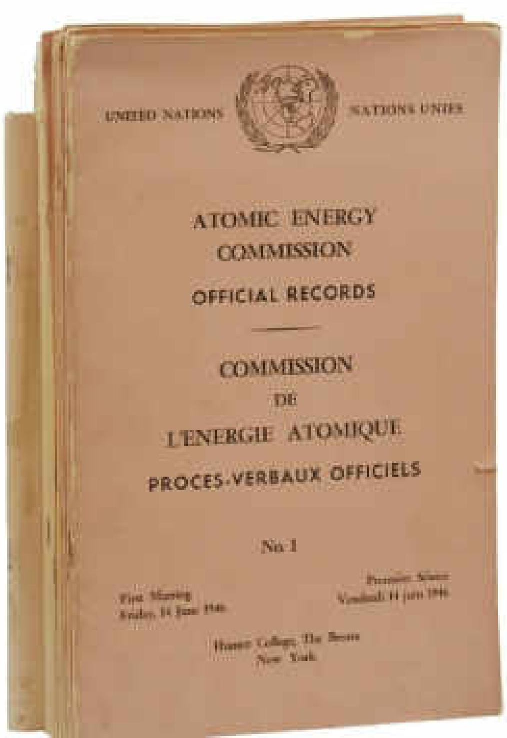
Lucite United Nations Atomic Energy Commission Memento with Uranium Ore, 1946

Post World War II, the fate of the wartime Manhattan Project's infrastructure, which spanned thirteen states, was uncertain. Employment plummeted at Manhattan Project sites, and many believed the hastily constructed plants would be decommissioned. Amid this uncertainty, atomic scientists, now able to speak freely, formed the Federation of Atomic Scientists in November 1945, advocating for civilian control over nuclear research and production.

The Atomic Energy Act of 1946, also known as the McMahon Act, was a response to these calls for civilian oversight of atomic energy. It led to the creation of the Atomic Energy Commission (AEC), a civilian committee responsible for the United States' nuclear development. The Act aimed to control atomic energy to promote public welfare, increase the standard of living, and ensure world peace. The AEC inherited the responsibilities from the Manhattan Engineer District and sought to establish a network of national laboratories to advance nuclear research.

The United Nations Atomic Energy Commission (UNAEC) was established on January 24, 1946, by the United Nations General Assembly's first resolution. Its primary purpose was to address the challenges posed by the discovery of atomic energy and propose measures for the peaceful exchange of scientific information, control of atomic energy, and elimination of atomic weapons. However, the UNAEC's ambitious goals faced significant obstacles, particularly the Soviet Union's rejection of the Baruch Plan, which led to escalating tensions and further nuclear arms development.

The UNAEC was tasked with making specific proposals to ensure atomic energy's use for peaceful purposes. On June 14, 1946, Bernard Baruch, the U.S. representative, presented the Baruch Plan. This plan proposed that the United States would dismantle its atomic arsenal, contingent on the establishment of international controls on atomic energy that would not be subject to the U.N. Security Council veto. The plan aimed to extend the exchange of scientific information for peaceful ends, control nuclear power, eliminate atomic weapons, and implement safeguards against violations.



Duly ignored.

Baruch's presentation emphasized the stark choice between peace and destruction, underscoring the new atomic age's perilous nature. The plan envisioned an International Atomic Development Authority to control uranium and thorium mining, refine ores, own nuclear materials, and operate nuclear plants under UNAEC's supervision.

The Soviet Union, however, rejected the Baruch Plan. Fearing the plan would perpetuate American nuclear superiority, the Soviets countered that existing atomic stockpiles must be destroyed before international control systems were implemented. They also insisted on retaining veto power in the Security Council, a condition the United States found unacceptable.

The Soviet Union's primary concern was the imbalance of power the Baruch Plan would create. They argued that it would leave the United States with a nuclear monopoly while negotiations and international

President Truman signs the Atomic Energy Act into law on August, 1, 1946.

control mechanisms were being established. This fundamental disagreement between the superpowers stalled progress and marked the beginning of Cold War tensions over arms control.

Negotiations over the Baruch Plan continued into 1947, but it became increasingly clear that an agreement was unlikely. The UNAEC was unable to bridge the gap between the U.S. and Soviet positions, leading to a deadlock. The Commission's failure to secure a consensus on international atomic energy control was a significant setback for global disarmament efforts. In response to the impasse, the United States continued to accelerate its weapons development and production.

EBR-1 today.

The post-war lull in nuclear research definitively ended with the Truman Doctrine in March 1947, promoting the containment of communism, and the Soviet blockade of West Berlin in 1948. Both nations accelerated their nuclear programs, and the Soviet Union intensified its efforts to build an atomic bomb. Soviet espionage within the Manhattan Project had already provided them with crucial information. The AEC also ramped up production of fissionable materials and weapons research. By 1951, the AEC had developed the Experimental Breeder Reactor-I (EBR-I) in Idaho, which was the first reactor to produce usable electrical power from nuclear energy (enough to illuminate four 200-watt light bulbs!) and achieve fuel breeding.

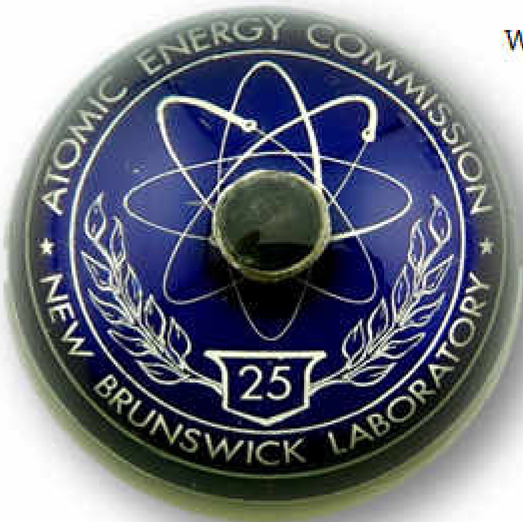
On August 29, 1949, the Soviet Union successfully tested its first atomic bomb, known in the West as "Joe-1", at the Semipalatinsk Test Site in Kazakhstan. This test marked the end of the United States' monopoly on nuclear weapons and significantly altered the geopolitical landscape. The bomb's design closely resembled the U.S. "Fat Man" bomb, thanks in part to intelligence gathered by Soviet spies.

The successful test shocked the world and confirmed fears that the nuclear arms race was not confined to a single nation. It spurred the United States to accelerate its own nuclear weapons program, leading to the development of the hydrogen bomb, which would be tested just a few years later. The establishment of the UNAEC represented a hopeful but ultimately unsuccessful attempt to control the spread of nuclear weapons and ensure atomic energy's peaceful use. The rejection of the Baruch Plan by the Soviet Union and their subsequent nuclear test highlighted the deep-seated mistrust and strategic competition between the superpowers. This period marked the beginning of a protracted and dangerous nuclear arms race that would define much of the Cold War era.

Members of the United Nations Atomic Energy Commission during a hearing. Country plaques visible are Poland, USSR, United Kingdom and the United States.

Russia's first nuclear test, named Joe-1 by the West.

Atomic Energy Commission New Brunswick Laboratory 25th Anniversary Commemorative Lucite with Unidentified Material, 1949 / 1974



With the U.S. nuclear monopoly broken by the Soviet Union's successful test of an atomic bomb in August 1949, the United States quickly shifted toward managing nuclear materials with heightened vigilance. The rejection of the Baruch Plan and the subsequent dissolution of the UNAEC left no international framework to regulate atomic materials. The United States Atomic Energy Commission (AEC), established by the Atomic Energy Act of 1946, assumed control over nuclear research and production from the wartime Manhattan Engineer District. Amid escalating Cold War tensions, the AEC recognized the critical need for precise accounting and control of fissionable materials, particularly uranium and plutonium, essential for maintaining the integrity of America's rapidly expanding nuclear arsenal.

In this charged environment, the AEC established the New Brunswick Laboratory (NBL) in 1949, originally located in New Brunswick, New Jersey. NBL's mission was explicitly centered around nuclear safeguards: ensuring accurate measurement, reliable analysis, and rigorous quality control of nuclear materials. The laboratory swiftly became the nation's primary reference center for analytical chemistry standards used to measure the purity and quantity of nuclear materials in reactors, enrichment facilities, and weapons-production sites.

Although NBL itself was not directly involved in weapon design or testing, its role was critical to the broader U.S. nuclear weapons complex. By certifying reference standards for nuclear materials, NBL provided the foundational metrology upon which all U.S. nuclear operations depended. Precise measurement was essential not only for weapons manufacturing and reactor operations but also for detecting discrepancies that could indicate loss, theft, or unauthorized diversion of nuclear materials.

As the arms race accelerated, NBL's importance grew. Its meticulous standards and analyses underpinned U.S. efforts in nonproliferation negotiations and verification protocols, eventually extending into international safeguards agreements with the International Atomic Energy Agency (IAEA).

The original New Brunswick Laboratory

In 1977, the laboratory moved from New Jersey to Argonne, Illinois, becoming part of Argonne National Laboratory.

This Lucite paperweight contains a disc made of an unidentified material, surrounded by a metal flange. I'm not sure I will ever know what it is!

Closeup.

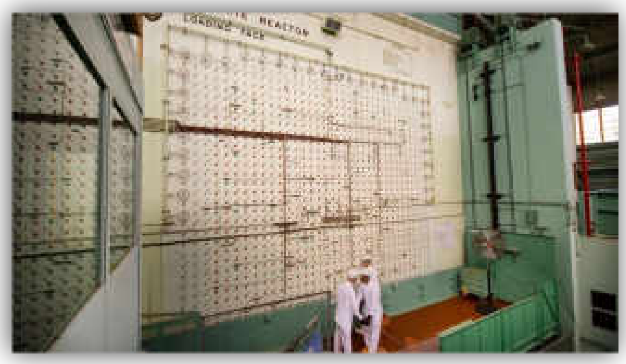
Oak Ridge National Laboratory Neutron Irradiated Silver Dime Encased in Plastic, 1953

The city of Oak Ridge, Tennessee, had been established by the Army Corps of Engineers as part of the Clinton Engineer Works in 1942 under the auspices of the Manhattan Project (see K-25 Building entry a few pages back). The site was subsequently chosen for the X-10 Graphite Reactor, used to produce plutonium from natural uranium.

After the end of World War II, the demand for weapons-grade plutonium fell and the reactor and the laboratory's 1,000 employees were no longer involved in nuclear weapons development. Instead, the facility was used for scientific research.

During the 1950s, the Oak Ridge Graphite Reactor was the world's single largest source of radionuclides, the availability of which revolutionized the field of medicine and many branches of science. The impact was no less great in the industrial sector. Radionuclides were produced in several ways, but neutron activation was perhaps the most important.

The purpose of the dime irradiator at Oak Ridge National Laboratory was to provide a dramatic demonstration of the principle of neutron activation. In the late 1940s and early 1950s, visitors' dimes such as this were irradiated and encased in plastic as souvenirs. Encased dimes were also produced at atomic energy exhibits conducted at various fairs during the 1950s and early 1960s.



The following description is from a 1954 press release:

"One of the most popular exhibits in the American Museum of Atomic Energy is a 'dime irradiator.' To date, more than 250,000 dimes have been irradiated, encased in plastic and returned to their owners as souvenirs. The irradiator works as follows: A mixture of radioactive antimony and beryllium is enclosed in a lead container. Gamma rays from the antimony are absorbed by the beryllium atoms and a neutron is expelled by the beryllium atom in the process.

These neutrons, having no electrical charge, penetrate silver atoms in the dime. Instead of remaining normal silver-109, they become radioactive silver-110. After irradiation, the dime is dropped out through a slot in the lead container and rests momentarily before a Geiger tube so that its radioactivity may be demonstrated. It is then encased in the souvenir container. Radioactive silver, with a half-life of 22 seconds, decays rapidly to cadmium-110 (In 22 seconds, half of the radioactivity in each dime is gone, in another 22 seconds half the remainder goes, and so on until all the silver-110 has become cadmium). Only an exceedingly minute fraction of the silver atoms has been made radioactive."

Lucite with Graphite from World's First Commercial Nuclear Reactor, USSR, 1954

Obninsk Nuclear Power Plant (Russian: Обнинская АЭС, romanized: Obninskaja AES) was located at the Institute of Physics and Power Engineering in the "Science City" of Obninsk, Kaluga Oblast, about 110 km southwest of Moscow. The plant holds a significant place in nuclear history as the world's first nuclear power station connected to a civilian electrical grid. Operational from June 27, 1954, the Obninsk reactor, designated AM-1 (Atom Mirny, "peaceful atom"), symbolized Soviet ambitions to demonstrate nuclear energy's peaceful applications for societal advancement, energy independence, and industrial progress.

Employing a graphite-moderated, water-cooled reactor design, the Obninsk plant produced a modest 5 megawatts of electric power. Although small by later standards, the reactor was a critical engineering milestone that provided essential operational data informing subsequent Soviet reactor designs. It marked the initial practical demonstration of commercial nuclear energy's viability.

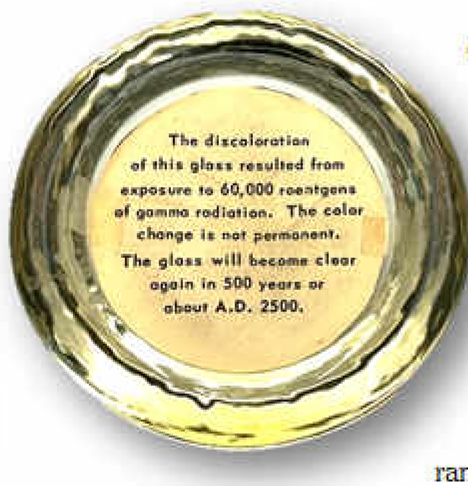
Beyond electricity generation, Obninsk served as a key research and training facility, contributing substantially to advancements in nuclear safety, fuel cycle management, and reactor operations.

The plant enabled Soviet scientists and engineers to refine methodologies and gain insights into nuclear reactor technology that influenced both civilian and military nuclear developments.

Operating continuously for nearly half a century until its closure in 2002, the Obninsk Nuclear Power Plant remains a landmark achievement in nuclear engineering, representing an early and influential chapter in the global development of civilian nuclear power.

This Lucite given to VIPs on the occasion of the reactor's 30th anniversary contains a sample of graphite moderator.

Irradiated Air Force Nuclear Engineering Test Facility Glass Paperweight, Will Be Clear Again in the year 2,500



Glass is highly susceptible to radiation-induced coloration / discoloration due to its amorphous, non-crystalline structure. The nature of the optical changes vary, but usually consist of coloration in the visible light region and the formation of absorption bands in the infrared and/or ultraviolet regions. The optical density is almost always increased. For example, high doses of gamma radiation turn glass shades ranging from deep brown to pale amber.

Clear glass discolors when exposed to gamma irradiation, such as from a Cobalt-60 source. Ordinary flint, borosilicate, and lead glass undergo a color change from clear to light amber, brownish to black, depending on the amount of energy absorbed. Milk glass, when exposed to gamma irradiation, yields a grayish color, depending on energy absorbed and any swirling effect is highlighted, probably due to concentrations of color in the glass that have not mixed uniformly.

FEATURE

Fruit Jars' Fake Colors: An Atom Bomb?

The actual mechanism of the formation of "color centers" has been described. The final color created is dependent on the chemical composition of the glass and can be altered by selection of additives (e.g., cerium ions can reduce browning, manganese ions induce an amethyst color). The final color is a combination of the original glass color and the effects of color center formation.

Color from irradiation is metastable and heat, for example, is known to reverse the effect. Depending on the type of color centers formed and the hardness of the glass, varying amounts of heat or energy penetration are required to reverse the discoloration. Glass with a low diffusion rate (high softening point) is more stable.

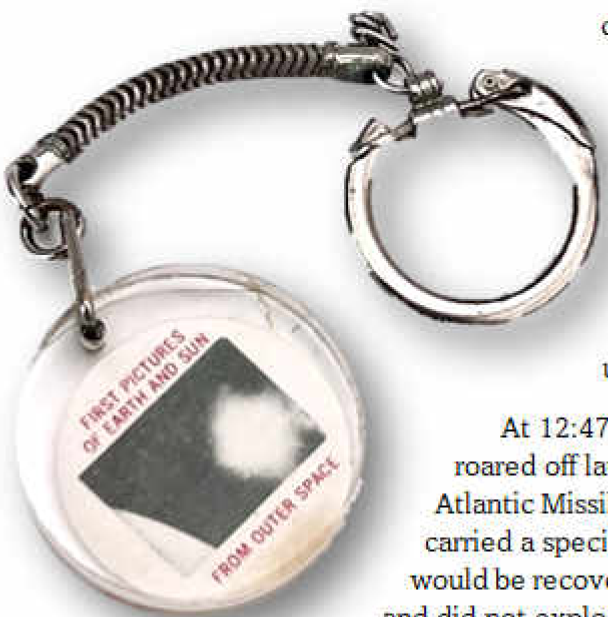
Very striking color contrasts can evolve, depending upon the color of the paints utilized on an item, the chemical composition, and impurities in the glass. At low doses, the color intensity increases linearly but eventually saturates at high doses. The final product is not radioactive or contaminated in any sense.

Iowa State University.

Founded in 1919 and degree-granting since 1956, the Air Force Institute of Technology (AFIT) is the Air Force's graduate school of engineering and management as well as its institution for technical professional continuing education. AFIT is located at Wright-Patterson Air Force Base (WPAFB), Dayton, OH, near the Air Force Research Laboratory (AFRL) and the National Air and Space Intelligence Center (NASIC).

AF INSTITUTE OF TECHNOLOGY

Lucite Keychain with First Photo of Earth and Sun from Space, Taken from Thor ICBM, 1959



The atomic bombs dropped on Hiroshima and Nagasaki had to be carried there by large bomber aircraft, at great expense and risk to their crews. During WWII, the Nazi's had developed the first ballistic missiles, launching objects into space and returning them to earth with devastating consequences. Increasing miniaturization of nuclear warheads soon converged the worlds of rocketry and nuclear war, and would eventually allow for a doomsday weapon to be lobbed easily almost anywhere upon Earth. In turn, these powerful ballistic missiles formed the foundation for many of the technologies that allowed us to begin exploring space.

At 12:47 on July 24, 1959, Air Force Thor Missile Number 202 roared off launch pad 18B at Cape Canaveral and headed Southeast out over the Atlantic Missile Range. In its blunt General Electric Mark 2 nose cone, Thor 202 carried a special payload, a 16mm camera installed in a small data capsule that would be recovered when the flight was over. The Thor missile was right on course and did not explode unlike many of its predecessors. Near its apogee, the copper-shielded nose cone silently separated from the rocket and adjusted its position, before beginning its fall back to earth as a fiery meteor. Fifteen minutes and 1,500 miles later, near Antigua, the sphere was hauled aboard a recovery ship and the vessel headed for shore. There, General Electric scientists began the careful processing of the capsule's contents: movie film showing nose cone separation, and the first images of Earth and our sun together taken from space.

Thor was the first operative ballistic missile of the United States Air Force (USAF), named after the Norse god of thunder. It was deployed in the United Kingdom between 1959 and September 1963 as an intermediate-range ballistic missile (IRBM) with thermonuclear warheads. Thor was 65 feet tall, with an 8-foot diameter.

Fearful that the Soviet Union, or worse yet, the U.S. Army with its Jupiter program headed by Wernher von Braun, would deploy a long-range ballistic missile before the USAF, it had had begun developing the Thor in 1954. The goal was a missile system that could deliver a nuclear warhead over a distance of 1,150 to 2,300 miles with an accuracy of 2 miles. This range would allow Moscow to be attacked from a launch site in the UK.

After many explosions and mishaps, Thor 105 (September 20, 1957) completed the first successful flight, which occurred 21 months after the start of the program. The operational variant of the Thor, the DM-18A, began testing in the autumn of 1958 after many more failures. After the first launch, Missile 138 went out of control shortly after liftoff and had to be destroyed. Nonetheless, Thor was declared operational.

Thor was a one-stage liquid fueled rocket powered by liquid oxygen and kerosene. Main engine burn time was 2.5 minutes, boosting the missile to a speed of 14,400 ft/s. After 10 minutes, the missile reached an altitude of 280 miles, close to the apogee of its elliptical flight path. At that point the reentry vehicle separated from the missile fuselage and begin its ballistic (unpowered) trajectory toward the target. Total flight time from launch to target impact was 18 minutes.

During the early 1950s, spaceflight researchers began to grapple with the significant challenge of reentry, specifically how to manage the extreme heat generated when a spacecraft re-entered Earth's atmosphere. Initial ideas, like those of Wernher von Braun,

involved circulating fluid through the vehicle's skin to absorb heat, which was practical for larger spacecraft but problematic for smaller ones. As the issue of reentry heat remained unsolved, various proposals for satellites avoided addressing the problem directly. Meanwhile, ballistic missiles, which had no choice but to re-enter the atmosphere, faced similar heat management challenges, leading to the exploration of reentry vehicle designs.

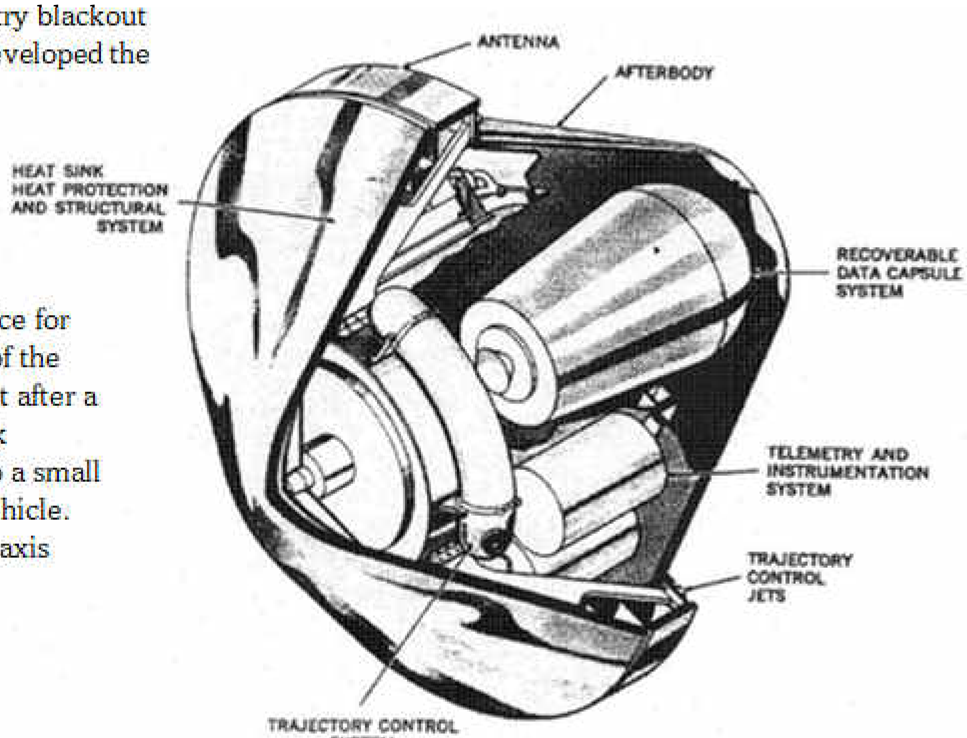
May 12, 1959, Thor Missile Number 187 lifts off on a nearly identical mission, equipped with the same camera system.

In the 1950s, research on missile reentry vehicles focused on long, slender designs that proved ineffective due to excessive heat transfer, causing them to burn up. A breakthrough came in 1952 when scientist H. Julian Allen discovered that "blunt body" designs, which increased drag, could deflect much of the heat generated during reentry.

This principle was applied to the very blunt conical General Electric Mk-2 reentry vehicle, designed for the Thor and Atlas rockets, the latter of which would soon launch the first Americans into orbit. It used a heat-sink concept with a radiatively cooled thermal protection system (TPS) based upon a metallic heat shield, but had limitations such as excessive weight and inefficiency for high-speed reentry, making it unsuitable for both missiles and space vehicles. The Mk-2 had other significant defects as a weapon delivery system, i.e. it loitered too long in the upper atmosphere due to its lower ballistic coefficient and also trailed a stream of vaporized metal making it very visible to radar. These defects made the Mk-2 overly susceptible to anti-ballistic missile (ABM) systems.

By the mid-1950s, General Electric began exploring alternatives to the heat-sink method, including transpirational cooling, re-radiation, and liquid metal cooling, but the most promising was ablation. Ablation involved coating the reentry vehicle with a material that absorbed heat, charred, and then flaked off or vaporized, effectively dissipating the heat. This technique proved effective, and by the late 1950s and 1960s, ablative materials became the standard for spacecraft like Mercury, Gemini, and Apollo, as well as missile warheads, marking a significant advancement in reentry technology. Thor missiles were converted to the slender G.E. Mk 3 ablative RV – the first operational reentry vehicle to use ablative materials. Both the Mk-2 and Mkl-3 RVs contained a W49 thermonuclear warhead with an explosive yield of 1.44 megatons.

As a backup for the problem of telemetry blackout during reentry, GE Re-entry Systems developed the buoyant Mk-2 data capsule that was carried inside the reentry vehicle, an 18" sphere made from two hollow hemispheres of polyurethane foam which housed a tape recorder, radio beacon, battery pack, dye pack and SOFAR (sound fixing and ranging) device for locating the capsule. The bottom half of the capsule was coated with shark repellent after a test capsule was recovered with a shark bite mark. The capsule was attached to a small rocket to boost it free of the reentry vehicle. The data capsule was the first to use 3-axis (individual) stabilization, an important contribution for future orbiting spacecraft.

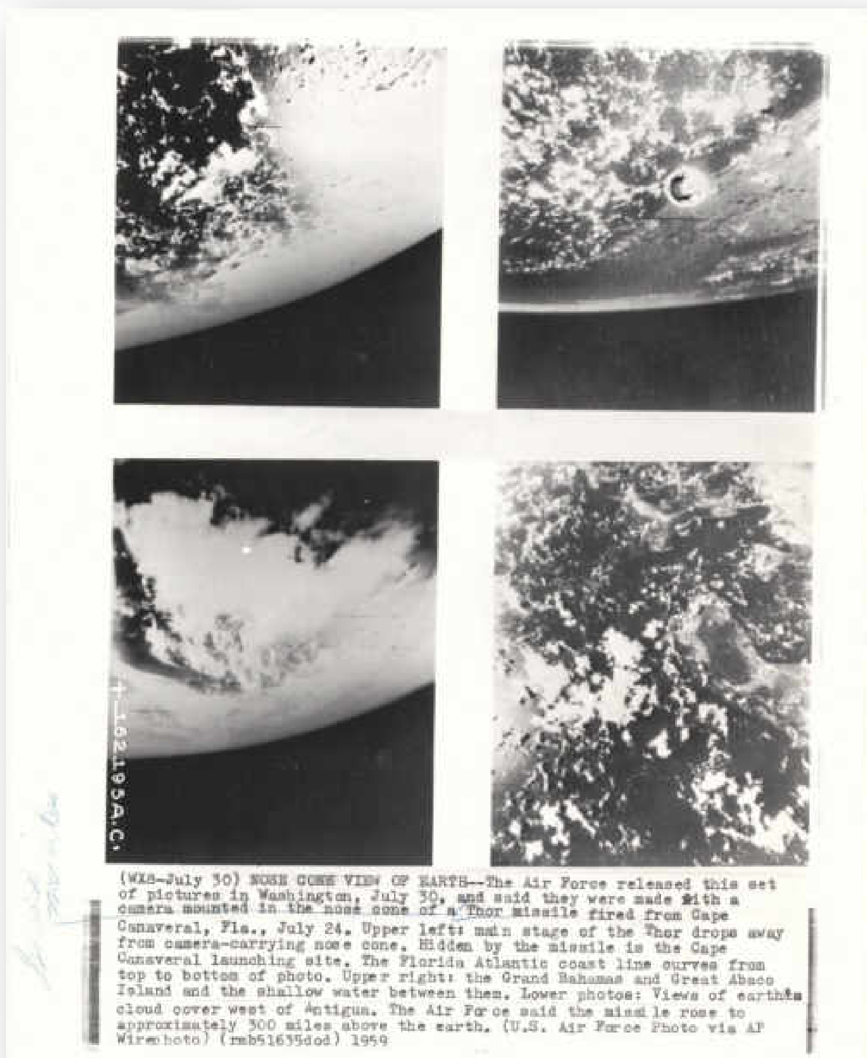


(WX9-July 30) --EARTH AND SUN-- This photograph taken approximately 300 miles above the earth during the July 24 flight of an Air Force Thor missile from Cape Canaveral, Fla., was released today in Washington by the Department of Defense. Caption material accompanying the picture said it is the first photograph of the sun and world's curvature in the same picture. The camera was embedded in the nose cone which seperated [*sic*] from the main stage of the missile as it neared its apogee. (U.S. Air Force Photo via APWirephoto) (rbo51635dod) 1959.

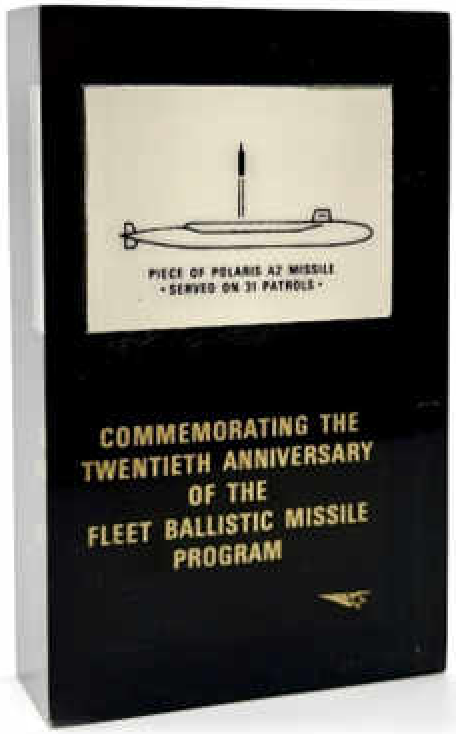
The first generation of Thor missiles were rushed into service, and design mistakes resulted in a 24% launch failure rate. The competing Jupiter missile saw more use, but both were quickly eclipsed by the Air Force's long range ICBM program, which could be fired from U.S. soil. By 1959, with the new intercontinental Atlas rocket well on its way to operational status, both Thor and Jupiter programs became obsolete as delivery vehicles, yet continued to be built and deployed until 1963 for political reasons and to maintain aerospace industry employment.

Thor's lasting legacy was not as a missile, but its use as the basis for the Thor/Delta space launcher family. The Thor rocket served as the workhorse for the American military and civil space programs for the first decade of the space age, evolving into the Thor-Delta and finally the venerable Delta II, the last remaining direct descendant of the Thor, retired in 2018. The last rocket of the Delta family flew on April 9, 2024. Many launches were conducted from Vandenberg Air Force Base on the California coast, boosting classified payloads into orbit.

(WX8-July 30) --NOSE CONE VIEW OF EARTH-- The Air Force released this set of pictures in Washington, July 30, and said they were made with a camera mounted in the nose cone of a Thor missile fired from Cape Canaveral, Fla., July 24. Upper right: main stage of the Thor drops away from camera-carrying nose cone. Hidden by the missile is the Cape Canaveral launching site. The Florida Atlantic coast line curves from top to bottom of photo. Lower right: the Grand Bahamas and Great Abaco Island and the shallow water between them. Left photos: Views of earth's cloud cover west of Antigua. The Air Face said the missile rose to approximately 300 miles above the earth. (U.S. Air Force Photo via AP Wirephoto) (rmb51635dod) 1959



Lucite with Polaris A2 Missile Skin, 1962



The UGM-27 Polaris missile was a two-stage solid-fueled nuclear-armed submarine-launched ballistic missile (SLBM). As the United States Navy's first SLBM, it served from 1961 to 1980. In the mid-1950s the Navy had been involved in the land-based Jupiter missile project with the U.S. Army, and influenced the design by making it squat so it could potentially fit in submarines. However, they had concerns about the use of liquid fuel rockets on board ships.

In 1956, during an anti-submarine study known as Project Nobska, Edward Teller suggested that very small hydrogen bomb warheads were possible. Work on its W-47 nuclear warhead began in 1957 at the facility that is now called the Lawrence Livermore National Laboratory by a team headed by John Foster and Harold Brown. A crash program to develop a missile suitable for carrying such warheads began as Polaris, launching its first shot less than four years later, in February 1960. The Navy accepted delivery of the first 16 warheads in July 1960.

At the time that the Polaris project went live, the accuracy of submarine navigation systems was adequate for existing weapons systems. Initially, developers of Polaris were set to utilize a "Stable Platform" inertial guidance system created at the MIT Instrumentation Laboratory in 1954. The developers of Polaris encountered many issues with this system from the outset of the project, including the outdated technology of the gyroscopes. The "Stable Platform" also did not account for the change in gravitational fields that the submarine would experience while it was in motion, nor did it account for the ever-altering position of the Earth. This problem raised many concerns, as this would make it nearly impossible for navigational readouts to remain accurate and reliable. The Polaris developers then turned to a guidance system that had been abandoned by the U.S. Air Force, the XN6 Autonavigator. The XN6 was designed for air-breathing cruise missiles, but by 1958 had proved useful for installment on submarines. The Inertial Measurement Unit (IMU) at the core of this system, developed by Draper, would later form the basis for the Apollo primary guidance, navigation, and control system (PGNCS).

Launch of Ethan Allen, the first SSBN, a nuclear-powered, ballistic missile sub.

The two stages of the Polaris were both steered by thrust vectoring. Inertial navigation guided the missile to about a 3,000-foot CEP (circular error probable, the radius within which 50% of the fired missiles are expected to land), insufficient for use against hardened targets. They were mostly useful for attacking dispersed military surface targets (airfields or radar sites), clearing a pathway for heavy bombers, although in the general public perception Polaris was a strategic second-strike retaliatory weapon.

As the Polaris missile was fired underwater from a moving platform, it was essentially invulnerable to counterattack. This led the Navy to suggest, starting around 1959, that they be given the entire nuclear deterrent role. This led to new infighting

between the Navy and the Air Force, the latter responding by developing the counterforce concept that argued for the strategic bomber and ICBM as key elements in flexible response. Polaris formed the backbone of the Navy's nuclear force aboard custom-designed submarines.

The first operational version, the Polaris A-1, had a range of 1,400 nautical miles and a single Mk 1 re-entry vehicle (RV), carrying a single W-47-Y1 600 kt nuclear warhead. The two-stage solid propellant missile had a length of 28.5 ft, a body diameter of 54 inches, and a launch weight of 28,800 pounds.

The upgraded Polaris A2 had a 1,500 mile range, weighed 32,500 pounds and was 31 feet long. It was the same diameter as the Polaris A1 and could be launched from the same tubes inside a submarine. The first A2 was launched from Cape Canaveral on November 10, 1960. It became operational in 1962, with the initial deployment of the Ethan Allen, the first submarine of its class designed from the keel up as an SSBN, a nuclear-powered, ballistic missile submarine.

Operation Dominic was a series of 31 nuclear test explosions ("shots") with a 38.1 Mt total yield conducted in 1962 by the United States in the Pacific. This test series was scheduled quickly, in order to respond in kind to the Soviet resumption of testing after a tacit 1958–1961 moratorium on nuclear testing between the U.S., U.K., and U.S.S.R. Most of these shots were conducted with free fall bombs dropped from B-52 bomber aircraft. Twenty of these shots were to test new weapons designs; six to test weapons effects; and several shots to confirm the reliability of existing weapons. Thor missiles were also used to conduct high-altitude nuclear explosion tests.

On May 6, 1962, a Polaris A-2 missile with a live W-47 warhead was tested in the "Frigate Bird" test of Operation Dominic in the central Pacific Ocean, the only American test of an operational ballistic missile with a live warhead. The missile was launched by the USS Ethan Allen at 13:18 (local) from a position 1500 nm east-northeast of

Frigate Bird nuclear explosion (viewed through the periscope of USS Carbonero (SS-337) 480 nm ENE of Christmas Island)

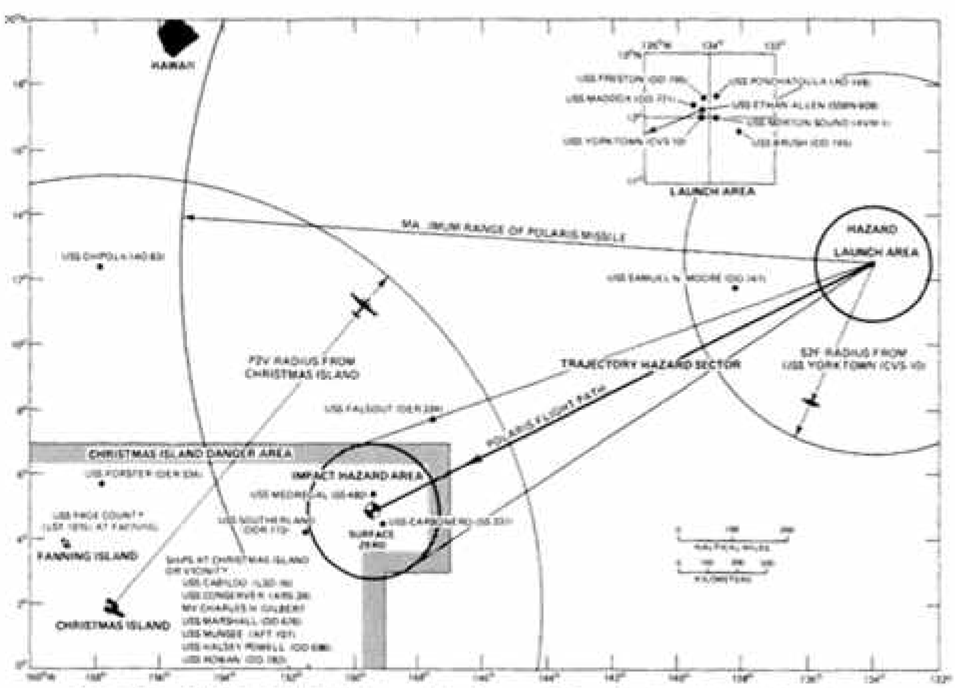


Figure 73. DOMINIC, FRIGATE BIRD operational area showing launch and impact hazard areas, trajectory hazard sector, and ship locations.

Christmas Island. The RV and warhead flew 1020 nm downrange toward Christmas Island before re-entering the atmosphere 12.5 minutes later, and detonating in an airburst at 11,000 feet. Operation Dominic was the last atmospheric test series conducted by the U.S., as the Limited Test Ban Treaty was signed the following year.

The Polaris program's complexity led to the development of a new project management methodology, the Program Evaluation and Review Technique (PERT).

Titan II Planetag, 1963

The Titan II missile's development, first proposed by the Martin Company in 1958 and approved by the Air Force in 1959, marked another significant advancement in the nuclear arms race between the United States and the Soviet Union. The construction of its launch complexes began in 1960, culminating in the first missile's installation by 1962 and its initial deployment to the Strategic Air Command (SAC) by March 1963.

The Titan II was designed to enhance the United States' second-strike capabilities, distinguishing itself from predecessors like the Atlas F and Titan I through four major technological advancements. It featured hypergolic propellants which improved reliability and allowed for indefinite storage. Its design enabled launch directly from underground silos, significantly reducing launch time, and incorporated an all-inertial guidance system for increased accuracy. Moreover, in a Mark 6 RV it carried the W-53 – the largest nuclear warhead ever deployed on a U.S. ICBM – and had a range of 5,500 miles.

Beyond its military utility, the Titan II helped advance space exploration. Adapted as the Titan II GLV for the Gemini program, it was used for two uncrewed and ten crewed NASA launches. The process of modifying the Titan II for human spaceflight, ensuring its systems and structures were safe and reliable for astronauts, set standards and practices for future human-rated launch vehicles and contributed to space travel techniques that laid the groundwork for the Apollo moon missions.

The missile's deployment saw fifty-four Titan II ICBMs stationed across three Air Force Bases in Arizona, Arkansas, and Kansas, each comprising a Strategic Missile Wing divided into Strategic Missile Squadrons. By the end of 1963, all units were operational. Initially restricted to men, positions opened to women in 1978, with First Lieutenant Patricia M. Fornes marking this significant inclusion.

On September 19, 1980, at a missile silo near Damascus, Arkansas, a two-person team was performing routine maintenance on a Titan II missile housed in its silo and armed with a nuclear warhead. A socket wrench was accidentally dropped by one of the technicians, and it fell about 70 feet before striking the missile. The impact punctured the missile's fuel tank, causing a leak of the highly toxic and flammable aerozine 50. Over the next hours, attempts were made to assess and contain the situation, with personnel evacuated from the immediate vicinity. However, the volatile nature of the rocket fuel and the difficulty in managing the leak led to a

Locked & loaded.

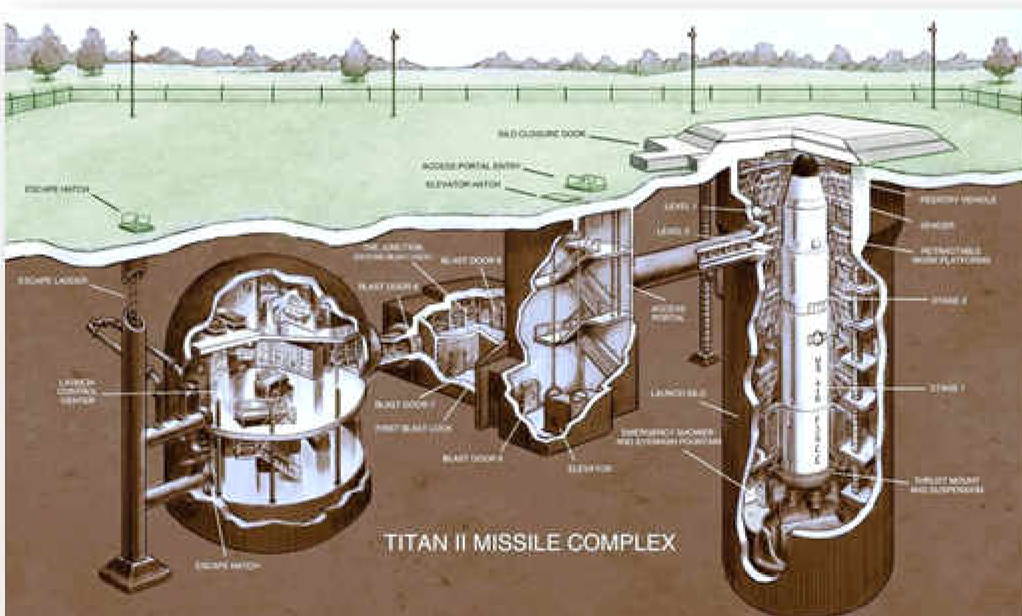
This weapon would soon hurl the Gemini capsules into space.

The Damascus Titan II Explosion.

catastrophic explosion early the next morning. The explosion blew off the 740-ton silo door and launched the nuclear warhead a short distance from the silo. Fortunately, the warhead did not detonate, averting a far more disastrous outcome. However, the explosion killed an Air Force serviceman and injured several others including Greg Devlin, who took the photo of the crater on this page, while causing significant property damage and raising public concerns about the safety of nuclear weapons and the Titan II specifically.

The Damascus accident highlighted the inherent risks of the Titan II system, particularly the dangers associated with handling and maintaining missiles fueled with toxic and hypergolic propellants. It also led to increased scrutiny of the United States' ICBM arsenal's safety measures and procedures, prompting improvements in missile handling practices and emergency response protocols.

This incident, among others, contributed to the eventual decision to decommission the Titan II missile system in the mid-1980s, as the U.S. moved towards newer, more reliable missile technologies. The Damascus accident remains a sobering reminder of the potential dangers associated with nuclear weapons and the importance of stringent safety measures in their management and storage.



Despite an intended ten-year service life, the Titan II's deployment extended through various modifications, including an upgrade to the Universal Space Guidance System. However, the emergence of more advanced missile systems and strategic considerations under President Reagan's Strategic Forces Improvement Program in 1981 led to its phased deactivation, concluding by 1987. Throughout its service, Titan II crews maintained rigorous schedules, managing the missile sites 24/7 and pulling an average of 8 to 9 alerts a month to maintain readiness and operational integrity.

This "Planetag" was made from the skin of a Titan II missile, specifically from the spacer section used to mate the Reentry Vehicle (where the W-53 warhead was carried) to the Stage II airframe. The material used is 2014-T6 aluminum, an alloy of aluminum and copper that was formulated specifically for the Titan II and not found anywhere else. The slightly golden color is the result of Iridite, a chromium chemical conversion process applied to the airframe to prevent corrosion.

What remained of the silo.
© *Greg Devlin*

Section of Minuteman ICBM Silo Hardened Intersite Cable System (HICS), 1963 – Present

The Titan II missile in the last article utilized liquid fuel, which allowed for quick launches but required the fuel to be stored in the missile, posing risks due to the fuel's volatile nature. Its large size also enabled it to carry a monstrous warhead over longer distances, but made its silos relatively conspicuous and susceptible to enemy strikes.

The LGM-30 Minuteman is an American land-based intercontinental ballistic missile (ICBM) in service with the Air Force Global Strike Command. The Minuteman series, starting with Minuteman I entering service in the early 1960s, employ solid fuel, a significant innovation that allows for quicker launches and reduced the risk of accidents, as solid fuel is more stable than liquid fuel. The Minuteman missiles are smaller, can be deployed in greater numbers, and their silos can be more easily concealed, complicating targeting by adversaries.

While carrying smaller warheads, such as the W-78 and W-87, than the Titan II, the Minuteman missiles benefit from advancements in accuracy and the ability to deploy multiple independently targetable reentry vehicles (MIRVs) in later versions. This allows a single Minuteman missile to strike several targets, complicating enemy defense planning.

As of 2022, the Minuteman III was the only land-based ICBM in service in the United States and represents the land leg of the U.S. nuclear triad, along with the Trident submarine-launched ballistic missile and nuclear weapons carried by long-range strategic bombers.

Development of the Minuteman began in the mid-1950s when research indicated that a solid fuel rocket motor could stand ready to launch for long periods of time. The Minuteman entered service in 1962 as a deterrence weapon that could hit Soviet cities with a second strike and countervalue counterattack if the U.S. was attacked. However, the development of the United States Navy Polaris missile, which addressed the same role, allowed the Air Force to modify the Minuteman, boosting its accuracy enough to attack hardened military targets including Soviet missile silos.

This technological advancement led directly to the development of the Apollo Guidance & Navigation System. The core of this incredible system was the Inertial Measurement Unit, which was derived from the guidance system developed by Draper for the Polaris missile. More on this elsewhere.

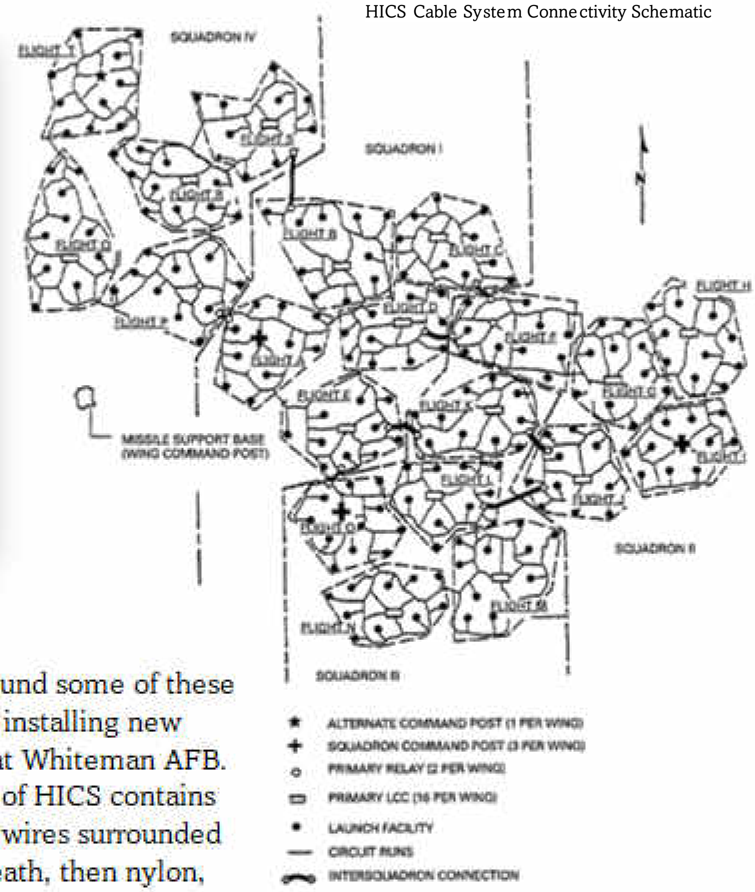
By the 1970s, 1,000 Minuteman missiles were deployed. This force had shrunk to 400 Minuteman-III missiles as of September 2017. Minuteman III will be progressively replaced by the new Ground Based Strategic Deterrent ICBM beginning in 2030 to be built by Northrop Grumman.

Digging a Trench to Bury the HICS Cable.

At each Minuteman site, The Hardened Intersite Cable System (HICS) is or was crucial in providing the Missile Alert Facility (Launch Control Center, or MAF) the ability to communicate with and monitor the status of the Minuteman missiles in their respective Launch Facilities. The HICS cable provides the means for the two Launch Control officers with the ability to monitor and assess each of the 10 missiles they are responsible for within their MAF. The computer equipment in each Launch Facility is continually assessing the missile, guidance and electrical systems, and other features, making sure that each missile is at its fully operational status. Of equal importance, the HICS cable also provides the Launch Control Center the ability to send the command to launch the missile.

Whiteman AFB, MO is one of the decommissioned sites, serving during the cold war as a major center for the many Minuteman missiles planted in Midwest farm country. After nuclear arms reduction was completed, the missile silos were blown up and filled with dirt, while missiles were dismantled and destroyed. Since this cable has no more use, most of that which has been located has been dug up and shipped to China for electronics manufacture due to the high quality of the copper.

HICS Cable System Connectivity Schematic



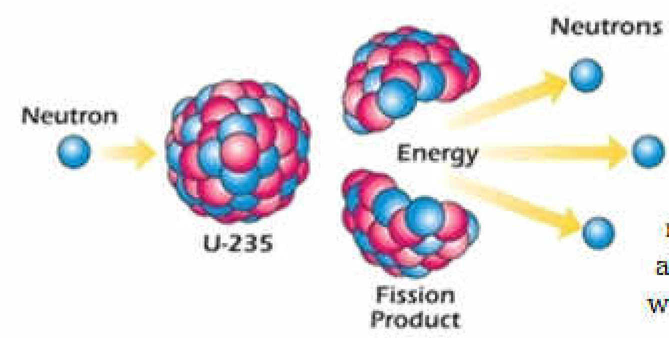
The seller found some of these cables while installing new fence posts at Whiteman AFB. This section of HICS contains 57 insulated wires surrounded by mylar sheath, then nylon, then copper, nylon, copper, nylon, copper, and finally another outer nylon protective sheath.

Lucite with Babcock & Wilcox Nuclear Fuel Pellet, 1970s

Nuclear fuel often comes in the form of ceramic cylinders approximately 3/8" x 5/8", consisting of uranium oxide enriched to increase the concentration of U-235.

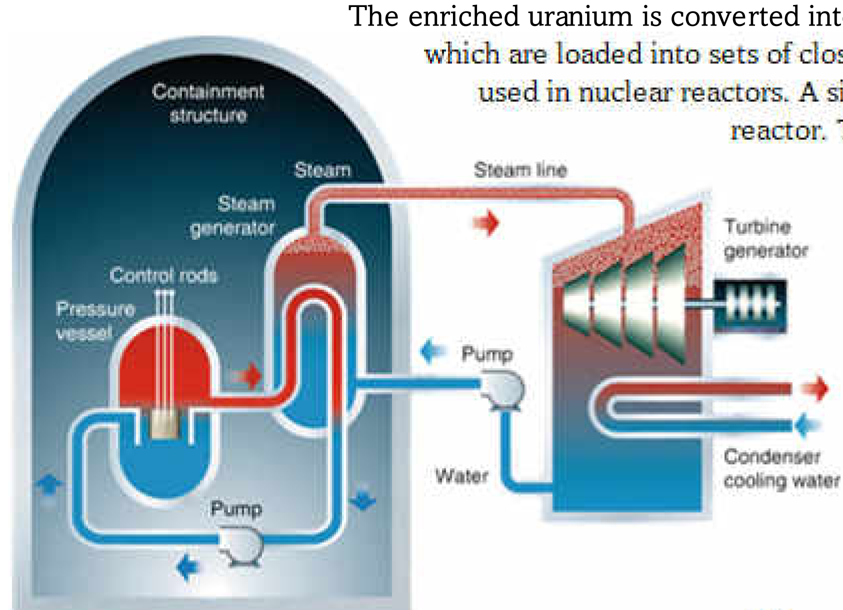
Aside from apocalyptic weaponry, nuclear technology has many peaceful uses, although they too come with tradeoffs. One of the most important is as a source of electrical power. Uranium is an abundant metal and one uranium fuel pellet creates as much energy as one ton of coal, 149 gallons of oil or 17,000 cubic feet of natural gas. Nuclear fuel has the highest energy density of all practical fuel sources, but its waste products last for millennia and are difficult to dispose of safely.

As in an atom bomb, the working principle in each nuclear power plant starts with fission, which occurs when a neutron slams into a larger atom, forcing it to excite and split into two smaller atoms and release heat. Additional neutrons are also released that can initiate a chain reaction. The typical core of a nuclear power plant uses the heat generated by fission of uranium and plutonium in fuel rods to heat and then pressurize water, generating steam that is used to drive turbines for electricity production.



Nuclear fuels contain isotopes of uranium and plutonium that can sustain nuclear fission. When the unstable nuclei of these atoms are hit by a neutron, they split, creating two daughter nuclei and two or three more neutrons. The neutrons released then go on to split more nuclei. This creates a self-sustaining chain reaction. In a nuclear power plant, the reaction is controlled with rods made of material that can absorb many neutrons without itself decaying. In a nuclear weapon, this reaction is uncontrolled.

Once mined, uranium still must be processed to create nuclear fuel. The processes involved in mining, refining, purifying, using, and disposing of nuclear fuel are collectively known as the nuclear fuel cycle. First, uranium is mined with conventional methods or by in-situ leach mining, where carbonated water is shot into underground deposits and piped up to the surface. Natural uranium is then processed to prepare it for enrichment so that it can be used in a nuclear reactor.



The enriched uranium is converted into a powder, and then pressed into fuel pellets which are loaded into sets of closed metal tubes called fuel assemblies, which are used in nuclear reactors. A single fuel assembly spends about five years in a reactor. The removed assemblies are then placed in a spent fuel pool where they cool over time. After the used fuel assemblies have cooled, they are removed from the pools and stored in containers made of steel-reinforced concrete. Every nuclear plant stores its own used fuel, as the industry awaits completion of either a consolidated national storage site or permanent disposal repository, perhaps similar to the WIPP in New Mexico, which we will encounter in a few pages.

The Apollo Site.

My Lucite contains a nuclear fuel pellet manufactured by Babcock & Wilcox at their Apollo facility. Before being acquired by them in 1971, the plant in which this pellet was made was operated by NUMEC (Nuclear Materials and Equipment Corporation) which had established a severely under-capitalized nuclear fuel processing plant in an old steel mill in the heart of Apollo, PA in the late 1950s.

A spent fuel pool (SFP).

The company handled highly enriched uranium, a key component of nuclear weapons and fuel for certain types of reactors. This facility was the subject of much controversy, involving suspicions of nuclear material diversion. In the mid-1960s, the U.S. Atomic Energy Commission discovered discrepancies in NUMEC's inventory; a significant amount of uranium-235 appeared to be missing. Dr. Zalman Mordecai Shapiro, the head of NUMEC at the time, was known to consort with people from the Israeli intelligence agencies Shin Bet and Mossad. This led to a suspicion of nuclear espionage and diversion of the material to Israel for its nuclear-weapons program, sparking a series of investigations by the Nuclear Regulatory Commission as well as the FBI, the Justice Department, the CIA, the Congressional Joint Committee on Atomic Energy, the General Accounting Office, the National Security Council, the Defense Intelligence Agency, and two committees of the U.S. House of Representatives spanning four presidential administrations. In the end, the DoJ chose not to prosecute Shapiro, and the government found him a nice new job that did not require a security clearance.

Also in my collection, Lucite with a vial of (simulated?) yellowcake powder.

Babcock & Wilcox also manufactured a containment vessel with the code name Jumbo for the Trinity test – the first explosion of an atomic weapon – described earlier in this chapter. The 214-ton Thermos shaped steel and concrete container was designed to hold the precious plutonium core of the bomb, "The Gadget", in case of a nuclear misfire. Jumbo was 28 ft long, had a 12 ft, 8 in diameter, and steel walls up to 16 inches thick. Despite the expense and difficulty involved with transporting it to the site, it was never used for its intended purpose. Jumbo's rusty remains are still at Trinity.

The Apollo site ceased manufacturing nuclear fuel in 1983, was razed, and finally abandoned in 1997. Today, it is an active Superfund site.

Jumbo before.

Jumbo after. *Chris Short / CC BY-SA 2.0*

Medal Celebrating Startup of Reactor No. 3 at Fukushima Daiichi Nuclear Power Plant, 1976

The Fukushima disaster was a 2011 nuclear accident at the aging Fukushima Daiichi Nuclear Power Plant in Ōkuma, Fukushima, Japan. The proximate cause of the disaster was the 2011 Tōhoku earthquake and tsunami.

It was the most severe nuclear accident since the Chernobyl disaster in 1986. It was classified as Level 7 on the International Nuclear Event Scale, after initially being classified as Level 5, joining Chernobyl as the only other accident to receive such a classification.

While a 1957 explosion at the secret Mayak facility in rural southern Urals was the second worst by radioactivity released, the INES ranks incidents by impact on population, so Chernobyl (335,000 people evacuated) and Fukushima (154,000) rank higher than the 10,000 evacuated from the classified restricted Mayak site.

The medal's packaging.

The accident was triggered by the Tōhoku earthquake and tsunami on March 11, 2011. On detecting the earthquake, the active reactors automatically shut down their normal power-generating fission reactions. Because of these shutdowns and other electrical grid supply problems, the reactors' electricity supply failed, and their emergency diesel generators automatically started.

This is not the Fukushima Daiichi NPP, but a blaze at an oil refinery in Ichihara.
Kyodo/REUTERS

Critically, these were required to provide electrical power to the pumps that circulated coolant through the reactors' cores. This continued circulation was vital to remove residual decay heat, which continues to be produced after fission ceases. However, the earthquake had also generated a tsunami 14 meters high that arrived shortly afterward and swept over the plant's seawall and then flooded the lower parts of reactors 1 – 4. This flooding caused the failure of emergency generators and loss of power to the circulating pumps. The resultant loss of reactor core cooling led to three nuclear meltdowns, three hydrogen explosions, and the release of radioactive contamination in Units 1 – 3.

Radioactive fish.
GreenOak/Shutterstock

The spent fuel pool of the previously shut down Reactor 4 increased in temperature on March 15 due to decay heat from newly added spent fuel rods, but thankfully did not boil down sufficiently to expose the fuel.

Fly_and_Drive/Shutterstock

Medal Celebrating Startup of Reactor No. 3 at Chernobyl Nuclear Power Plant, Pripyat, 1981

The Chernobyl nuclear accident occurred on April 26, 1986, at the No. 4 reactor in the Chernobyl Nuclear Power Plant, near the city of Pripyat in the north of the Ukrainian SSR in the Soviet Union. It is considered the worst nuclear disaster in history both in cost and casualties. It is one of only two nuclear energy accidents rated at seven – the maximum severity – on the International Nuclear Event Scale, the other being the 2011 Fukushima Daiichi nuclear disaster in Japan.

The accident occurred during a safety test on the steam turbine of an RBMK-type nuclear reactor. During a planned decrease of reactor power in preparation for the test, the power output unexpectedly dropped to near-zero. The operators were unable to restore the power level specified by the test program, which put the reactor in an unstable condition. This risk was not made evident in the operating instructions, so the operators proceeded with the test. Upon test completion, the operators triggered a reactor shutdown. But a combination of operator negligence and critical design flaws had made the reactor primed to explode. Instead of shutting down, an uncontrolled chain reaction began, releasing enormous amounts of energy.

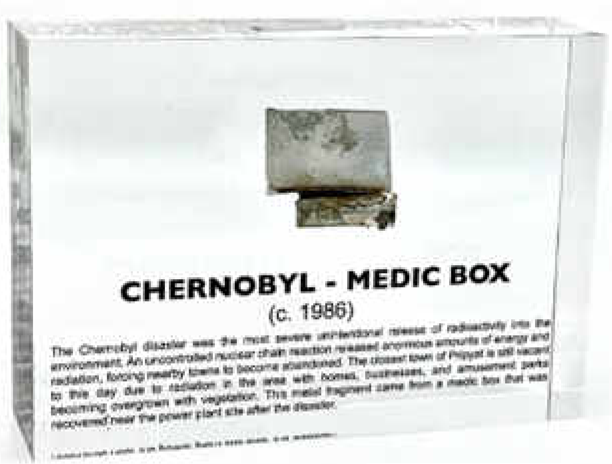
The core melted down and two or more explosions ruptured the reactor core and destroyed the reactor building. This was immediately followed by an open-air reactor core fire. The explosion blew the 1,000-ton roof off one of the plant's reactors, belching out 400 times more radiation than released by the atomic bomb dropped on Hiroshima.

Firefighters arrived at the scene within minutes and began to fight the blaze without gear to protect them from radiation. Eyewitness accounts of the firefighters who helped battle the fires described the radiation "tasting like metal", and feeling pain like pins and needles on their faces. Days later, many would be dead.

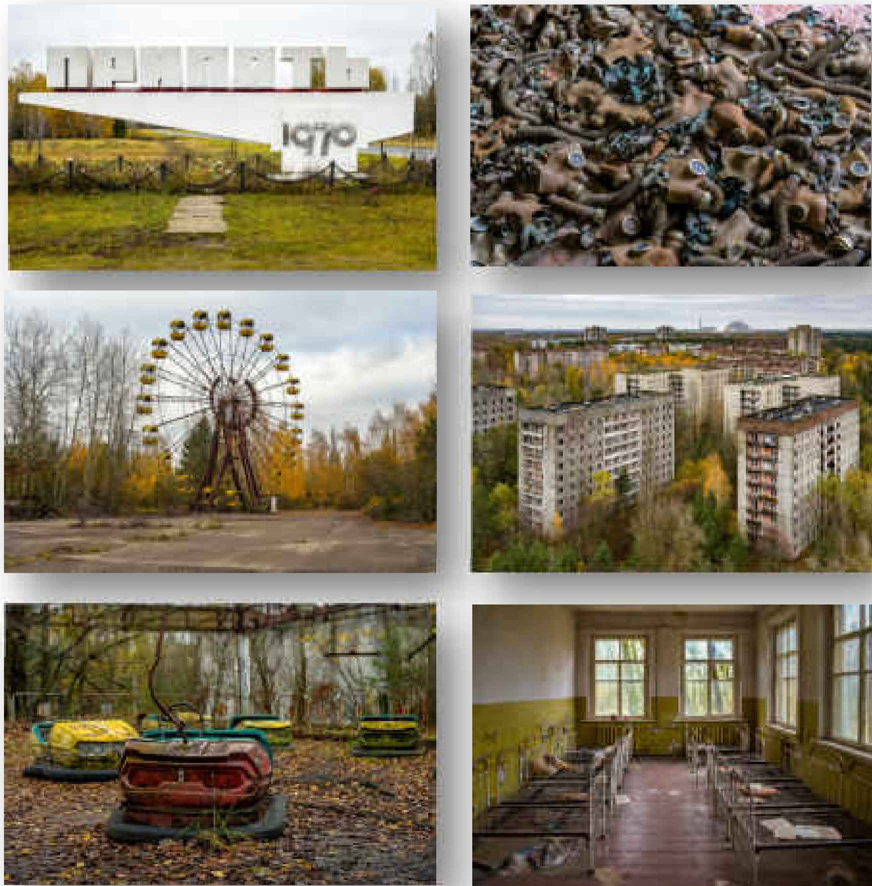
SHONE / GAMMA / Gamma-Rapho via Getty Images

A scientist, believed to be Georgiy Reichman, in the depths of the reactor in 1990.
Igor Kostin

It wasn't until 5 a.m. the following day that Reactor No. 3 was shut down. Some 24 hours later, Reactors No. 1 and 2 were also shut down. By the afternoon of April 26, the Soviet government had mobilized troops to help fight the blaze. Some were dropped at the rooftop of the reactor to furiously shovel debris off the facility and spray water on the exposed reactor to keep it cool. The workers were picked up within seconds to minimize their radiation exposure. It would take nearly two weeks to extinguish all the fires using sand, lead and nitrogen.



Also in my collection.



Pripyat today.
Jorge Franganillo / CC BY 2.0

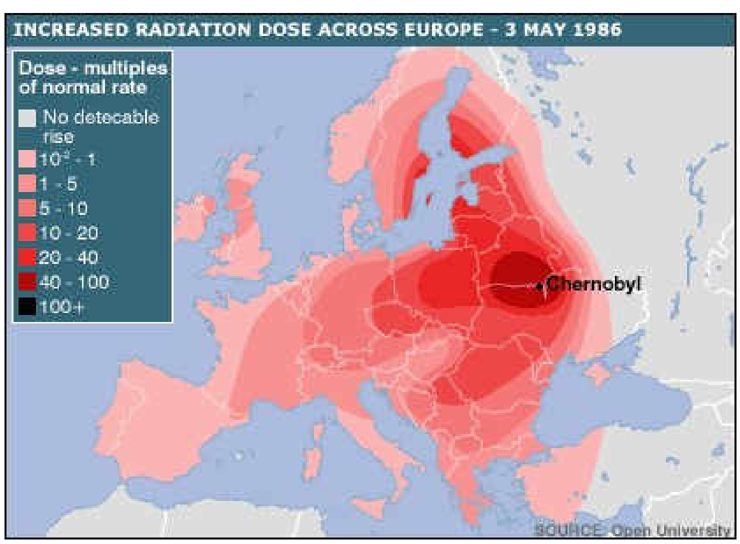
Meanwhile, life went on as usual for almost a day in the neighboring town of Pripyat. Aside from the sight of trucks cleaning the streets with foam, there were initially few signs of the disaster unfolding just miles away.

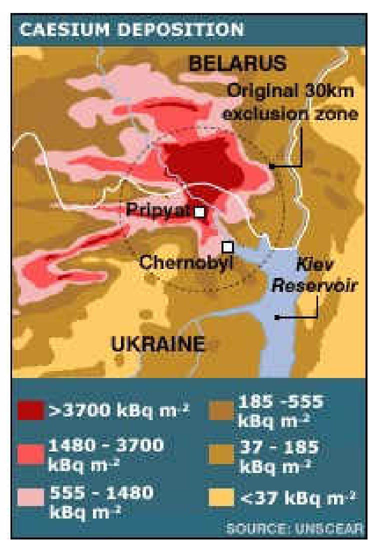
It wasn't until the next day, April 27, when the government began evacuations of Pripyat's 50,000 residents. Residents were told they would be away for just a few days, so they took very little with them. Most would never return to their homes. It took days for Soviet leadership to inform the international community that the disaster had occurred. The Soviet government made no official statement about the global-scale accident until Swedish leaders demanded an explanation when operators of a nuclear power plant in Stockholm registered unusually high radiation levels near their plant.

The stricken Chernobyl facility continued to release a large quantity of airborne radioactive contaminants, including iodine-131, cesium-137, plutonium and strontium-90, over a period of 10 days. The radioactive cloud was deposited nearby as dust and debris, but was also carried by wind over the Ukraine, Belarus, Russia, Scandinavia and other parts of Europe. Because of the fallout we couldn't eat broccoli or other high iron vegetables in The Netherlands for I think two years, and we had a reindeer skin we bought in Norway in 1987 that would never stop shedding and we eventually threw away.

The Chernobyl disaster not only stoked fears over the dangers of nuclear power, it also exposed the Soviet government's lack of openness to the Soviet people and the international community. The meltdown and its aftermath drained the Soviet Union of billions in clean-up costs, led to the loss of a primary energy source and dealt a serious blow to national pride. Then-Soviet leader Mikhail Gorbachev would later say that he thought the Chernobyl meltdown, "even more than my launch of perestroika, was perhaps the real cause of the collapse of the Soviet Union five years later". Today, Pripyat and the surrounding area is still a restricted zone, although limited tourism does exist.

The obverse of this steel table medal depicts the nuclear power plant and the inscription "START-UP of the 3rd CHNPP POWER UNIT". CHNPP is the Chernobyl nuclear power plant named V. I. Lenin. The reverse shows the buildings of the city of Pripyat and the inscription "Pripyat 1981".





Lucite with SS-23 Spider Missile Fragment, ISR 1989

The OTR-23 Oka (Russian: OTP-23 «Ока», NATO reporting name SS-23 Spider) was a Soviet mobile theater ballistic missile developed during the late Cold War period to modernize and enhance Soviet tactical nuclear capabilities. Introduced in the early 1980s to replace the aging SS-1C "Scud B", the Oka represented a substantial advancement in missile technology. Equipped with improved inertial guidance systems combined with radar-based digital terrain matching, the missile boasted remarkable accuracy for its era, significantly improving its effectiveness against hardened and mobile targets. The Oka's design allowed it to carry conventional or nuclear warheads, delivering payloads with high precision over an officially stated maximum range of approximately 400 km.

This coin, made of metal from a destroyed SS-23, is affixed to the bottom of the artifact.

American analysts, however, believed that its actual operational range exceeded this declared limit. The missile's mobility, facilitated by its transporter-erector-launcher (TEL) vehicle, along with a rapid reaction capability of approximately five minutes from deployment to launch, rendered it a formidable weapon system. Its trajectory, combined with a terminal phase that was extremely challenging to intercept, made it especially threatening to NATO airfields, nuclear command centers, missile sites, and other high-value military installations in Europe.

Label on the reverse side.

Closeups.

Despite its technical merits and operational importance, the Oka had a notably brief and controversial operational lifespan. In 1987, as part of ongoing arms control negotiations with the United States, Soviet leader Mikhail Gorbachev unexpectedly offered to eliminate the Oka missile system, even though Soviet military leaders strongly opposed its inclusion.

U.S. President Ronald Reagan and Soviet leader Mikhail Gorbachev exchange pens during the INF treaty signing ceremony in the White House on Dec. 8, 1987.

At the heart of this dispute was Gorbachev's decision to incorporate the Oka missiles into the Intermediate-Range Nuclear Forces (INF) Treaty, which banned all land-based missiles with ranges between 500 and 5,500 kilometers – a range beyond the Soviet-declared capability of the Oka.

The decision to destroy the Oka was met with fierce internal resistance, particularly from Soviet military leadership and the missile's chief designer, Sergei Nepobedimy. He characterized Gorbachev's decision as an act of "state treason" and "a crime".

Senior Soviet military officials vehemently protested, with some reportedly threatening resignation over the issue. Nevertheless, Gorbachev proceeded with the destruction as a gesture of goodwill.

SS-23 tactical ballistic missile unit at the Army Museum in Sofia, Bulgaria.
Aleksander Dragnes / CC BY 2.0

Ambassador Eileen Malloy, chief of the arms control unit at the U.S. Embassy in Moscow, at the Saryozek site.

By 1989, over 200 Oka missiles and 106 launch vehicles had been systematically dismantled or destroyed under international supervision. A central location for carrying out these dismantlements was the Saryozek Missile Elimination Site in eastern Kazakhstan. Established specifically to fulfill INF obligations, Saryozek was a carefully monitored facility where Soviet missile systems such as the Oka, along with other banned missiles, were destroyed under mutual supervision by U.S. and Soviet inspectors.

Missile stages, guidance systems, launchers, and related equipment were permanently rendered unusable through mechanical cutting, crushing, or controlled explosive demolition.

Despite the systematic elimination of Soviet-held missiles, controversy resurfaced in 1990 when it emerged that at least 120 conventionally armed Oka missiles had been covertly transferred by the Soviets to Warsaw Pact allies, including Bulgaria, Czechoslovakia, and East Germany, during INF Treaty negotiations. The disclosure triggered diplomatic tensions between the U.S.S.R. and the U.S. Bulgaria, under sustained diplomatic pressure, only completed the demilitarization of its launchers in 2001.

The 957th and last of the Soviet Union's SS-23 shorter range missiles is destroyed at Saryozek, 27. October 1989, in keeping with the US-Soviet INF Treaty.

The elimination of the Oka left a considerable gap in Soviet tactical missile capabilities. Only decades later did Russia fully restore this capability with the introduction of the advanced Iskander missile system, which became operational in the mid-2000s. The Iskander, leveraging lessons learned from the Oka, offers even greater accuracy, mobility, and operational flexibility.

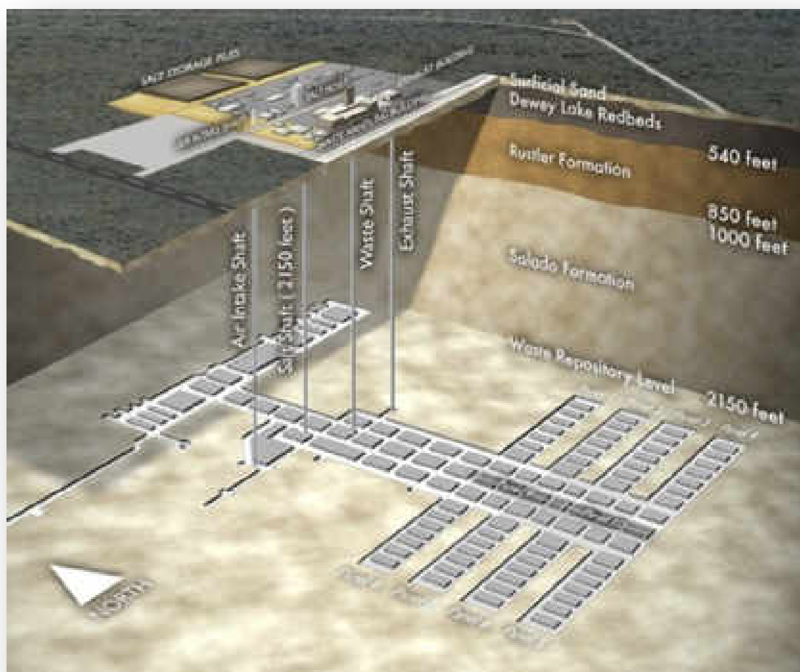
Permian Salt from Waste Isolation Pilot Plant (WIPP), 1999

The Waste Isolation Pilot Plant, or WIPP, is a unique underground facility located in southeastern New Mexico, designed by the U.S. Department of Energy to permanently isolate radioactive waste left over from nuclear weapons production. Specifically, it handles transuranic waste – materials contaminated with radioactive elements heavier than uranium, such as plutonium. These come from gloves, tools, clothing, and other materials used in defense-related nuclear programs. The waste is packaged and transported to WIPP, where it is placed deep underground, more than 2,000 feet below the surface, in rooms carved out of salt.

What sets WIPP apart is the geology in which it's embedded. The facility is located within the Salado Formation, a massive bed of salt that formed during the Permian Period, roughly 250 million years ago. Back then, this part of what is now the American Southwest was a shallow sea. As the water evaporated, it left behind thick layers of salt, which eventually became deeply buried under sediments and transformed into rock salt, or halite. This salt bed is not only geologically stable, but exhibits an unusual property: over long timescales, it behaves like a very slow-flowing fluid. As a result, fractures or voids in the salt will gradually close, naturally sealing off the waste and preventing the migration of contaminants.

The salt's impermeability to fluids and its complete lack of circulating groundwater make it an especially effective natural barrier. The isolation provided by the salt is so robust that even when a radiological release occurred in 2014 due to a mishandled drum, the surrounding formation continued to provide containment. WIPP's long-term success has made it a rare example of operational deep geologic disposal, and a point of reference for broader debates about the future of nuclear waste storage in the United States, particularly for high-level waste, which WIPP is not designed to accommodate.

This artifact is a bagged lump of Permian salt excavated from the site.



Medal Celebrating the Elimination of Weapons Grade Plutonium Production (EWGPP) Program, 2009

Up until 2008, Russia had been separating enough weapons-grade plutonium each year to manufacture 200 Nagasaki bombs. That year, in the never-ending tussle between the U.S. and Russia over arms control, Rosatom set about closing the two remaining reactors at the Siberian Chemical Combine in Seversk, ending that city's 43 years of weapons-grade plutonium production. Russia's last plutonium production reactor was shut down at midnight on May 31, 2009.

Production at these reactors was terminated under a joint program, Elimination of Weapons Grade Plutonium Production (EWGPP), between the National Nuclear Security Administration (NNSA) and Rosatom, the Russian state-owned nuclear agency. The program was initiated to shutter the three remaining Russian plutonium-producing reactors in order to prevent plutonium from being stolen and sold on the black market. William Tobey, NNSA deputy administrator for defense nuclear nonproliferation, hailed the closures as "another step closer to eliminating the production of nuclear weapons-grade plutonium in Russia." Together, the three reactors were able to produce more than a metric ton of plutonium annually.

Besides proliferation concerns, the reactors also caused worries about safety. All three of them were of the RBMK type, a light-water-cooled, graphite-moderated model that gained infamy through the Chernobyl accident in 1986, see earlier in this chapter. These concerns were briefly realized in Seversk in 1993, when a tank containing an industrial solution used to decontaminate decommissioned nuclear reactors exploded, contaminating the surrounding countryside.

Siberian Chemical Combine.

Despite the halt of weapons-related plutonium production activities, Seversk remains a major site for the storage and handling of weapon-usable fissile materials and nuclear weapons components. At present, Seversk produces uranium feedstock and enriched uranium, converts and stores fissile materials, and produces thermal and electric power. In addition to supplying some of Russia's domestic fuel needs, reprocessed uranium is also enriched for foreign customers – including the United States.

Under the EWGPP program, Seversk also purifies and converts weapon-grade highly enriched uranium to uranium oxide, then converts it to uranium hexafluoride (UF6), and downblends it. There is also a plutonium storage facility, as well as a new reactor under development.

Plutonium Element Cube

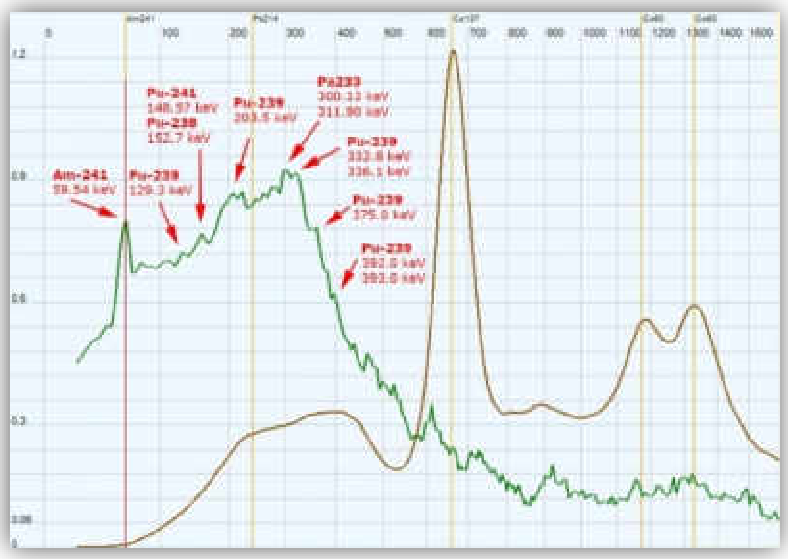
No element is more synonymous with danger and inaccessibility to the average person than plutonium. It is the magic ingredient that makes nuclear weapons go bang, and that fuels nightmares of another Chernobyl or Fukushima, or of Libyan terrorists killing Doc Brown.

Just like the polonium later in this chapter, plutonium emits alpha radiation, a highly ionizing form, rather than beta or gamma radiation. External exposure to alpha particles isn't much of a health risk, because they have a low penetration depth and are usually stopped by skin. Just wash your hands after handling. When alpha-emitters get inside cells, on the other hand, they are extremely hazardous. Alpha rays sent out from within cells cause somewhere between 10 and 1,000 times more chromosomal damage than beta or gamma rays.

Plutonium enters the bloodstream via the lungs, then moves throughout the body and into the bones, liver, and other organs. It generally stays in those places for decades, subjecting surrounding organs and tissues to a continual bombardment of alpha radiation and greatly increasing the risk of cancer, especially lung cancer, liver cancer and bone sarcoma. There are documented cases of workers at nuclear weapons facilities dying within days of experiencing brief accidental exposure to plutonium.

In the Soviet Union of the 1960's, the first commercial smoke detectors came to market. As in the West, the crude electronics of the age required relatively large amounts of a radioactive signal to be detected by a nearby sensor. In case of a fire its smoke would waft across the air gap in between the source and detector disrupting the signal which would then trip an alarm. While the smoke detectors in American devices contained americium-241 for this purpose, their Russian counterparts used a dab of plutonium-239.

That "dab" is very small, approximately 35 billionths of a gram. That sounds tiny, but that infinitesimal amount of plutonium, smaller than a mote of dust, is shedding mass at the rate of 21,000,000 atoms every second of every hour. That's equivalent to 0.4 mSv or, viewed in a more relatable way, about a week's worth of normal radiation condensed into a second; except continuously. The isotope of plutonium found in this artifact, Pu-239, has a half-life of 24,100 years, so it will stay in the environment for many centuries. Radioactive contaminants are dangerous for 10 to 20 times the length of their half-lives, meaning that dangerous plutonium released to the environment today will stick around for the next half a million years.



Thankfully my sample is not a dust mote, but a Lucite containing the radioactive source from one such vintage detector, with the Cyrillic acronym РИД-6М. It is a brass spindle with a porcelain sleeve, with a mixture of plutonium oxide and glaze baked on. This radioactive surface would emanate its rays in the direction of the sensor. The continued presence of the element in this object can be confirmed by gamma ray spectroscopy as shown on the chart at right, which also shows traces of other radioactive isotopes born from plutonium's decay.

Russian law has made owning one of these samples practically impossible. Two men were arrested near Bishkek, Kyrgyzstan in September 2004 while trying to sell 60 "containers" with plutonium-239. However, subsequent reports indicated that the "containers" were merely these Soviet-era smoke detectors, with a miniscule amount of plutonium. The arrests were the result of a sting operation, with Kyrgyz National Security Service agents posing as buyers. The principal suspect, a 50-year-old farmer from the town of Malovodnyy, reportedly asked $3,000 for the plutonium which he had been storing in an abandoned sheep barn. Although regulations call for these detectors to be sent to radioactive waste storage sites, economic difficulties at many industrial facilities have led to them being abandoned and often disposed of improperly. It is unlikely after these events though that many more will take the risk of exporting these devices for our amusement.

Plutonium is not just useful for smoke detectors and nuclear weapons; it is also critical to space exploration. All spacecraft need electrical power to function. Most use solar panels – derived from the Bell Labs artifact described elsewhere – that harvest energy from the Sun, but this solution has its limitations. Missions exploring the distant reaches of the solar system cannot generate enough energy from the distant, dim Sun. Shadowed craters, two-week-long lunar nights, and the dusty plains of Mars also prevent dependence on solar energy for long-lived missions. We need another source of power to explore the cosmos.

That solution is plutonium-238 (Pu-238), a non-weapons-grade radioactive material that generates large amounts of heat. This heat is used to generate electricity for spacecraft day or night, dusty or clear, distant or not. It powers the Voyager spacecraft beyond the solar system, Perseverance on Mars, and Cassini during its decade-long exploration of Saturn.

Finally, plutonium was, before Doc Brown invented practical nuclear fusion in 2015, essential to fictional time travel. In the movie Back to the Future, plutonium fueled a nuclear reactor in the DeLorean time machine which could generate the 1.21 gigawatts of power required for temporal displacement of the vehicle, while traveling at 88 miles per hour. Dispensing the plutonium into the DeLorean required use of a full radiation suit. A vial of plutonium could only power a single jump through time; a round trip would require at least two vials.

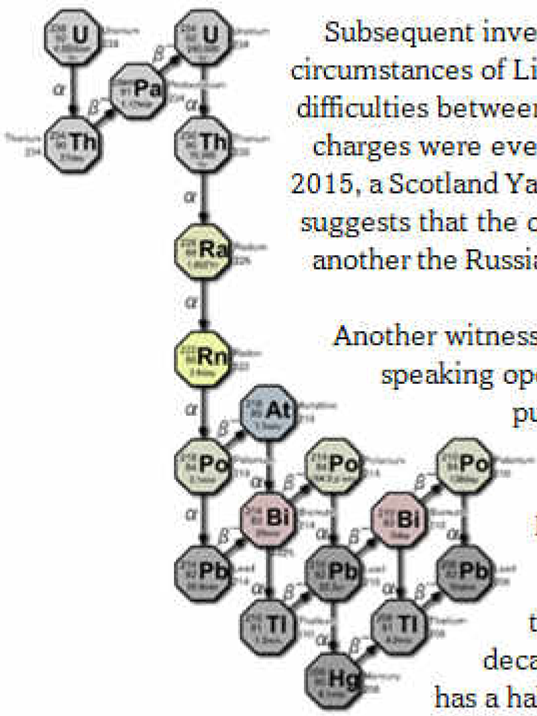
After Doc fueled the DeLorean with plutonium in 1985, Marty accidentally traveled thirty years into the past, but quickly realized that the case of plutonium had stayed behind. Unfortunately, plutonium was not readily available in 1955 or 1985, leaving Marty stranded. Young Doc and Marty instead settled on an alternate plan to channel a bolt of lightning into the flux capacitor. Soon after Marty returned home, present day Doc traveled to the year 2015. While there, he upgraded the time machine. One of these upgrades allowed it to make use of the Mr. Fusion home energy reactor. This reactor relied on nuclear fusion rather than fission, and could make use of everyday garbage instead of plutonium as fuel. As of this writing, the first energy-positive nuclear fusion reactor was demonstrated at the Lawrence Livermore National Laboratory, and has the potential to revolutionize the energy economy. Great Scott!

Sample of Po-210 (Polonium), 2021

Look at the date on this sample to determine its remaining radioactivity.

After the Cold War, Russia found other novel uses for nuclear science. Alexander Litvinenko was a former officer of the Russian Federal Security Service (FSB) and the KGB. After speaking critically about corruption within the Russian government, he fled retribution to the UK, where he remained a vocal critic of Russian President Vladimir Putin and the Russian government. Six years after fleeing, he was assassinated by two Russians by poisoning.

On November 1, 2006, Litvinenko suddenly fell ill and was hospitalized. He died three weeks later, becoming the first confirmed victim of lethal polonium-210-induced acute radiation syndrome. Litvinenko's allegations about misdeeds of the FSB and his public deathbed accusations that Putin was behind his unusual malady resulted in worldwide media coverage.



Tosaka / CC BY 3.0

Subsequent investigations by British authorities into the circumstances of Litvinenko's death led to serious diplomatic difficulties between the British and Russian governments. No charges were ever laid, but during a public hearing in 2014–2015, a Scotland Yard representative testified that "the evidence suggests that the only credible explanation is in one way or another the Russian state is involved in Litvinenko's murder".

A closeup of the sample on the reverse of the wax puck.

Another witness stated that Dmitry Kovtun had been speaking openly about the plan to kill Litvinenko, intended to "set an example" as a punishment for a "traitor". The main suspect in the case, a former officer of the Russian Federal Protective Service (FSO), Andrey Lugovoy, remains in Russia. In September 2021, the European Court of Human Rights ruled that Russia was responsible for the assassination.

Polonium-210 (Po-210) is a radioactive material that occurs naturally in the earth's crust at very low levels. Po-210 is a product of the radioactive decay of uranium-238, which decays to radon-222 and then to polonium, and has a half-life of 138 days. Like my plutonium, Po-210 emits alpha particles which carry high amounts of energy that can damage or destroy genetic material.

Polonium-210 was discovered by Marie Curie in the late 19th century. While radioactive, it emits a high-energy form of radiation, but the particles do not travel far and it decays relatively quickly. If polonium-210 enters the body, through inhalation, swallowing, broken skin, the results can be fatal. By mass, polonium-210 is one of the deadliest toxins, around 250 billion times more toxic than hydrogen cyanide.

Litvinenko and a masked colleague accuse fellow officers of corruption in 1998.
REUTERS / Sergei Kaptilkin / Files (RUSSIA)

Litvinenko suffers the consequences eight years later.
Natasja Weitsz via Getty Images

Pantex, Tonopah Test Range, and KUMMSC Challenge Coins and Bottle Openers, 2010's – 2020's

The United States halted underground nuclear explosions in 1992, tentatively embracing the still-unratified Comprehensive Nuclear-Test-Ban Treaty. Since then, every judgment about a warhead's safety and military credibility has had to come from laboratory science and field-testing that stop short of a nuclear yield. The National Nuclear Security Administration's Stockpile Stewardship Program – anchored in the super-computing, laser-fusion and hydrodynamic facilities at Los Alamos, Lawrence Livermore and Sandia National Laboratories – now supplies the physics data that full-scale tests once provided, allowing designers to model aging materials and new components down to the micron and microsecond.

Those virtual designs become physical hardware at Pantex, the Amarillo-area plant that disassembles, rebuilds and re-certifies every U.S. nuclear bomb and warhead. When the plant announced completion of the final B61-12 production unit in January 2025, it marked the end of a ten-year effort that replaced legacy electronics, installed modern safety devices and unified four older bomb variants into a single configuration expected to serve for at least two more decades. Similar assembly bays are now turning out the W88 Alt 370 for the Navy and preparing pilot runs of the W80-4 and W87-1, each rebuild tracked with measurement data that the laboratories fold back into their simulation codes.

Verification that the rebuilt bombs will actually release, guide, and survive to their targets comes at the remote Tonopah Test Range in Nevada, where Sandia flight-test teams drop telemetry-packed mock weapons from frontline aircraft and record every millisecond of their fall. Because no nuclear package is present, the tests can occur without violating the moratorium, yet they still generate the aerodynamic, structural and fuze-sequence data that commanders once gleaned from full-yield shots. Recent Tonopah campaigns with F-35A and F-15E jets have validated the B61-12's compatibility at supersonic speeds and fed another stream of evidence into the annual certification letter the laboratories send to the President.

Once a warhead leaves Pantex and clears its flight evaluations, most of the inventory moves to the Kirtland Underground Munitions Maintenance and Storage Complex – KUMMSC –

buried beneath Kirtland Air Force Base in New Mexico. Opened the same year the test ban began, KUMMSC's 300,000 square feet of underground vaults and service bays hold thousands of gravity bombs and cruise-missile warheads in a climate-controlled environment, where technicians from the 898th Munitions Squadron perform the timed swaps of neutron generators, batteries and pressure reservoirs that keep each unit certified between major overhauls. The facility also stages refurbished weapons for deployment and receives retired ones on their way back to Pantex for dismantlement, providing both a logistics buffer and quality-assurance lab.

In practice, the test-ban era has forced a closed, continually measured loop: laboratory simulations inform Pantex rebuilds; Tonopah verifies flight performance without a nuclear yield; KUMMSC stores, services and samples the finished weapons; and the resulting data flow back to the laboratories to refine next year's models. Together, these sites let the United States promise a modern, reliable deterrent while observing a prohibition on explosive nuclear testing – a manufacturing-and-measurement substitute for the ground-shaking proofs of the past, and an important strategic advantage.

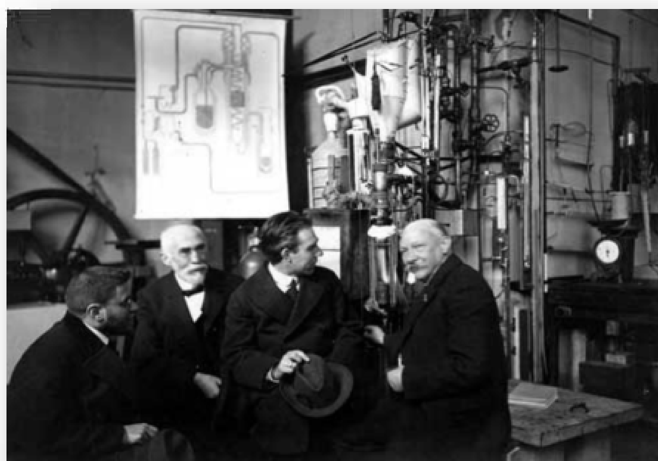
These challenge coins are small marvels of graphic design, incorporating "if you know, you know" imagery and messaging, and combining military braggadocio, occasionally grammatically suspect Latin phrases, and the dark humor prevalent in the nuclear weapons industry. Some of them also glow in the dark.

Lucite with Yttrium Barium Copper Oxide High Temperature Superconductor Sample

This Lucite puck contains a disc of yttrium-barium-copper oxide (YBCO) – a ceramic that, when it is cooled with ordinary liquid nitrogen, can carry electricity forever without losing a single watt to resistance. Most superconductors need far more exotic liquid-helium plumbing to do the same trick; YBCO was the first material that didn't, switching to its "super" state at about –180 °C, comfortably above nitrogen's boiling point (–196 °C).

Superconductivity was discovered on April 8, 1911, by Heike Kamerlingh Onnes, who was studying the resistance of solid mercury at cryogenic temperatures using the recently produced liquid helium as a refrigerant. At the temperature of 4.2 K, he observed that the resistance abruptly disappeared. In the same experiment, he also observed the superfluid transition of helium at 2.2 K, without recognizing its significance. The precise date and circumstances of the discovery were only reconstructed a century later, when Onnes's notebook was found. In subsequent decades, superconductivity was observed in several other materials.

What does that have to do with nuclear technology? To turn hydrogen into energy in the manner of the Sun, engineers must heat the gas until it becomes a roiling, electrically charged soup called plasma. It is millions of degrees hot – far hotter than any solid container can survive – so the only practical way to hold it in place is with invisible magnetic fields. For this, a new device was needed.

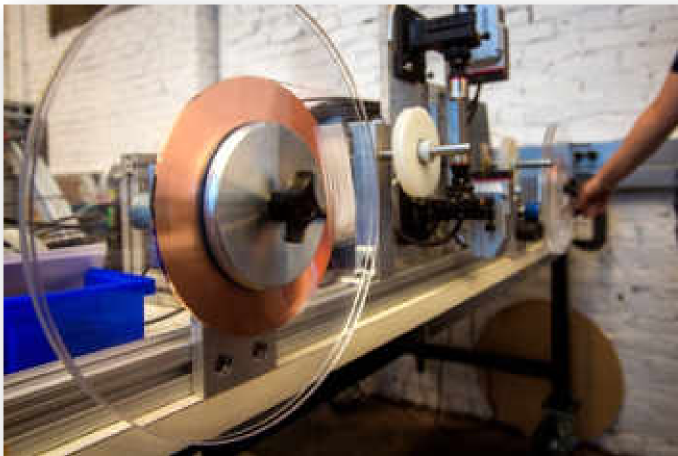


Paul Ehrenfest, Hendrik Lorentz, Niels Bohr, and Heike Kamerlingh Onnes.

Among the 2,100 papers submitted by the participants to the Second Atoms for Peace conference, held in Geneva in October 1958, was an article about the "Stability and Heating of Plasmas in Toroidal Chambers." The paper presented the results Soviet fusion scientists had achieved in an "experimental arrangement" – a small fusion machine which used a powerful magnetic field, generated by external magnets, to confine plasma in the shape of an axially symmetrical torus.

Later known as T-1, this was the first of a new reactor type dubbed "tokamak" (/ˈtoʊkəmæk/; Russian: токамáк), an acronym derived from "Toroidalnaya Kamera i Magnitnaya Katushka" (Toroidal Chamber and Magnetic Coil). The tokamak concept is currently one of the leading candidates for a practical fusion reactor.

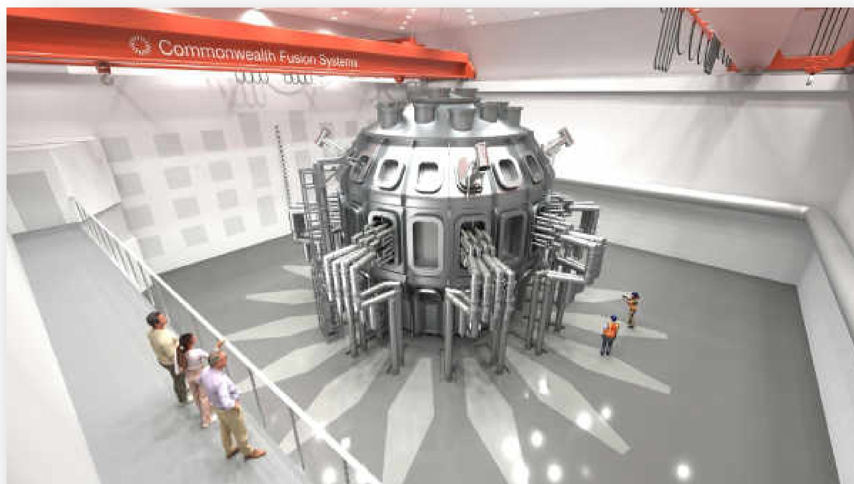
T-1, the first tokamak.



Spool of YBCO tape.

The stronger and more precisely shaped the magnetic fields in a tokamak are, the smaller and cheaper a fusion machine can be. That is where YBCO comes in. Layers of this material are deposited onto long, flexible metal ribbons, forming what looks like a shiny piece of tape. Wind thousands of meters of that tape into a coil, cool it with liquid nitrogen or simple refrigeration, and you get an ultra-powerful electromagnet that stays superconducting even when the magnetic field itself grows enormous. In 2021, an MIT-led team wrapped YBCO tape into a magnet that hit 20 tesla – roughly 400,000 times Earth's magnetic field – while staying perfectly cold and stable. Building a single next-generation reactor will require kilometers of this "coated-conductor" tape.

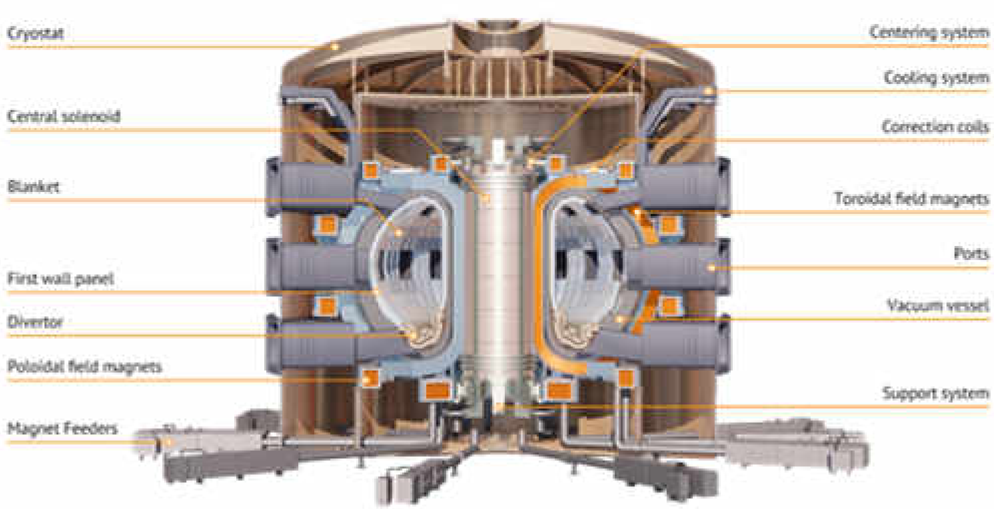
Commonwealth Fusion Systems, the company behind a compact tokamak called SPARC that is now rising outside Boston, expects to use about 10,000 km of YBCO tape just for SPARC's main magnets. Those magnets are designed to squeeze the plasma hard enough that the tiny machine – about the size of a tennis court – should produce more energy from fusion reactions than the electricity used to heat and control it, something no previous device has achieved in a sustained way. The project is scheduled to start operations in 2026, with the goal of demonstrating net power ($Q > 1$) in 2027.



Rendering of SPARC, a compact tokamak under construction as of this writing.

YBCO's relevance is not limited to one company or design. Its ability to create record-breaking magnetic fields while operating at easy-to-reach temperatures promises simpler cooling as the liquid nitrogen needed to cool it is cheap, safe, and already used in hospitals and chip factories, smaller reactors because every extra notch of magnetic strength lets engineers shrink the plumbing around the plasma, cutting cost and construction time, and lower power bills considering that superconducting coils waste almost no electricity, so more of the plant's output can go to the grid instead of back into its own magnets.

The unassuming black crystal in this artifact may be a key to unlocking the power of the Sun and creating practical fusion power – clean, carbon-free electricity drawn from abundant hydrogen. Producing YBCO tape quickly and cheaply enough remains a manufacturing challenge, but the physics milestone has been passed. Magnets built from this material are ready to bring star power down to Earth.



Various Other Nuclear Artifacts

This Soviet temperature gauge uses ra-226 to glow in the dark and helpfully came with a piece of lead.

Another Lichtenberg figure.

Vintage American smoke detectors use(d) americium instead of plutonium.

Roof tile from Hiroshima.

Another medal celebrating a reactor startup at Chernobyl.

Zirconium, the material of fuel assemblies.

509th Composite Group commemorating the 50th anniversary of the first atomic bombardment.

Autunite is naturally occurring calcium uranium phosphate fluoresces green under UV light.

Fracking with nukes.

The year-old strontium-90 sample still really gets my Geiger counter going.

A cool Westinghouse atom paperweight thing.

Souvenir from the Hiroshima Peace Memorial.

Some keychains from Three Mile Island, site of another famous nuclear disaster.

This (huge) (non-flux) capacitor has uranium glass that lights up under UV.

Lucite reactor model.

Advent of Computing

Curta Type I Mechanical Calculator, 1949

Let's begin this chapter with an ending, a final triumph as the brief age of the mechanical adding machine came to a close. The smallest mechanical calculator in the world was a sensation at the end of the 1940s – and so it remains. It is the enduring legacy of inventor Curt Herzstark, who survived his time at the Buchenwald concentration camp as an "intelligence slave". We will examine it before moving on to electronic computers.

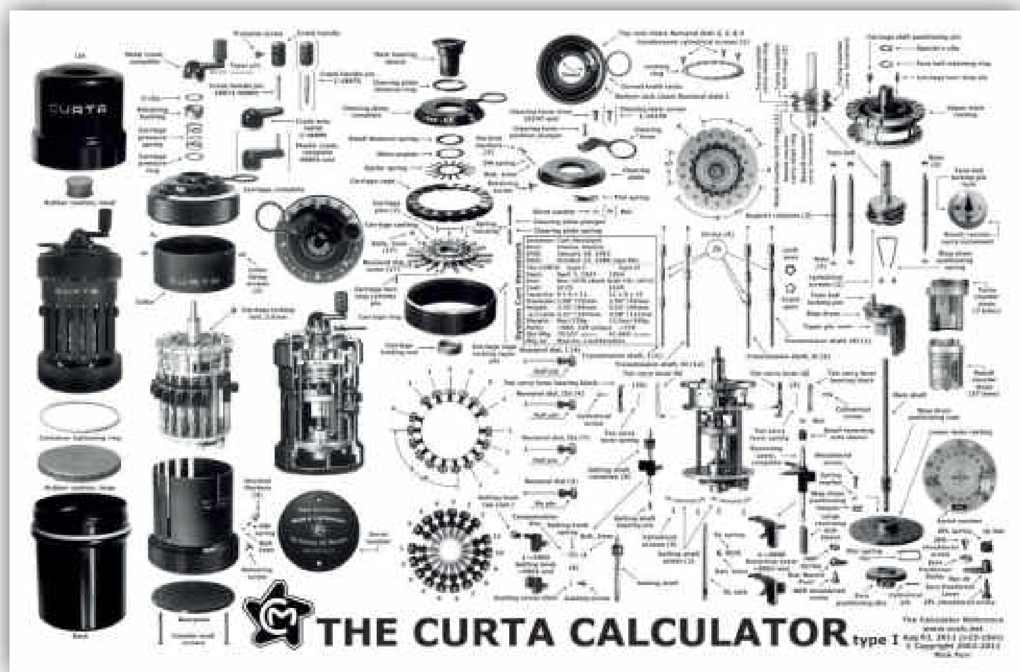
Curt Herzstark was born in 1902 and grew up in Vienna, where his Jewish father had established a factory manufacturing calculators and other precision instruments, and naturally young Curt followed in his father's footsteps. As a salesman for the firm, Curt soon realized there was a huge demand for a new kind of portable calculator to replace the bulky, heavy, and expensive adding machines of the time. But any dreams Herzstark had of designing such an instrument himself were scuppered when war broke out in 1939 and the Herzstark factory was ordered to make tools for use in the war effort.

Because of his Jewish ancestry, Herzstark's career became very precarious in Nazi Germany and by 1943 he found himself an inmate of Buchenwald. Luckily, his talents as an instrument maker were recognized and he was allowed some free time to work on his plans for a new, smaller calculator that would fit in the hand of its owner. Herzstark quickly determined that existing calculator designs could not be made much smaller.

Instead he used the dimensions and the precision mechanics of a watch movement, a pocket watch, as a guide, and considered how he could enlarge the tiny mechanism. He approached the problem from a novel angle. He acted as if he had already invented the pocket calculator and had had the special shape of the device firmly anchored in his mind beforehand. In doing so, he took customer requirements into consideration too – keeping his finger on the pulse of the market. His technical skills, his unconventional way of thinking and practical experience from his work at his father's factory came together to enable him to house a fantastically complex mechanism in the round case with the crank handle.

As Herzstark explained much later in an interview: "The head of the department, Mr. Munich said, 'See, Herzstark, I understand you've been working on a new thing, a small calculating machine. Do you know, I can give you a tip. We will allow you to make and draw everything. If it is really worth something, then we will give it to the Führer as a present after we win the war. Then, surely, you will be made an Aryan.' For me, that was the first time I thought to myself, my God, if you do this, you can extend your life. And then and there I started to draw the Curta the way I had imagined it." By the time Herzstark and the other survivors saw the death camp liberated in 1945, his prototype drawings were almost complete.

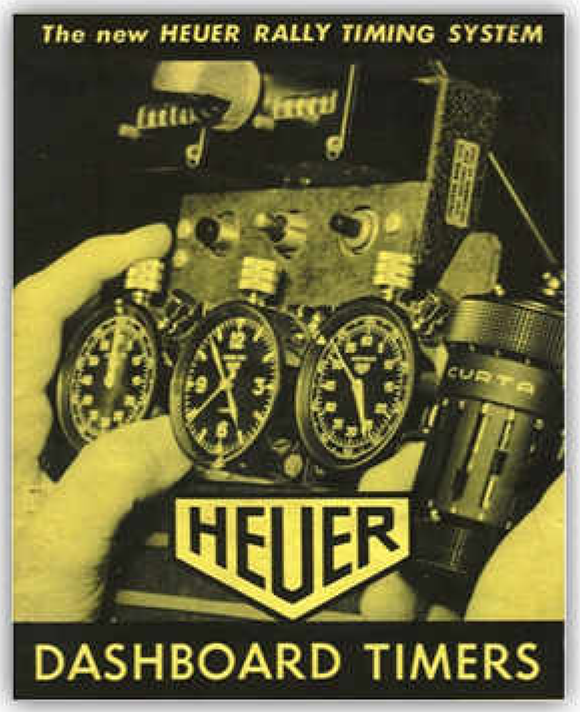
Following his new-found freedom, Herzstark experienced another stroke of luck when his talents were also recognized by none other than Prince Franz Josef II of the Principality of Liechtenstein, who invited the Curta man to work on his calculators in a new, specially built factory in his tiny country. A new company was formed, Contina AG, with Herzstark as technical director. It took a few more years for the Curta to finally appear in 1949, with a price tag – high at the time – of $125. The new calculator was handy, efficient, and ingenious, a pepper-pot-sized drum design more accurate than a slide rule and more user-friendly than anything imaginable at the time. It ran like clockwork: the 571 individual parts in the Curta, were orchestrated in such a way that the elegant device could be used to perform the four basic arithmetic functions and later, in a second version, even root extraction with the utmost precision.



© Rick Furr / Vcalc.net

So how does the Curta work? If you imagine a pepper-pot shaped metal barrel with a winding handle at the top and a ring pull next to it, that is the basic design. The handle, or crank, is turned clockwise to make the calculations. Around the barrel are a set of tiny levers or slides which can be lifted up and down to create the numbers you wish to calculate. At the top, you find two sets of corresponding numbers: the black numbers on a white background show the number of times the handle has been turned to make the calculations, and the white numbers on a black background show the result of the calculation. And all this in the palm of your hand, weighing only 230 grams.

Perhaps Herzstark's most inspired engineering trick was the inclusion of two sets of teeth within the barrel: one for addition and multiplication and another for subtraction. Herzstark hit on the idea of using the complement system (complements are the constituent numbers which add up to 9, so the complement of 8 is 1, while the complement of 5 is 4, and so on), which basically means adding numbers to work out a subtraction. Instead of turning the crank anti-clockwise to subtract, the handle can be lifted up slightly until a little red band appears, and then turned clockwise to engage the upper set of teeth and a subtraction has been made.



In the past, watch brands like Omega, Universal and Heuer advertised their watches showing Curta calculators in their marketing campaigns, and the Curta remains popular with watch collectors. Curtas particularly match 1960s racing watches, as the ingenious calculators were used as accurate measuring tools in rally races. The popularity of the Curta among rally drivers was due to two salient facts: Herzstark's invention was irrefutably accurate and, at the same time, tough enough to take the knocks of high-speed racing. So much so, that rally teams continued using their Curtas to measure times, speeds and distances into the 1980s, despite the emergence of modern pocket calculators. Racing drivers who swore by their cylindrical devices earned the memorable nickname of "Curta-crankers".

The precision of the Curta also attracted pilots, who needed highly accurate results when checking such things as weight, balance and other calculations essential in determining the safety of their airplanes. Being virtually error-free, the Curta's mechanical rigor can be relied upon to calculate precisely, whether facing a life-or-death situation, or as a trusty companion to architects, surveyors, engineers and craftsmen.

The Curta is much more than a fantastic refinement of a product that was immediately surpassed by electronics, an intelligent toy for math enthusiasts, or collector's gem. It saved its inventor's life. Curt Herzstark was an innovative, highly motivated man with extraordinary inner strength, technical skill, and artistic talent. His creativity lives on in what will probably remain the finest mechanical calculator ever made.

Lucite with Capacitor from Whirlwind I, 1946 – 1959

The emergence of the first generation of electronic computers, represented by this artifact, began when vacuum tubes replaced mechanical relays; the second depended on transistors; the third, the integrated circuit; and the fourth generation of computers came about after the invention of the microprocessor. Today, we are interacting with the fifth generation of computing technology, using Artificial Intelligence as we experiment with ChatGPT and other generative AI. The next frontier could be quantum, it could be biological (see DNA entry elsewhere in this book), it could be something nobody has imagined yet, or it could already exist in someone's garage.

The search for devices to aid computation had begun in ancient times. The abacus, developed in various forms by the Babylonians, Chinese, and Romans, was the first digital computer because it calculated values by using digits. A mechanical calculating machine was built in France in 1642, but a 19th century Englishman, Charles Babbage, devised most of the principles on which modern computers are based. His "Analytical Engine", begun in the 1830s but never completed for lack of funds, was based on a mechanical loom and would have been the first programmable computer.

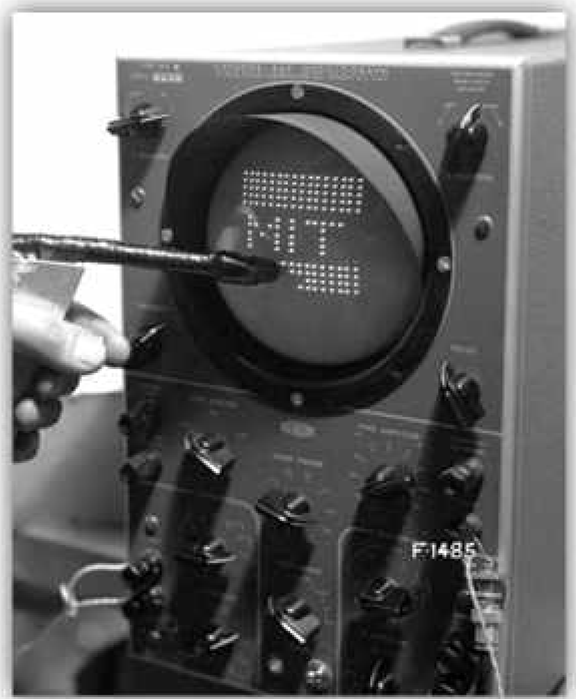
By the 1920s, companies such as IBM were supplying governments and businesses with complex punch-card tabulating systems, but these mechanical devices had only a fraction of the calculating power of the first electronic digital computer, the Atanasoff-Berry Computer. Completed by John Atanasoff of Iowa State in 1939, it could by 1941 solve up to 29 simultaneous equations with 29 variables. Influenced by Atanasoff's work, Presper Eckert and John Mauchly set about building the first general-purpose electronic digital computer in 1943. The sponsor was the U.S. Army Ordnance Department, which wanted a better way of calculating artillery firing tables.

ENIAC, which stood for Electronic Numerical Integrator and Calculator, was completed in 1946 at a cost of nearly $500,000. It contained 17,468 vacuum tubes, 7,200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors and around 5 million hand-soldered joints. It weighed more than 27 tons, occupied 1,800 square feet of space, consumed 150 kW of power, and was programmed by plugging and replugging some 6,000 switches. It was first used in a calculation for Los Alamos Laboratories in December 1945, and was formally dedicated in February 1946.

In late 1944, the U.S. Navy had asked the MIT Servomechanisms Laboratory to develop an analog flight simulation system. The project was assigned to Jay Forrester, who spent a year on the problem before determining that available analog techniques were too slow to function as control devices for a real-time flight simulator. In January 1946, his fellow graduate student Perry Crawford saw an early demonstration of ENIAC, and suggested Forrester leverage digital computer technology to solve the real-time speed

Jay Forrester.
MIT Archives

problem. Forrester's proposal was accepted by the Navy's Office of Research and Inventions, and the project was given the name "Whirlwind". During the next few years Forrester and his team designed and built Whirlwind I. The construction effort employed 175 people including 70 engineers and technicians, and the project's budget was around $1 million a year, vastly higher than other computers of the era. The flight-simulator portion of the project was dropped in 1948, the Navy deciding instead to concentrate on producing a general-purpose computer. The Whirlwind Project soon became too expensive for the Navy to fund and the work was taken over by the Air Force.



MIT Archives

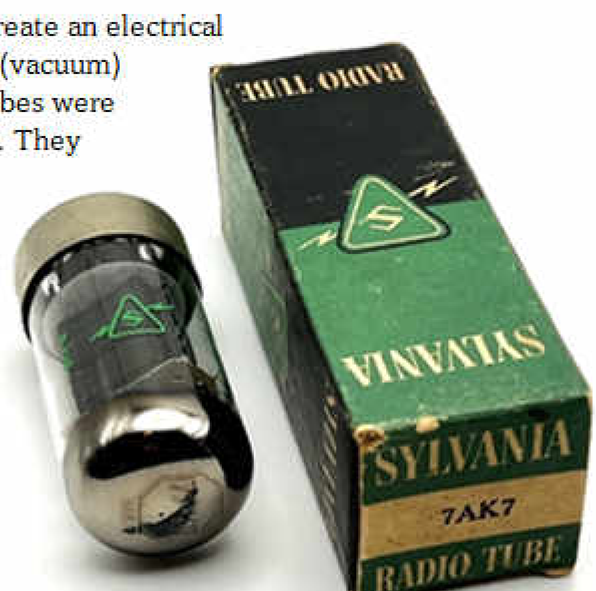
By late 1949, Whirlwind I was advanced enough to solve an equation and display its solution on an oscilloscope, and even for the very first animated and interactive computer graphic game. Finally Whirlwind "successfully accomplished digital computation of interception courses" on April 20, 1951, although in those days it would crash every 20 minutes on average.

A second version, Whirlwind II, was used as the basis for the United States Air Force SAGE air defense system which was used into the 80s, and the project indirectly led to almost all business and minicomputers in the 1960s. The mantra "short word length, speed, people" led to enduring designs.

Some of the most impactful contributions by Whirlwind were to the field of memory storage technology. The original Whirlwind memory specification called for 2,048 words of 16 bits each of random-access storage. In 1949, the only two technologies available that could hold this much data were mercury delay lines, and vacuum tubes. A mercury delay line consisted of a tube filled with mercury, a mechanical transducer on one end, and a microphone on the other. Pulses were sent into the mercury at one end and took a certain amount of time to reach the other end. They were detected by the microphone, amplified, reshaped into the correct pulse shape, and sent back into the delay line. Thus, the memory was said to recirculate.

Mercury delay lines operated at about the speed of sound, very slow in computer terms even by the standards of the time. The speed of sound in mercury is also dependent on temperature. Since a delay line held a defined number of bits, the frequency of the clock had to change with the temperature of the mercury. If there were many delay lines and they did not all have the same temperature, data could easily become corrupted. Whirlwind designers quickly discarded this technology as too slow and too unreliable.

The vacuum tube, a form of electrostatic storage also known as an electron tube or a thermionic valve, is a device that can be used to amplify, switch, modify, or create an electrical signal by controlling the movement of electrons in a low-pressure (vacuum) space. Invented by Sir John Ambrose Fleming in 1904, vacuum tubes were vital components of any electronic circuit between 1915 and 1950. They were used in devices including radios, telephone networks, sound recording & amplification, radar, televisions, and computers. Today they are still used in high end amplifiers and in other niche applications. There were several tubes capable of storing complex data in existence in 1949. These worked by projecting patterns of charged dots in a similar way to a television or radar cathode ray tube, which could then be detected using a thin metal sheet. The best-known today is the Williams tube, one of the earliest forms of random-access memory. Whirlwind engineers considered it but instead settled on a design being developed at the MIT Radiation Laboratory.



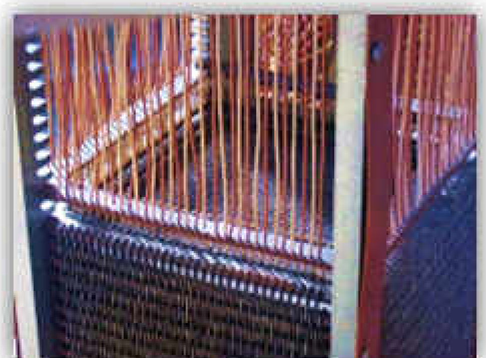
This 7AK7 "Computer Tube" (never mind the box), developed specifically for Whirlwind I, is also in my collection.

RCA 6571 Williams Tubes, used in early computers such as the IBM 701, also in my collection.

The choice was unfortunate. The Williams tube was better developed, could hold 1,024 bits, and was reliable. The MIT version was not, and the goal of 1,024 bits per tube was never attained. Also, the specifications called for an access time of six microseconds, but this tube came in around 30 – making the entire machine slower.

Whirlwind I used 5,000 vacuum tubes, leading to serious reliability issues since a single tube failure could cause a systemwide failure, and tubes available at the time simply did not have an adequate service life. Research found that silicon in the tungsten alloy of the filament was causing cathode poisoning; deposits of barium orthosilicate forming on the cathode prevented it from emitting electrons. A special "computer tube", the 7AK7, with a high-purity tungsten filament, was then specially developed for Whirlwind by Sylvania.

A next major innovation in data storage, Whirlwind's magnetic-core memory, was added in 1953 and not only addressed the reliability issues but represented a fundamental turning point in the development of computing. This type of memory uses rings of a hard magnetic material as transformer cores, where each wire threaded through the core serves as a winding. Magnetic hysteresis allows each of the cores to store a state, or one bit of information by being magnetized in either a clockwise or counterclockwise direction. Magnetic core would remain the dominant form of high-speed random-access memory until the introduction of DRAM in the 1970s, discussed later. Whirlwind I led to various other novelties such as self-checking procedures, sophisticated visual display facilities, feedback control loops, and techniques for sending digital data over telephone lines.



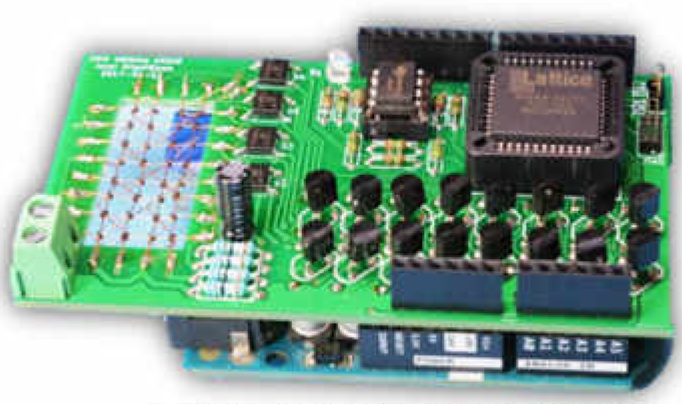
Whirlwind's magnetic-core memory.
Dpbsmith / CC BY-SA 3.0

Whirlwind team members also made important contributions to the emerging art of software development, and seeded the next generation of hardware developments at MIT's Lincoln Labs, MITRE, DEC, and others.

The importance of this experimental "one-of-a-kind" computer to the development of technology cannot be overstated: it was the first to use magnetic core memory; the first to operate with a direct keyboard interface; the first to use video displays for output; and the first to generate an animated interactive computer graphic. As "the only computer in the world that allowed a person to work with it individually" it was a precursor to almost all computers built in the decades that followed.

A current computer comparable in power to Whirlwind would be the Arduino DIY microcontroller. It is similar in capacity, although it's many times faster. Below is an Arduino outfitted with a tiny magnetic-core memory plane.

This Lucite artifact holds a prototypical mica capacitor, the colored dots indicating the strength of its capacitance. It is hand-soldered between two terminals, sectioned from a larger piece of a Whirlwind circuit board. Most of Whirlwind that was not destroyed is now shown at MIT's museum; these Lucites represent the only known parts in public hands. It is one of 40 made and was distributed as a memento at the reunion of the Project Whirlwind team on 30 June, 2009, 50 years after Whirlwind was shut down. Guest of honor was Jay Forrester.

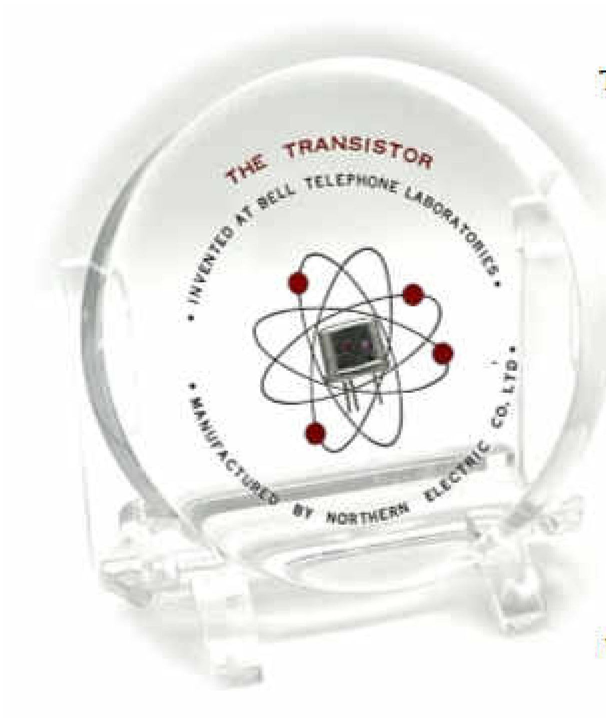


An Arduino with a tiny DIY core memory plane setup.
© *David Ives*

	Whirlwind	Arduino
Word Size	16	8/16 bits
Instruction types	36	131
Read/write memory	2K Words	2K bytes
Programmable read-only memory	32 *words*	32 Kbytes
Non-Volatile Storage	64K Words (drum storage)	2K bytes (EEPROM)
Adds per Second	50K	~2M
Integer multiplies per second		
Power Consumption	100 kW+	25 mA@5V = 0.13W
Cost	$3M+ (in 1950 dollars)	$24.95

Whirlwind vs. Arduino.

Lucite with Single Bell Labs Transistor, 1951



The invention of the transistor heralded the second generation of computers. A transistor is a semiconductor device with at least three terminals for connection to an electric circuit. In the common case, the third terminal controls the flow of current between the other two terminals. This can be used for amplification, as in the case of a radio receiver, or for rapid switching, as in the case of digital circuits. The transistor replaced the much larger vacuum tubes and relays, which used significantly more power to operate.

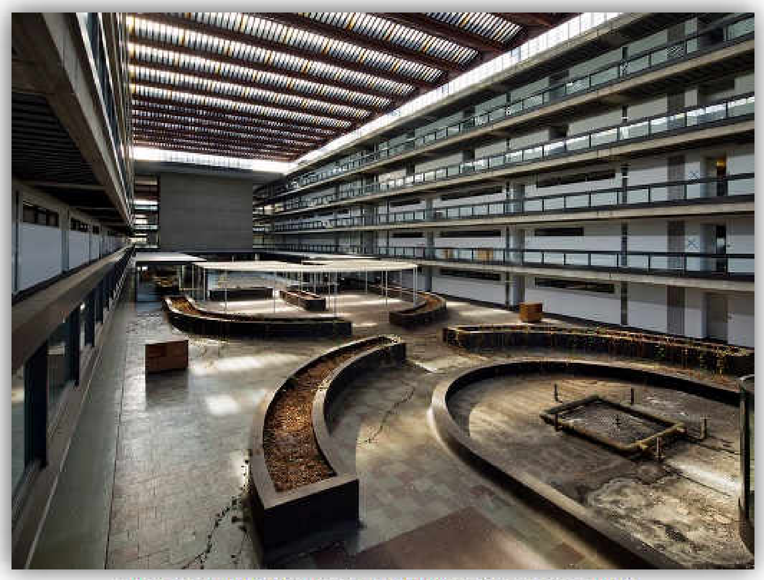
The first transistor was successfully demonstrated on December 23, 1947, at Bell Laboratories in Murray Hill, New Jersey. The three individuals credited with the invention of the transistor were William Shockley, John Bardeen and Walter Brattain. The introduction of the transistor is often considered one of the most important inventions in history, and in 1956 the team received the Nobel Prize in Physics for their invention.

It took some years for the transistor to mature, become reliable, and gain widespread commercial adoption. The world's first commercial transistor production began on October 1, 1951, at the Western Electric plant in Allentown, Pennsylvania. You'll find an artifact from that plant a few pages further.

Bell Labs didn't just invent new technologies, it also pioneered new ways of working. You hear a lot about "Agile" project management these days. Teams using agile methods get things done faster than teams using traditional processes. They keep customers happier. They enjoy their work more. Agile has indisputably transformed software development, and many experts believe it is now poised to expand far beyond IT. Ironically, that's where it began – outside of IT.

Some trace agile methodologies all the way back to Francis Bacon's articulation of the scientific method in 1620. A more reasonable starting point might be the 1930s, when the physicist and statistician Walter Shewhart of Bell Labs began applying Plan-Do-Study-Act (PDSA) cycles to the improvement of products and processes. Shewhart taught this iterative and incremental-development methodology to his mentee, W. Edwards Deming, who used it extensively in Japan in the years following World War II. Toyota hired Deming to train hundreds of company managers, eventually developing the famous Toyota Production System - the primary source of today's "lean" thinking. Iterative and incremental development methods were also a major contributor to the successful creation of the X-15 hypersonic jet in the 1950s. Fragments of X-15 #3 are elsewhere in this book.

A replica of the first transistor, also in my collection.



The beautiful, abandoned Bell Labs offices circa 2013.
© *Gorlin Architects*

Now transformed into inviting space once again.

Even the open, collaborative workspace itself at Bell Labs was an innovation, a precursor to the modern tech HQ. The historic building in Holmdel, N.J. is a midcentury triumph and was listed in the National Register on June 26, 2017. The complex is significant for the architectural design work of Eero Saarinen and Associates and the corporate campus landscape design by Hideo Sasaki of Sasaki, Walker and Associates.

Constructed between 1959 and 1966, Bell Laboratories-Holmdel marked a deliberate shift toward a modernist design befitting the modern research housed within. The property is characteristic of the midcentury move toward suburban landscaped campuses for corporate headquarters and research sites.

From 1959 to 2007, the building functioned as a research and development facility for Bell Laboratories and its successor Alcatel-Lucent. Bell Laboratories-Holmdel gained significance as a key research and development facility for Bell Laboratories, which spearheaded significant breakthroughs in twentieth-century science.

In addition to the transistor, researchers working at Bell Labs are credited with the development of radio astronomy, the laser, the photovoltaic cell, shown later in this book, the charge-coupled device (CCD), information theory, the Unix operating system, and the programming languages C, C++, and S.

Between 1982 and 1985, Eero Saarinen's partners, Kevin Roche and John Dinkeloo, oversaw the design and construction of additions to the building's east and west ends, which maintain the configuration, volume, massing, circulation pattern, and material palette of the original structure.

Today, the building – as long as three football fields – has been reimagined once again as Bell Works and bills itself as a one-of-a kind destination for business and culture, with an ecosystem of technology, traditional offices, retail, dining, hospitality, and more. It is open to the public seven days a week.

© *Bell Labs/Alcatel-Lucent*

Lucite with Exploded and Cutaway RCA Nuvistor Electron Tubes, 1959

By the early 1950s, the transistor was being used in a few products such as hearing aids and telephone exchanges, but there were still significant issues preventing its broader application, such as sensitivity to moisture and the fragility of the wires attached to germanium crystals. Donald G. Fink, Philco's director of research, summarized the status of the transistor's commercial potential with an analogy: "Is it a pimpled adolescent, now awkward, but promising future vigor? Or has it arrived at maturity, full of languor, surrounded by disappointments?"

Early transistors were chemically unstable and only suitable for low-power, low-frequency applications. In addition to their general fragility, for use in military and aerospace applications there was a still-valid concern that any transistor-based equipment would fail in the case of a nuclear attack due to the electromagnetic pulse (EMP) produced by the explosion.

To address these concerns and to compete with both traditional vacuum tubes and the newfangled bipolar junction transistors, RCA announced a new type of vacuum tube called the Nuvistor in 1959. Nuvistors were much smaller than conventional tubes of the day, almost approaching the compactness of early discrete transistor casings. Due to their small size, there was no space to include a vacuum fitting to evacuate the tube; instead, Nuvistors were assembled and processed in a vacuum chamber with simple robotic devices.

Jim Rees / CC BY-SA 2.5

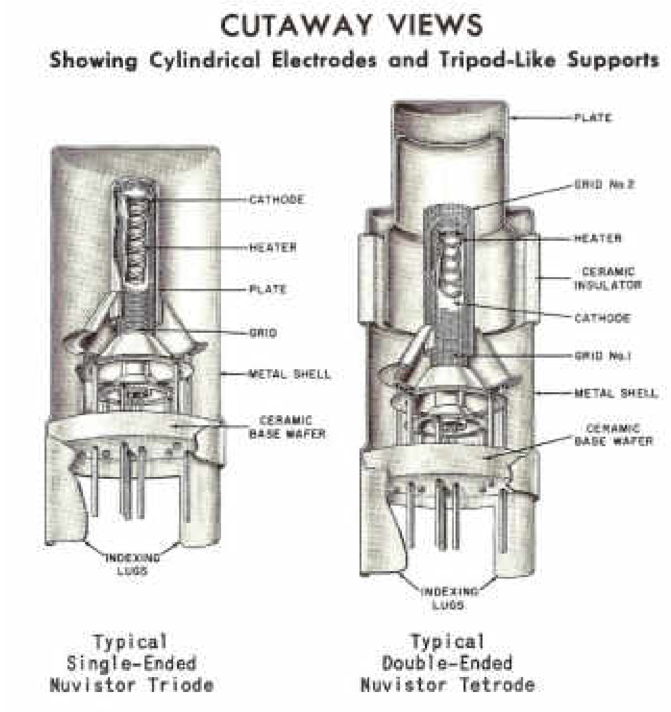
Foxiest / CC BY-SA 4.0

Nuvistors were widely used in televisions (beginning with RCA's "New Vista" line of color sets in 1961), radio and high-fidelity equipment primarily in RF sections, and oscilloscopes. Other Nuvistor applications included the Ampex MR-70, a studio tape recorder whose entire electronics were based on Nuvistors, as well as studio-grade microphones from that era. RCA discontinued their use in television tuners for its product line in late 1971.

Nuvistors also went to space. The Ranger series of unmanned spacecraft were launched between 1961 and 1965, and were the first U.S. attempt to obtain close-up images of the Moon's surface in preparation for the manned landings at the end of the decade. Rangers 1-6 were all failures, and variously failed to leave Earth parking orbit, lost contact with the Earth, missed the Moon or suffered failures of their cameras. Rangers 7, 8 and 9 (redesigned from the initial craft and launched in 1964 and 1965) were successes and as they hurtled towards their destiny of crashing into the Moon sent back detailed images from their six cameras, which were extremely useful for planning the Apollo missions. A NASA report published in 1966 gives an interesting insight into these spacecraft:

"The camera preamplifiers were reworked to incorporate either multiple-wrap leads on the Nuvistor or the new long-lead-type Nuvistors. As a result of a proof-test-model (PTM) Nuvistor failure prior to the Ranger 1711 mission, it had been determined that the Nuvistor leads which had only a single wrap before soldering were susceptible to cold joints and subsequent fracture."

Nuvistors were not just useful in the harsh conditions of space. The Collins R390A valve-based radio, first used "in anger" during the Korean War, was rushed back into U.S. military service in the first Gulf War because many of the state-of-the-art solid-state receivers with their transistor RF front-ends were failing due to the high static charges attributed to the desert heat, low humidity and sandstorms.



In 1976 a Russian MIG-25 "Foxbat" pilot defected to Japan and brought his plane along. Before returning the plane to its rightful owners in 30 crates, the Americans took it apart and analyzed its technology in great detail. What surprised them was the crudeness of the plane's structure and its avionics, and it was found that a lot of the ostensibly modern avionics in the aircraft used Russian copies of Nuvistors, for what was believed to be nuclear survivability.

There was cold logic behind having nuclear-hardened hardware in manned military equipment, whether it was Russian or made in the West. Although the human crew might receive a lethal dose of radiation it would take time for them to finally succumb, the expectation was that they would try to complete the mission in that time. Russian Nuvistors are still available today.

© RCA

© RCA

IBM Lucites with Transistor, Primitive Memory Components, Hybrid ICs, and SLT Chip Manufacturing Process, 1959

The early 1960s promotional IBM paperweight on the left contains, among other things, a hybrid integrated circuit (SLT module). These miniaturized electronic circuits preceded true "monolithic" ICs and were constructed of individual devices, such as semiconductor devices (e.g. transistors and diodes) and passive components (e.g. resistors, inductors, transformers, and capacitors), bonded to a substrate or printed circuit board. This Lucite also holds a single transistor and some primitive memory bits. The other artifact, at bottom right, shows the SLT module manufacturing process.

The artifact was produced around the same time as the IBM 1620, announced on October 21, 1959, and marketed as an inexpensive all-transistor "scientific computer". After a total production of about 2,000 machines, it was withdrawn in late 1970. Modified versions of the 1620 were used as the CPU of the IBM 1710 and IBM 1720 Industrial Process Control Systems (making it the first digital computer considered reliable enough for real-time process control of factory equipment).

Being variable-word-length decimal, as opposed to fixed-word-length pure binary, made it an especially attractive first computer to learn on – and hundreds of thousands of students had their first experiences with a computer on the IBM 1620.

RTC/ CC BY-SA 3.0

ArnoldReinhold / CC BY-SA 2.0

Core memory cycle times were 20 microseconds for the (earlier) Model I, and 10 microseconds for the 1962 Model II. This is about a thousand times slower than typical computer main memory would be less than 50 years later.

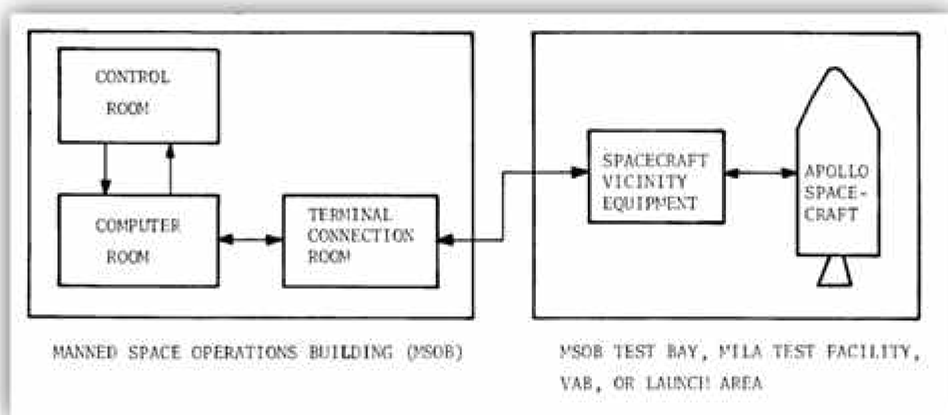
Lucite showing SLT module fabrication steps, also in my collection.

Radiation, Inc. Logic Modules Used in Acceptance Checkout for the Lunar Excursion Module (LEM) and Voyager Craft, 1960s

In telemetry, commutation is a process whereby multiple data streams ("measurands"), possibly with differing data rates, are combined into a single frame-based stream for transmission, before being separated again (decommutated) upon reception; it is a form of time-division multiplexing and requires frame synchronization.

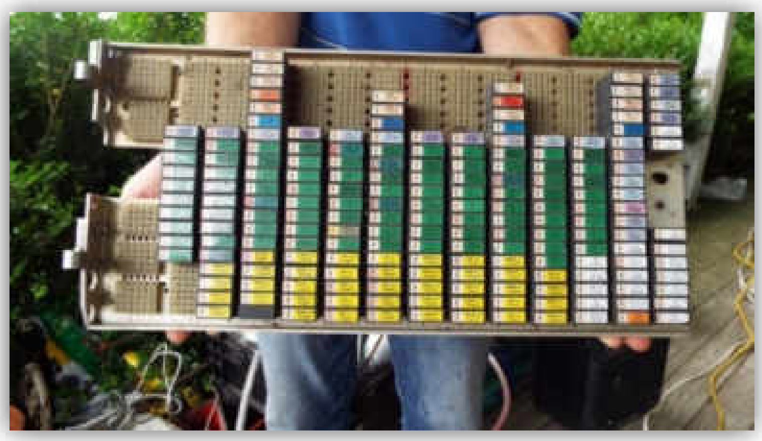
These logic modules were removed from a Radiation, Inc. Model 540 Decommutator that was first designed for and used as Acceptance Checkout Equipment (ACE-S/C) for the Apollo / Saturn program, and then also employed in subsequent missions. The unit housing these modules was in the ACE computer room in the Manned Space Operations Center at Kennedy Space Center. This room contained two CDC 160G computers, two Radiation 540 decommutators, and peripheral equipment, performing testing and checkout of Apollo Lunar Excursion Modules (LEMs) as well as the Voyager spacecraft and possibly others.

As modern computers based on integrated circuits (ICs) began to take over, the equipment eventually fell into disuse and the discarded computers ended up in a sale of NASA surplus in the 1970s. They were finally found and later given to me as a kindness by Jimmie Loocke of Apollo Guidance Computer fame, also an entry in this book.



During the early years of missile and rocket development, numerous electronic problems had been encountered due to the extreme operating conditions. Resistance to the high levels of force and vibration expected was one of the key factors considered in all Apollo hardware.

With manned space flight as the goal, extreme reliability was also needed in ground support, testing, and checkout technology. Radiation Inc. delivered that in the form of these modules.



Modules like this were socket mounted and interconnected in panels (see image). These panels held large numbers of them to form complex test equipment and other ground support systems.

There are no ICs in them, they are made from encapsulated discrete transistors and other passive components. The push for miniaturization was on, and these modules were the direct predecessors of commercial integrated circuits.

Lucite with IBM Hybrid IC as Used in Saturn Launch Vehicle Digital Computer, c. 1967

The Launch Vehicle Digital Computer (LVDC) resided in the Instrument Unit (IU) perched above the Saturn IVB, the second stage in a Saturn IB rocket, and the third stage in a Saturn V rocket. The LVDC was a completely separate computer system from the Apollo Guidance Computer (AGC), with a different (less innovative) architecture, different instruction-set, and different runtime software. The AGC is discussed later in this book.

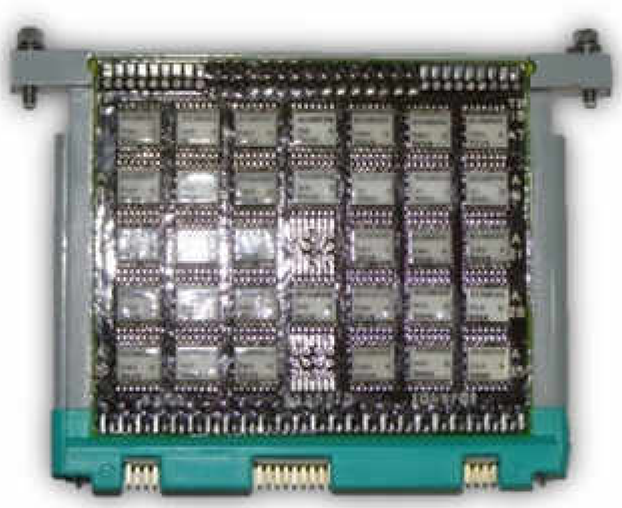
The purpose of the LVDC was to precisely control the Saturn from shortly before liftoff until the point at which the Saturn was discarded by the CSM. The computer and data adapter, which were designed and manufactured by IBM's Electronics Systems Center in Owego, N.Y., were a key part of the launch vehicle's guidance system. They were located one over the other and were connected by wire harness in the instrument unit.

The computer handled the following functions:

Prelaunch Checkout: Using a self-contained program, it tested itself and the rest of the Saturn IVB launch vehicle's guidance and control system and its telemetry system. It also ran a mission simulation.

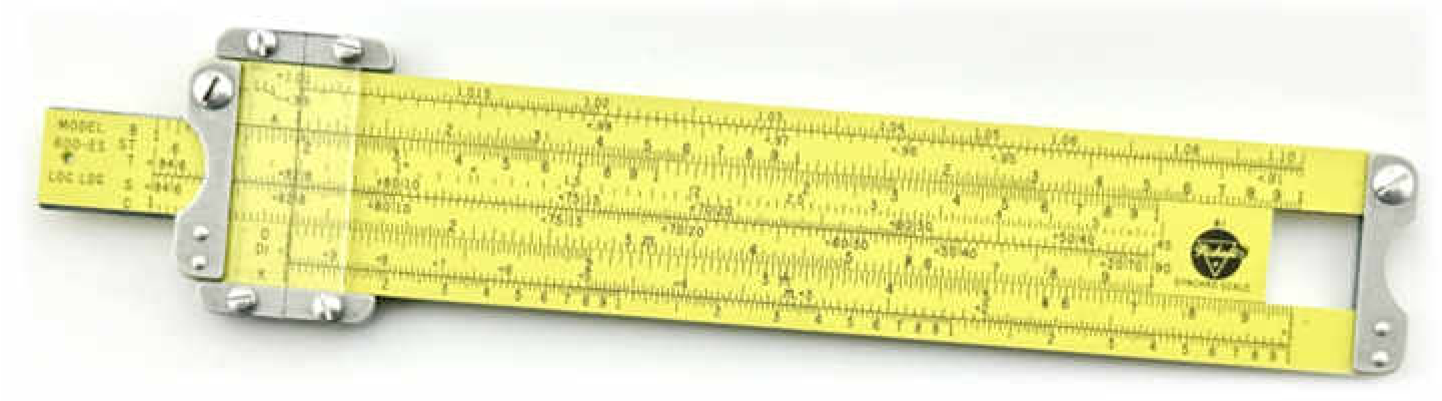
Booster Guidance: Processed data on velocity, position, altitude and time. 25x / second, it issued steering signals controlling the direction of thrust of the gimbaled rocket engines to keep the launch vehicle on course to orbit.

Saturn V Lunar Trajectory Injection: Issued signals to ignite the S-IVB engine and navigate the vehicle out of its earth orbit into a lunar trajectory. It calculated escape velocity and signaled engine cutoff. During the Apollo's turnaround and docking maneuver, it helped to keep the S-IVB stage stable.



This particular chip, labeled "TMV 6", is a logical majority detector, where the output is the majority of the 3 inputs. This too is not yet a true IC in that it contains physical transistors and other mounted components.

Pickett N600ES Slide Rule, 1962



The Pickett N600-ES slide rule occupies a small but iconic place in engineering and space history, most notably as the slide rule carried to the Moon by the Apollo astronauts.

The slide rule is an ingenious contraption, invented around 1620, primarily by William Oughtred. It used logarithmic scales on two parallel rulers to perform multiplication, division, and other mathematical operations. It was the pocket calculator of its day, a way for mathematicians and engineers to make speedy calculations on a ruler-within-a-ruler, no batteries required. The power of the slide rule lay in its ability to show relationships between numbers, on several different scales at the same time. It took the tedium out of calculations. A savvy engineer could multiply, divide, find the square and calculate complex logarithms simply by knowing which way to slide that middle piece.

The N600-ES was introduced in 1962–1963 as part of Pickett & Eckel's line of all-metal scientific slide rules. It was made from aluminum with a yellow anodized finish marketed as "Eye Saver," intended to improve visibility and reduce glare. Precision-machined, durable, and packed with a full complement of mathematical scales, the N600-ES became a favorite among engineers, students, and professionals at the height of the Space Race.

During the Apollo program, NASA issued the N600-ES as standard gear for astronaut training and ground-based mission planning, and it was photographed in use by astronauts including Buzz Aldrin during pre-mission calculations for Apollo 11. While the Apollo Guidance Computer handled in-flight navigation, the slide rule served as a manual backup tool for calculations.

Buzz Aldrin with a floating Pickett slide rule (and pipe) during Gemini XII.

Though it wasn't used for in-flight course corrections, at least one Pickett N600-ES is widely believed to have made the journey to the Moon as part of the Command Module's reference materials, quietly riding alongside the most advanced digital systems of the era. In this way, it formed a bridge between the analog craftsmanship of mid-20th century engineering and the emerging digital frontier, while reflecting NASA's conservative practice of including analog tools as contingencies in case of equipment failure.

After Apollo, slide rules like the N600-ES were quickly made obsolete by the rise of electronic calculators, but its legacy endures. Today, it is a prized collector's item and an evocative artifact of a time when mastering the slide rule was as essential to space travel as gigantic brass balls.

Lucite With Burroughs Silicon Wafer and ICs, 1960s

An integrated circuit, or IC, is a complete electronic circuit contained in one package. Its invention allowed for extreme miniaturization of system components, driving another revolution in electronics, and bringing about the third generation of computers. An IC package often includes transistors, diodes, resistors, and capacitors along with connecting wiring and terminals, and is also often called a chip. Early computers used thousands of switching circuits, and transistors were able to quickly perform this switching function. But as computer circuits became ever larger and more powerful, electronic circuits needed to become smaller. Because the components of circuits have to be wired together, producing smaller circuits was a complex task. Printed circuit boards helped, but the wiring was still bulky. This problem was solved by integrating all these components into one solid piece of material, the integrated circuit, or IC.

In 1952, G.W.A. Dummer of the British Royal Radar Establishment had the idea for an IC. However, his ideas were not put to use until a process for planar transistors was developed at Fairchild Semiconductors in 1957, allowing semiconductor emitters, bases, and other parts to be made on the surface of a silicon wafer.

In early 1958, Jack Kilby of the Texas Instruments Corporation was developing micro-modules. These were to be made by printing the components on a ceramic wafer. He realized that semiconductors and other components could be made on the same surface through a manufacturing process. The first commercially produced integrated circuit resulted from this work. It was made on a thin wafer of germanium. However, it still had wire connections, which caused major problems when wiring together large numbers of transistors and other conductors.

About the same time, another process for making ICs was being studied at Fairchild Semiconductors. Using the principles of planar transistor manufacturing, Robert Noyce used silicon dioxide dopants to protect and insulate junctions.

The integrated circuit dramatically changed the electronics field. In 1965, about 30 components could fit on a silicon chip five millimeters square. By 1982, that number had increased to 1,000,000. While the IC has become smaller and smaller, even reaching microscopic sizes, the basic principles remain the same.

Closeup of the wafer in Lucite.

Date	Type of component integration	Level of component integration
1964	Small scale integration	Up to 10 components or gates
1968-1969	Medium scale integration (MSI)	Up to 100 components or gates
1970	Large scale integration (LSI)	Up to 1000 components or gates
Early 1980s	Very large-scale integration (VLSI)	1000 or more components or gates
Late 1980s	Mega integration	1 million or more components per chip

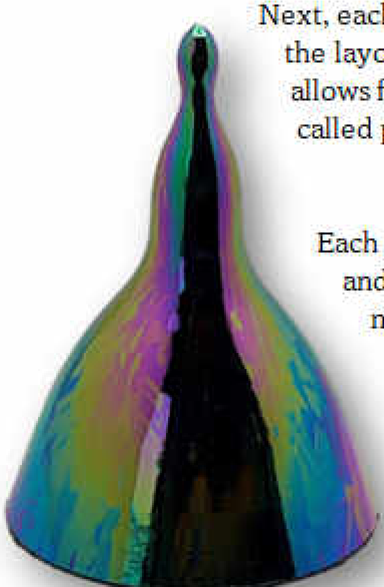
Levels of complexity. I think these days we have ULSI, "ultra large-scale integration", with billions of components per chip.

An integrated circuit consists of many extremely thin layers of different materials arranged in configurations such as transistors, diodes, resistors, and capacitors. A single chip may contain billions of transistors in the space of less than one square inch.

The circuit designer begins the production process by designing the complete integrated circuit. One factor affecting design is the intended use of the IC. With this in mind, the designer plans the best IC for use. She submits the completed design in the form of a schematic diagram.

This circuit diagram will be reduced hundreds of times before it is used.

From this schematic diagram, the layout designer creates a detailed technical drawing. The circuit is drawn in a much larger scale than the final product so that when the drawing is reduced there will be enough space between parts. If any of the lines touch each other, the circuit will short out when tested.



Rainbow-hued end piece of a silicon boule, also in my collection.

Next, each circuit layout is photographically reduced. It is not unusual for the layout to be reduced over 1,000 times or more. A reduced layout allows for thousands of circuits to be put on one wafer. Working plates, called photomasks, are made from the reduced layouts.

Each photomask goes with a certain step in the production process, and contains a large number of identical, actual size parts so that many chips can be printed at once. The photomasks are now ready for use and production of the IC can begin.

The substrate of an IC is a pure silicon crystal. These crystals must first be produced. First, liquid silicon is purified. A solid silicon particle, or seed, is dipped into the melted silicon. It is slowly withdrawn and placed in a cool area. The grown crystal is sliced into wafers about 0.5 mm thick, which are then polished to remove surface scratches and contaminants. Small portions of impurities are then added, this "doping" gives the silicon its electrical traits.

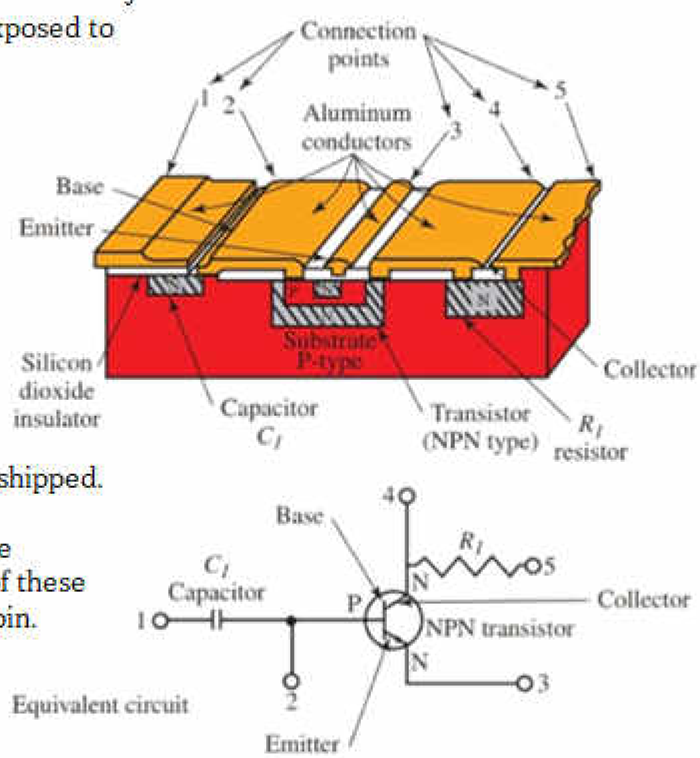
A silicon "boule". *Massimiliano Lincetto / CC BY-SA 4.0*

On the thin wafers of doped silicon, the basic building process begins. The circuit is built layer by layer, on the silicon wafer, or substrate. Each layer receives a pattern from the photomask. Then the wafer is exposed to ultraviolet light, causing the image to transfer to the wafer.

A thin coat of aluminum is vacuum deposited over the entire circuit. The aluminum coating is then sensitized and exposed through another special mask. After etching, only the interconnecting aluminum remains. It forms a pattern between transistors, diodes, and resistors.

After testing, the wafers are separated into individual chips, usually by scribing them with a diamond-tipped tool. The chips are then mounted onto a small can or flat package. Leads are bonded, and the ICs are washed. The cavities that hold the ICs are sealed, and finally, the ICs are shipped.

An example of how a transistor, resistor, and capacitor can be integrated into one circuit is shown to the right. Thousands of these circuits can be placed onto an area the size of the head of a pin.



Courtesy of Electrical Academia, from 'Integrated Circuit (IC) Construction, History & Types' www.electricalacademia.com

Lucite with IBM RAM Chip, 1967

In 1967, Robert Heath Dennard invented what is considered one of the most significant advances in computer technology: one-transistor dynamic random-access memory, or “DRAM”.

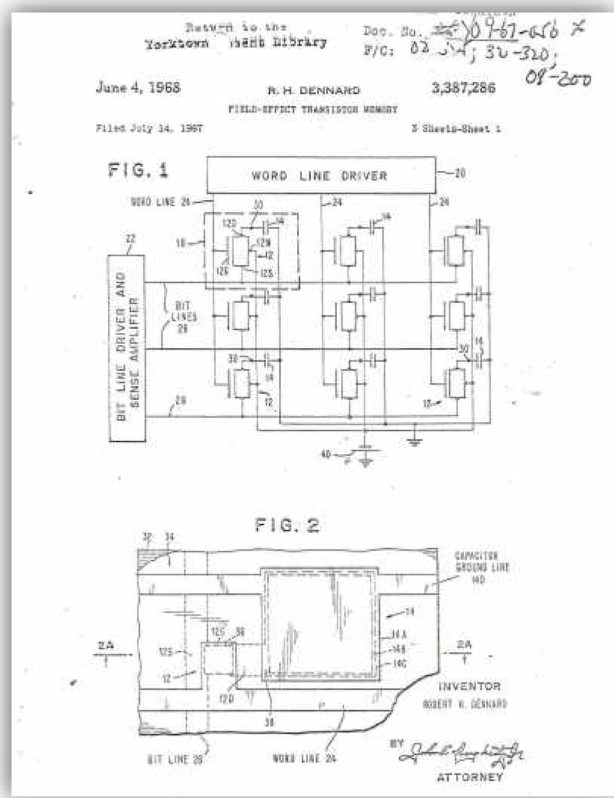
Born on September 5, 1932, in Terrell, Texas, Dennard began his career in 1958 as a Staff Engineer in IBM’s research division. This was an era when technicians fed punch cards into computers so big that they filled rooms and required their own A/C systems (some still do). UNIVAC had been produced in 1951, but the notion of an average person owning a computer was still a dream.

The invention of the integrated circuit constituted the first step toward the feasible personal computer because the microchip made it possible to drastically shrink devices. In 1966, Dennard took the second step. His team was working on field-effect transistors and integrated circuits, using the then standard six-transistor memory cell for each bit of data. After an in-house presentation by a rival team piqued his sense of competition, Dennard set out to streamline the memory cells he was working on.

At that time, RAM was a known and used concept: memory reserved for writing to and reading from in a temporary fashion, erased every time the computer is turned off. However, in the mid-1960s magnetic-core memory required an elaborate system of wires and magnets that was bulky and power hungry, negating RAM’s theoretical efficiency. Magnetic-core memory was quite expensive as well.

Dennard’s revolutionary achievement was to reduce RAM to a cell with only a single transistor. His insight was that it should be possible to store binary data as a positive or negative charge on a capacitor. After several months of experimenting, Dennard had reduced his RAM cell to a small capacitor and a single field-effect transistor, gating the flow of data to and from a data line.

Dennard was granted a patent for his one-transistor DRAM in 1968. By the early 1970s, the first DRAM chip, the Intel 1103, became commercially available, and by the mid-1970s, DRAM had replaced core memory as the dominant form of storage.



A drawing submitted with the application for Bob Dennard's invention of single-transistor, single-capacitor computer memory – known as Dynamic Random Access Memory (DRAM) – for which he received a patent in 1968.

Lucite with 1103 and successive generations of Intel DRAM, also in my collection.

When personal computers became a realistic possibility, DRAM allowed them to perform complex operations, still fit on a desktop, and become affordable.

Since then, “How many gigabytes of RAM. . .?” has become a commonplace question, and the answers more impressive for each new generation of computers.

The RAM chip in this Lucite is of the kind used in the first PC, which we will encounter later, and is not from 1967. The oldest I own is the 1103 to the left.

Lucite with NCR Memory, Disk, and Processing Components from the World's First IC Computer, 1968

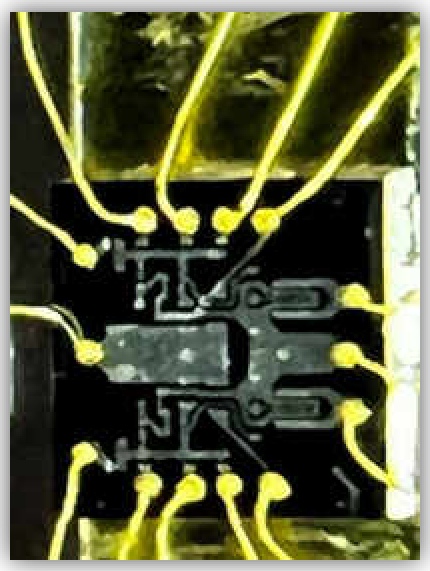
The NCR Century 100 was NCR's first all integrated circuit (IC) computer, built in 1968. The console of the system had only 18 lights and switches and allowed entry of a boot routine, or changes to loaded programs or data in memory. A typewriter console was also available.

This Lucite contains, among other things, one of these early ICs. The extreme closeup below, showing the simple design, was taken with a more modern computing marvel, an Apple iPhone 13 Pro – pretty amazing. Logic gates were created by wire-wrapping NAND gates together, forming flip-flops and other complex circuits.

Rod memory, a unique form of thin-film magnetic-core memory, was first commercially introduced by NCR in their model 315 RMC (Rod Memory Computer) and was also used in their "Century" line up to 1968. Rod memory was similar to magnetic core memory; both technologies would last only a few short years as neither was able to compete with the new semiconductor memory chips. You will find an example of the latter on the next page.

© NCR

A day in the life of an NCR Century, captured in LEGOs.
© Johan Alexanderson



Logic board with multiple chips, also in my collection.

Intel 4004, The First Microprocessor (2,300 Transistors), 1969

In 1969, Nippon Calculating Machine Corporation approached Intel to design 12 custom chips for its new Busicom 141-PF desktop printing calculator. Intel engineers suggested a family of just four chips, including one that could be programmed for use in a variety of products, setting in motion an engineering feat that dramatically altered the course of electronics and gave birth to a fourth generation of computers.

Intel designed a set of four chips known as the MCS-4. It included a central processing unit (CPU) chip, the 4004, as well as a supporting read-only memory (ROM) chip for the custom applications programs, a random-access memory (RAM) chip for processing data, and a shift-register chip for the input/output (I/O) port. The CPU was a new breed of computer component – a microprocessor – the first integrated circuit containing all the functions of a central processing unit of a computer

Intel purchased the rights from Nippon Calculating Machine Corporation and launched the Intel® 4004 processor and its chipset with an advertisement in the November 15, 1971, issue of Electronic News: "Announcing A New Era In Integrated Electronics".

Lucite celebrating the 50th birthday of the 4004 in 2021 with image of the chip mask, also in my collection.

That's when the Intel® 4004 became the first general-purpose programmable processor on the market – a "building block" that engineers could purchase and then customize with software to perform different functions in a wide variety of electronic devices.

The Intel 4004 had around 2,300 transistors. In 1965, Intel founder Gordon Moore had perceived that the number of transistors on a chip doubles every two years, though the cost of computers is halved. This became known as Moore's Law, which states that we can expect the speed and capability of our computers to increase every couple of years, and we will pay less for them. Another tenet of Moore's Law asserts that this growth is exponential.

In the decades that followed Gordon Moore's original observation, Moore's Law guided the semiconductor industry in long-term planning and setting targets for research and development (R&D). Moore's Law has been a driving force of technological and social change, productivity, and economic growth that are hallmarks of the late 20th and early 21st centuries. Later in this chapter, you will encounter a CPU with 8 billion transistors, pushing the boundaries of physics. Experts agree that computers should reach the physical limits of Moore's Law at some point in the 2020s. The high temperatures of transistors eventually would make it impossible to create smaller circuits. This is because cooling down the transistors takes more energy than the amount of energy that already passes through the transistors.

The Busicom 141-PF.
© *www.vintagecalculators.com*

Bowmar 901B, The First American Pocket Calculator, 1971

The first calculators and computers were bulky, expensive, and complex machines, typically confined to universities, research institutions, and large corporations. The advent of the pocket calculator in the early 1970s brought computational power into the hands of everyday users, dramatically democratizing access to digital computing capabilities.

The development of the pocket calculator was a remarkable achievement in the miniaturization of electronic components. The engineering innovations developed for pocket calculators, such as microprocessors and LCD displays, had far-reaching implications for the entire field of electronics.

The pocket calculator replaced the slide rule and thus transformed education, particularly in the teaching of mathematics and engineering. It made complex calculations more accessible to students, allowing for more time to be spent on understanding underlying concepts rather than on manual computation.

On an economic level, the pocket calculator contributed to the growth of the consumer electronics industry, and the advancement of microprocessor technology and software engineering. Socially, it symbolized the increasing role of technology in everyday life, changing how people approached problems and tasks in their professional and personal lives.

Snap-action Klixon discs gave positive tactile feedback and durability due to the gold surface and the Mylar sealed protection. The flat construction of the keyboard array made an overall thickness of just 0.15" possible.

The first pocket calculator introduced in the United States was the Bowmar 901B, aka the "Bowmar Brain", which hit the market in September 1971. Produced by Bowmar Instrument Corporation, a small company specializing in high technology components for the space program, it was intended as a demonstration device for its new Light Emitting Diode (LED) displays. The Bowmar 901B was the first portable electronic calculator available in the U.S. market and represented a significant advancement in consumer electronics.

The Bowmar 901B was a four-function calculator, capable of performing addition, subtraction, multiplication, and division, based on another innovation, Texas Instruments' TMS0103 "calculator-on-a-chip", among the first of its kind.

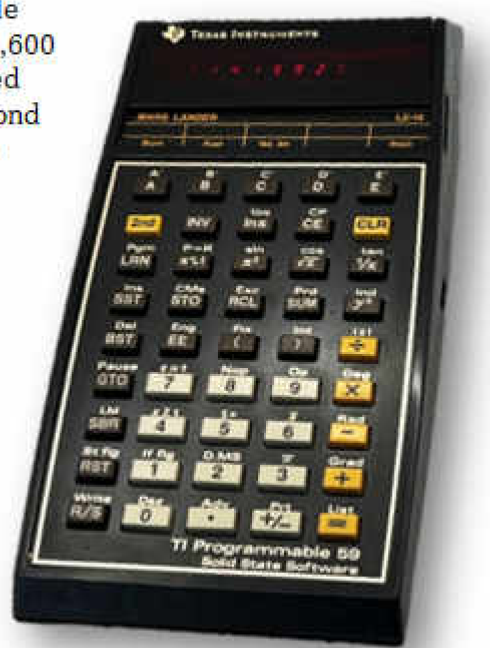
The keyboard first introduced on the Bowmar 901B went on to live a storied life of its own. The Klixon™ hermetic miniature and sub-miniature snap action switches found on many early pocket calculators had been developed by Texas Instruments in 1960. These Precision Hermetic Switches were used for many decades in a wide range of applications, including in the Space Shuttle. The Klixon keyboard (registered trademark of TI) was perfectly designed to work with TI's integrated circuits – their main line of business. This was a time when TI had little desire to get into the actual calculator business. They were content supplying ICs, keyboards, and LED displays to other manufacturers. TI's first calculator, the Datamath TI-2500, was still a good year or two from the concept stage.

Klixon controls in space. Say it like "Pigs in Space!"

The Bowmar Brain was notable for its small size, fitting comfortably in a pocket, which was a remarkable feat at the time. The device featured an LED display and was powered by rechargeable Nickel-Cadmium batteries. Its portability and functionality made it an instant hit. Priced at

around $240 (equivalent to over $1,800 in 2024 dollars), the Bowmar 901B was considered a luxury item. Despite its high price, demand for the Bowmar Brain underscored the public's appetite for portable computing devices, setting the stage for the rapid development and proliferation of more affordable and advanced calculators in the years that followed.

An example of the latter is my TI-59, which aside from representing fond childhood memories, represented a significant leap forward in portable computing when it was released 1977 at a list price of $299 (about $1,600 in 2024 dollars). The TI-59 was one of the first calculators that allowed users to program it to perform complex mathematical operations beyond the standard functions available on most calculators at the time. This made it especially valuable for engineers, scientists, and other professionals who needed to perform repetitive and complex calculations. The TI-59 introduced the use of magnetic cards for storage, allowing users to save their programs and data. The calculator could also be expanded with modules that added special functions or capabilities. This feature extended the life and usefulness of the TI-59 well beyond that of typical calculators.



My TI-59.

The TI-59 introduced many to the concepts of programming and computational thinking. Its success demonstrated the demand for programmable and expandable devices, influencing the design and features of later calculators, personal digital assistants (PDAs), and even early smartphones. Perhaps most notable about this powerful machine was the vibrant community it fostered of users who shared programs, tips, and techniques, contributing to a growing body of knowledge around computing and programming.

The final evolution of pocket calculators is represented by the graphing calculator, such as my TI-89, released in 1998. These machines represented another significant leap forward, and like their predecessors became an important tool for students, engineers, and professionals. The TI-89 offered a range of functionalities that were advanced for its time, including symbolic manipulation (ability to solve equations algebraically), calculus operations (such as derivatives and integrals), and complex numbers. This made it an invaluable tool for higher-level math, physics, and engineering courses.

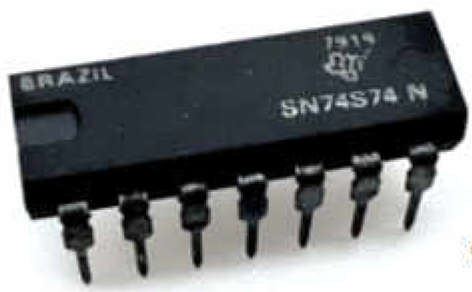
I actually used this one in school.

Mostly though, the TI-89 was notable for its powerful graphing capabilities. It could graph 3D functions, parametric equations, polar equations, and more, providing a visual understanding of complex mathematical concepts which were difficult to visualize otherwise. Continuing the tradition of programming on these tiny machines, the TI-89 allowed users to write their own custom formulas and functions, games, and utilities in TI-BASIC or Assembly language. One of the standout features of the TI-89 was its ability to manipulate algebraic expressions and solve equations symbolically, not just numerically.

Like many Texas Instruments calculators, the TI-89 was known for its indestructability. Many units remained in use for decades; mine was purchased in 2003. As we saw with the TI-59, the longevity and enduring popularity of the TI-89 led to the creation of a vast ecosystem of support materials, including textbooks, tutorial websites, and forums.

The introduction of the Bowmar 901B and its subsequent success marked a significant milestone in the history of computing. The final culmination of its evolution in the TI-89 represented a bridge between the pocket calculator and the more advanced portable computing devices that would soon follow.

Nasa JSC Mission Control MODCOMP Computer Chip, 1970s-80s



This simple Texas Instruments chip, a dual in-line package, or DIP, containing two D-type positive-edge-triggered flip-flops with preset and clear, was extracted from a circuit board of the MODCOMP computer system used by NASA Mission Control at Johnson Space Center during the 1970s-80s.

Many space missions were managed using this system including both Voyager probes, SkyLab, and even a few early Space Shuttle missions.

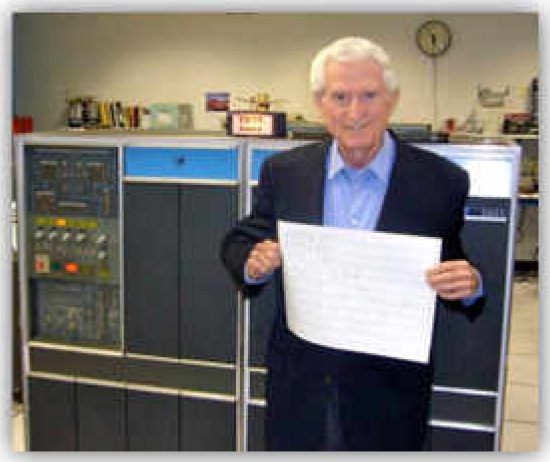
Though it is now obsolete, the MODCOMP system was cutting-edge technology at the time. The computers were housed in large cabinets in NASA's Mission Control Center and were responsible for computing critical data such as spacecraft telemetry.

This tiny, basic chip helped process spacecraft transmissions using its simple binary logic functions. It supported craft in active exploration of outer space, and so contributed to our understanding of the universe.

Lucite with Air-Cooled Amdahl 5680 Logic Chip, 1980

In the late 1970s & 80s most large computers were water (or fake blood) cooled, until Amdahl, an IBM competitor, invented air-cooling technology for its mainframe computers. Gene Amdahl came from South Dakota farm country, where he attended a one-room school without electricity. In the 1960s, he designed a revolutionary and influential family of mainframe computers for IBM, but left the company in 1970 to create a rival organization. For five long years, his company worked feverishly, developing a computer that was faster and less expensive than the IBM System/360 mainframe computer systems.

The 470V/6, introduced in 1975, was an immediate success. The following year, Amdahl Corporation went public. In the 1970s, when IBM had come to dominate the mainframe industry, Amdahl created plug-compatible computers that could be used with the same hardware and software as models from IBM, but were more cost-effective. These machines gave IBM some of the little competition it had in that very high-margin computer market segment.



Gene Amdahl.
© IBM

During this time savvy IBM customers liked to have Amdahl coffee mugs visible in their offices when IBM salespeople came to visit. While winning only about 8% of the mainframe business worldwide, Amdahl did win a position as market leader in some regions.

Amdahl logic chips offered speed and performance, but used a lot of electricity which generated a lot of heat that had to be dispersed. The unique cooling tower design that Amdahl engineers came up with allowed the chips to not overheat. The Amdahl model 5860 was the 2nd generation Amdahl mainframe computer following the pioneering model 470V/6. Amdahl continued to lead IBM with this air cooling and its machines outperformed IBM's best in the early 1980s.

Amdahl's Law is also named after Gene. It is a formula which gives the theoretical speedup in latency of the execution of a task at a fixed workload that can be expected of a system whose resources are improved. In other words, it is a formula used to find the maximum improvement possible by just improving a particular part of a system. It is often used in parallel computing to predict the theoretical speedup when using multiple processors.

This Lucite paperweight contains an actual Amdahl logic chip with an air-cooling tower device mounted on top – a pioneering achievement for the time. Air cooling has now become the standard for all but the most powerful CPUs.

Lucite with Intel 4004 and 8086 Chips, The First PC, 1981

Computers small and inexpensive enough to be purchased by individuals for use in the home first became feasible in the 1970s, when large-scale integration made it possible to construct a sufficiently powerful microprocessor on a single chip, and with the introduction of DRAM. A small firm named MITS developed the first "personal computer", the Altair, in 1974 using Intel's 8080.

The Altair was popular among hobbyists, but its commercial appeal was limited. The personal computer industry truly began in 1977, with the introduction of three preassembled mass-produced personal computers: the Apple II, the TRS-80, and the Commodore Personal Electronic Transactor (PET).

These machines used 8-bit microprocessors and possessed rather limited memory capacity, but because personal computers were much less expensive than mainframe computers (the bigger computers typically deployed by large business, industry, and government organizations), they could be purchased by individuals, small and medium-sized businesses, and primary and secondary schools.

IBM, the world's dominant computer maker, did not enter the new market until 1981, when it introduced the IBM Personal Computer, or PC. The PC used the Intel 8088 (a variant of the 8086), was significantly faster than rivals, had 10 times the memory, and was backed by IBM's large sales organization. It also ran Lotus 1-2-3, an extremely popular spreadsheet introduced in 1982.

The IBM 5150, the first "PC".
Rama & Musée Bolo / CC BY-SA 4.0

The IBM PC became the world's most popular personal computer, and both its microprocessor, the Intel 8088, and its operating system, which was adapted from Microsoft Corporation's MS-DOS system, became industry standards, followed by Microsoft Windows some years later. Rival machines that used Intel microprocessors and MS-DOS became known as "IBM compatibles" if they tried to compete with IBM on the basis of additional computing power or memory and "IBM clones" if they competed simply on price. The suffix "x86" now denotes a whole family of computer architectures based on the 8086 and its 8088 variant.

No fans or heatsinks, the Intel 8088 is just another chip on this board.
German / CC BY-SA 3.0

Advances in software and operating systems were matched by the development of PC microprocessors following Moore's law of ever-greater numbers of circuits, with resulting increases in processing speed and power. Today, most desktop and laptop computers sold are still based on the x86 architecture. At the high end, x86 also continues to dominate computation-intensive workstation and cloud computing segments. The fastest supercomputer in the TOP500 list for June 2022 was the first exascale system, Frontier, built using AMD Epyc CPUs based on the x86 ISA; it broke the 1 exaFLOPS barrier in May 2022. There is an artifact later in this chapter from the first petaFLOP supercomputer, also built using x86 CPUs made by AMD.

Lucite with Cray Y-MP 2,500 Gate Array, 1988

Known as the "father of supercomputing", Seymour Cray was an enigmatic figure who shunned the spotlight while revolutionizing high-performance computing with his innovative designs and groundbreaking machines. Born in Chippewa Falls, Wisconsin, in 1925, Cray was an early technology prodigy, constructing a rudimentary computer from Erector Set parts while still in high school. After serving in World War II he earned degrees in electrical engineering and applied mathematics.

Cray's career took off when he joined Engineering Research Associates in the late 1940s and began developing cutting-edge computers for military and scientific applications. Following a series of mergers, Cray found himself at the newly formed Control Data Corporation (CDC), where he helped design one of the first commercially successful transistor-based computers. The age of the vacuum tube was over.

While at CDC, Cray's singular focus on performance led to the creation of the world's first supercomputer, the CDC 6600, which was an astounding ten times faster than any other computer at the time. The 6600 far outstripped IBM's fastest machines, and IBM was understandably upset. There is an apocryphal story that IBM chairman Thomas J Watson berated his staff with a memo asking how it was possible that giant IBM could possibly be outdone by tiny CDC, whose workforce numbered only 34, "including the janitor".

At CDC, Cray's legendary dislike of bureaucracy soon became apparent. Asked to write a five-year plan for the company, his response was: "Five-year goal: Build the biggest computer in the world. One-year goal: Achieve one-fifth of the above." In 1972, Cray left to form his own company, Cray Research. It was there that he developed the iconic Cray-1 supercomputer, which once again pushed the boundaries of computing. Sporting a unique cylindrical design, the Cray-1 was a marvel, and the fastest machine in the world when it debuted in 1976. Its sleek, C-shaped tower and futuristic aesthetic made it an icon of the computer age.

The Cray-1 quickly became the benchmark for high-performance computing, with organizations such as the National Center for Atmospheric Research (NCAR) and the Los Alamos National Laboratory utilizing it for advanced scientific research. A piece of a Cray-1 is included in one of my Mini Museums, shown later in this book.

Seymour Cray's designs for supercomputers were for much of the 1960s, 70s and 80s the most powerful – and the most expensive – on the planet, and ingenious to the point of miraculous. Seeking a way to cool the Cray-2 he built in 1985, at the time the fastest computer in the world, he characteristically chose to cool it by completely immersing it in artificial human blood. Ever stylish, Cray included a decorative fountain in the coolant circulation system. In 1988, Cray Research released the Cray Y-MP, the first supercomputer to break the one gigaflop barrier – one billion floating-point operations per second. This machine's remarkable speed and memory capacity made it an indispensable tool for complex scientific simulations, nuclear research, and meteorology.

A Cray-2 supercomputer with decorative movie blood fountain.
© Cray Computer Corporation

In June 1997, when NCAR's Cray Y-MP was decommissioned after seven years of hard, productive work, staff serenaded "Old Big Iron" with bagpipes and a rendition of "Auld Lang Syne". This Lucite contains a gate array from one of these computers.

The Cray-3 used a three-dimensional module design, with a constraint of one-foot maximum wire length to enhance performance and reduce size. © *Mark Richards. Courtesy of the Computer History*

Cray was known for his unique work habits. He often worked alone, late into the night, and was famous for insisting on a quiet environment, free of distractions. When his first wife, Verene, wanted to surprise him with a romantic getaway, she had to plan the trip around the availability of a nearby machine shop so he could continue working on his designs. When he encountered a particularly challenging problem, Cray would retreat to a nearby bar with a pad of paper and a pencil. Over the course of several hours, he would consume a series of beers, scribbling down his thoughts all the while. When he reached the point where he could no longer read his own handwriting, he knew it was time to stop. The next morning, he would return to work and decipher his notes, often finding the solution to the problem hidden within his tipsy scribbles.

The Cray-3's ambitious design and cutting-edge technology led to delays and costs overruns. The company went bankrupt in 1995 after delivering only one unit, it would be Seymour Cray's last completed design. © *Cray Computer Corporation*

Fellow engineers marveled at Cray's uncanny ability to hold every tiny detail of a computer design in his head. One anecdote has it that Cray was called in to fix a baffling problem with a Cray-2. He locked himself in the machine room and after contemplating for 6 hours, eventually called an engineer. Cray pointed to a single wire and asked for it to be replaced. The machine worked again. There was also a story that each spring he would build a sailboat to sail on the lake near his home, then burn it in the fall.

Even stranger was Cray's love for digging tunnels. He built a tunnel system beneath his house in Chippewa Falls, to which he would often retreat to when in need of solitude or focused thinking. This might seem peculiar, but it was a testament to Cray's commitment to finding creative solutions to problems, even if that meant literally digging beneath the surface. When a visitor once asked what were the secrets of his success, Cray said "Well, we have elves here, and they help me". Cray subsequently showed his visitor his tunnel, explaining that when he reached an impasse in his computer design, he would retire there to dig. "While I'm digging in the tunnel, the elves will often come to me with solutions to my problem".

Despite his modest demeanor, Cray's impact on the world of computing is immense. His innovations have touched nearly every aspect of modern life, from the weather forecasts we check daily, to the intricate simulations that help design safer automobiles and aircraft and model nuclear explosions. Cray once said of himself "I was one of those nerds before the name was popular". He will be fondly remembered as the father of the supercomputer. The company he founded is now owned by HP, and still manufactures supercomputers. Today, instead of using bespoke chips, these powerful machines are built using huge numbers of commodity CPU's. It is a fitting tribute to Seymour Cray's legacy that many of today's supercomputers, including "Jaguar" which appears later in this chapter, still bear his last name.

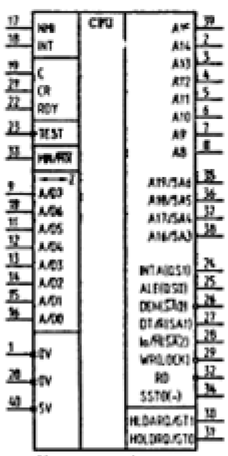
Soviet Clones of Intel 8088 (29,000 Transistors), 1989

The Soviet Union began to develop its own computers after World War II, and a universally programmable electronic computer was created by a team of scientists at the Kiev Institute of Electrotechnology. The computer, known as MESM (Russian: МЭСМ; Малая Электронно -Счетная Машина, Small Electronic Calculating Machine), became operational in 1950. The MESM's vacuum tubes were obtained from radio manufacturers.

However, the attitude of Soviet officials to computers was hostile during the Stalinist era. Joseph Stalin considered the computer an evil product of capitalism. Government rhetoric portrayed cybernetics in the Soviet Union as a capitalist attempt to undermine workers' rights.

By the early 1970s, the lack of common standards in peripherals and digital capacity led to a significant technological lag behind Western producers. Hardware limitations forced Soviet programmers to write programs in machine code until the early 1970s. Users were expected to maintain and repair their own hardware; local modifications made it difficult to share software, even between similar machines.

The government decided to end original development in the industry, encouraging the pirating of Western systems. These two chips are Soviet copies of the Intel 8088, the heart of the American IBM PC.



Условное графическое обозначение К1810ВМ88, КМ1810ВМ88, КР1810ВМ88

Shown in the image above are two similar chips:

KR1810VM88 - Russian Segmented Plastic clone (Kvazar plant, 1993) of Intel 8088 CPU. Very rare because these were mainly produced in ceramics.

KM1810VM88 - Russian Gold Ceramic clone (Kvantor plant, 1992) of Intel 8088 CPU. Very rare because these were mainly produced in Kvazar.

Poisk.

Poisk (Russian: Поиск, "The Search") is an example of a Soviet IBM PC clone. It was built by KPO Electronmash in Kyiv, Ukrainian SSR during the Soviet era, and was based on the very microprocessor shown above. Developed in 1987-1988 and released the following year, it was the most common IBM-compatible computer in the Soviet Union. The basic version did not include an expansion module for parallel or serial ports for connecting a printer, mouse or other devices. It was not fully IBM compatible, and its performance lagged behind the IBM XT. Poisk entered mass production in 1991, just before the Soviet collapse, and production output in the early 1990s peaked at several tens of thousands of units per year.

Lucite with RAD6000 Radiation Hardened CPU, 1996

Phobos-Grunt, Russia's most ambitious deep space mission ever, crashed into the ocean in early 2012. The craft was to land on the battered Martian moon Phobos, gather soil samples, and return them to Earth. Instead, it ended up helplessly drifting in Low Earth Orbit for weeks; its computer crashed before it could fire the engines to send it on its way to Mars. In their report, Russian authorities blamed heavily charged particles in cosmic rays that hit the SRAM chips and led to a latch-up, a chip failure resulting from excessive current passing through. Billions of dollars went down in flames.

The SRAM chip in the Phobos-Grunt that was hit by a heavily charged particle went under the name of WS512K32V20G24M. It was well known in the space industry, because those chips had been tested in a particle accelerator and described as "extremely" vulnerable – not a surprising result as the WS512K32V20G24M was never meant for space. But they were cheaper than space-grade memory, so the Russians went for them.

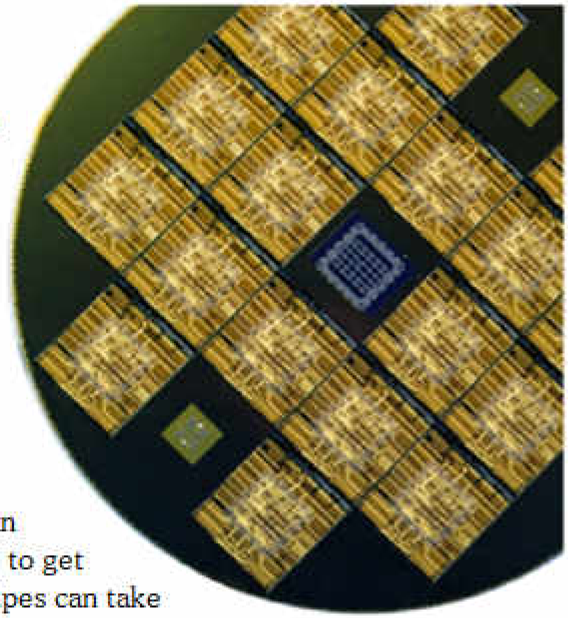
Curiosity, the most advanced rover ever to land on Mars and still operational as of this writing, works with two BAE RAD750 processors clocked at 200MHz. It has a paltry 256MB of RAM and 2GB of SSD. In 2019 when it launched, the RAD750 stood as the state-of-the-art space-grade processor, the best we could send. It is a radiation hardened version of the PowerPC 750, a processor that IBM and Motorola introduced in 1997. Compared to the smartphone in our pocket the RAD750's performance is pathetic, as has also been said unjustly of the Apollo Guidance Computer.

Despite this lackluster performance, the price tag of a RAD750 is $200,000. Why not just throw an iPhone in there and call it a day? iPhones are generations ahead of RAD750s and cost just $1,000 each. In retrospect, this is basically what the Phobos-Grunt team attempted. They tried to boost performance and cut costs – but ended up cutting corners. In fact, 62% of the microchips used in Phobos-Grunt were not qualified for spaceflight. The probe design was 62% driven by a "let's throw in an iPhone" mindset.

Today, radiation is one of the key factors designers consider when building space-grade computers. But it wasn't always that way. The first computer flew in space onboard a Gemini spacecraft. The machine had to undergo more than a hundred different tests to get flight clearance. But none of those tests covered radiation exposure. Still, the computer worked fine. That was because the Gemini onboard computer was literally too big to fail. The whole thing weighed 58.98 pounds.

Over time, we have made transistors smaller and smaller, moving from 240nm to as low as the 5nm designs we have in modern smartphones. The smaller the transistor, the lower the voltage necessary to turn it on and off. That's why older processors with larger feature sizes were mostly unaffected by radiation. Voltage created by particle strikes was too low to affect the operation of large computers. But when we reduced feature size to pack more transistors onto a chip, those particle-generated voltages became more than enough to cause trouble.

Mars Rover Flight Computer.
© Lockheed Martin, BAE



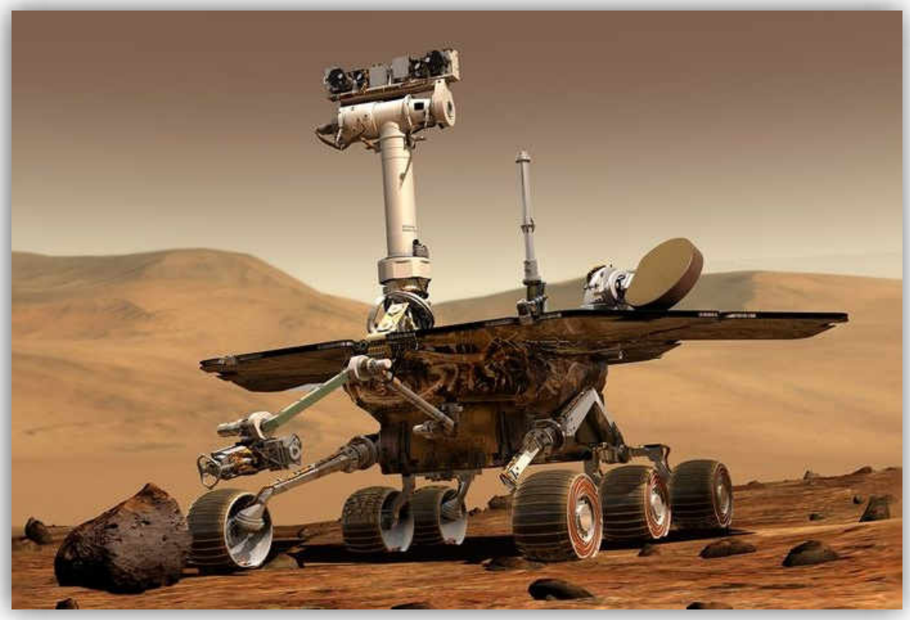
Another thing engineers and developers do to improve CPUs is to increase clock speeds. The Intel 386SX that ran the "glass cockpit" in the Space Shuttle was clocked at 20MHz. Modern processors go as high as 5GHz in bursts. A particle strike can corrupt data stored in memory only during a brief moment in time called a latching window. In low-clocked processors like the 386SX, these windows were relatively few. But when clock speeds increased, so did the number of latching windows per second. This one reason that radiation-hardened processors are usually clocked lower than their commercial counterparts. Almost everything that makes CPUs faster also makes them more fragile.

Power consumption and cooling are also challenges. On earth, fans can keep a computer cool. In space, fans would do nothing. The only way to get heat out of a spacecraft is through radiation, which takes time. Heat pipes can take excessive heat away from the processor, but this heat has to go somewhere. Furthermore, most spacecraft are powered by solar cells with their limited capacity to provide electricity. Running at lower clock speeds allows chips to run cooler and consume less power. Everything is a tradeoff.

In the early days, designers addressed radiation effects by modifications to the semiconductor manufacturing process. It was sufficient to take a commercially available chip and implement it on a radiation hardened process. Known as "radiation hardening by process", this technique relied on using materials like sapphire or gallium arsenide that were less susceptible to radiation than silicon. Such chips, such as the one in this artifact, worked well in radiation-heavy environments but required an entire foundry to be retooled to make them.

Considering the cost of a modern semiconductor factory, custom modifications to the manufacturing process ceased to be feasible for a niche market like space. This trend eventually forced engineers to use commercial processors, prone to failure. Manufacturers had to turn to alternative radiation-hardening techniques, especially one called "radiation hardening by design" or RHBD.

RHBD allowed manufacturers to use standard fabrication methods. Space-grade processors could be made in commercial foundries, bringing prices down. Radiation was dealt with by engineering ingenuity rather than the sheer physics of the material. For example, Triple Modular Redundancy (TMR) is a popular way to increase radiation resistance of an otherwise standard chip. In TMR, three identical copies of every single bit of information are stored in the memory at all times. All three copies are read, and the correct one is chosen by majority voting.



Mars Exploration Rover Spirit.

The idea behind TMR is that copies are stored at different addresses in the memory that are placed at different physical locations on a chip. To corrupt data, three particles would have to simultaneously strike exactly at all three locations where copies of the same bit are stored, which is extremely unlikely. The downside to TMR is that it leads to a lot of overhead. A processor has to go through every operation thrice, which means it can only reach one-third of its peak performance, or consume three times as much power and generate three times as much heat. More tradeoffs.

Today, the goal is to get space-grade processors ever closer to their commercially available counterparts. Instead of designing an entire system on a chip with radiation-hard components, engineers choose where radiation hardness is really necessary and where it can safely be dispensed with.

This Lucite contains a RAD6000 CPU, just like the ones which powered Mars Rovers Spirit and Opportunity. It is a direct transfer to a radiation hardening fabrication process of the PowerPC 601, introduced in IBM RS/6000 workstations and the first Apple Power Mac. Hardening has been applied to all storage elements in the RAD6000 including latches, registers, and RAMs. No RHBD here. The RAD750 currently operating in Mars Rover Curiosity is an evolution of this extremely reliable and successful design.

Over 200 RAD6000 processors power a variety of NASA, military, and commercial spacecraft, including:

- Mars Exploration Rovers Spirit and Opportunity
- Deep Space 1 probe
- Mars Polar Lander and Mars Climate Orbiter
- Mars Odyssey orbiter
- Spitzer Infrared Telescope Facility
- MESSENGER probe to Mercury
- STEREO Spacecraft
- IMAGE/Explorer 78 MIDEX spacecraft
- Genesis and Stardust sample return missions
- Phoenix Mars Polar Lander
- Dawn Mission to the asteroid belt using ion propulsion
- Solar Dynamics Observatory
- Burst Alert Telescope Image Processor on board the Swift Gamma-Ray Burst Mission
- DSCOVR Deep Space Climate Observatory spacecraft

Also in my collection, an IBM keyring with a non-radiation hardened PowerPC 601 CPU.

Artificial Intelligence software running on the humble RAD6000s in Mars Rovers Spirit and Opportunity gives them the capability to select rocks for examination, and avoid obstacles, pits, and cliffs, allowing the rovers to work autonomously taking samples and photographs.

No RAD6000 is ever known to have failed.

This cool object, which exists at the intersection of radiation science, computing, and space exploration, would have been equally at home in the space or atoms chapters.

Lucite with AMD Athlon CPU (22,000,000 Transistors), 1999

In 1999, AMD released its seventh-generation processor, the K7, later renamed Athlon. With the Athlon release, AMD was first to market with a 1 GHz processor (two days before Intel's 1 GHz Pentium III). This type of processor could be found in the powerful desktop computers that had become ubiquitous by the late 1990's. The rise of the internet and PC gaming drove the need for ever faster, multimedia capable CPUs.

Athlon comes from the Ancient Greek ἆθλον (athlon) meaning "(sport) contest", or "prize of a contest", or "place of a contest; arena". With the Athlon name originally used for AMD's mid-range processors with combined CPU/GPU processors with the GPU disabled, AMD currently uses Athlon for budget APUs with integrated graphics. AMD positions the Athlon against its rival, the Intel Pentium range.

This chip did away with drawbacks of earlier models and had a floating-point unit (FPU), or math co-processor, even better than Intel's. The Athlon was the fastest x86 processor (still based on that same architecture!) and had many strong points, including a fast frontside bus (FSB) – the communication interface that serves as the main link between the CPU and system memory and other parts of the chipset and motherboard – and high-performance numbers.

From August 1999 until January 2002, this initial K7 processor was the fastest x86 chip in the world. The Los Angeles Times wrote on October 5, 1999, "AMD has historically trailed Intel's fastest processors, but has overtaken the industry leader with the new Athlon. Analysts say the Athlon, which will be used by Compaq Computer, IBM and other manufacturers in their most powerful PCs, is significantly faster than Intel's flagship Pentium III, which runs at a top speed of 600MHz." A number of features helped the chips compete with Intel. By working with Motorola, AMD had been able to refine copper interconnect manufacturing about one year before Intel, with the revised process permitting 180-nanometer processor production. The accompanying die-shrink resulted in lower power consumption, permitting AMD to increase Athlon clock speeds to the 1 GHz range.

The Athlon architecture also used a bus licensed from DEC as its main system bus, allowing AMD to develop its own products without needing to license Intel's.

By the summer of 2000, AMD was shipping Athlons at high volume and the chips were being used in systems by Gateway, Hewlett-Packard, and Fujitsu Siemens Computers among others. The image of a 1999 PC is generic, I have not been able to find a catalogue that old with a guaranteed-to-be AMD powered machine.

Lucite with Pentium II Laptop CPU (27,000,000 Transistors), 1999

In the 1980s and early 1990's, laptops were a niche market, appealing mostly to business professionals who needed to work on the go. However, as technology evolved, so did the appeal and functionality of laptops, making them a staple in homes, offices, and classrooms worldwide.

One of the key drivers behind the laptop's rise to ubiquity was the miniaturization of components. This made it possible to pack powerful processors, ample storage, and long-lasting batteries into increasingly compact and portable devices. As laptops became more powerful, their uses expanded beyond simple word processing and spreadsheets to demanding applications like graphic design, video editing, and gaming.

The cost of producing laptops also began to decrease over time, thanks in part to economies of scale and more efficient manufacturing processes. This reduction in cost made laptops more accessible to a broader audience, including students, small businesses, and emerging markets. Another factor was the improvement in battery technology, which extended the life of laptops away from power sources, enhancing their portability. The advent of Wi-Fi further cemented the laptops' position as the go-to device for mobile computing.

The reverse, note the connector on the chip which allowed for a very flush mount.

The rise of the internet and the digital age also played a crucial role in the laptop's popularity. As more aspects of daily life and work moved online, the demand for devices that could provide access to the internet anytime and anywhere grew exponentially. Laptops, with their built-in connectivity options, were perfectly poised to meet this demand. Later, shifts in work culture towards more flexible and remote work arrangements increased the need for laptops. They offered professionals the flexibility to work from anywhere, be it from home, a café, or while traveling. The education sector also saw a growing reliance on laptops as digital learning became more integrated into curricula, making laptops essential for students of all ages. All these factors combined to make laptops not just a luxury item for the few but a necessary tool for the many, integral to the way people work, learn, and entertain themselves in the modern world.

The Pentium II Mobile, introduced by Intel in the late 1990s, was a significant step forward in the evolution of mobile computing processors. Designed specifically for laptops, the Pentium II Mobile aimed to bring desktop-class performance to mobile computers without compromising battery life excessively. The Pentium II Mobile was based on Intel's desktop Pentium II processors, but included several optimizations to reduce power consumption and heat generation, and enhance the performance of multimedia applications, a growing demand in the laptop market at the time. This was particularly important for video playback, audio processing, and even the early days of mobile gaming, making laptops more versatile as entertainment devices.

Lucite with AMD Opteron Processor from Cray XT5 "Jaguar" Supercomputer at Oak Ridge National Laboratory (11,250,000,000,000 Transistors), 2005

Yes, there are eleven and one quarter trillion transistors total in the supercomputer pictured below. Just think though, a multitrillionaire like me could afford to pay almost nine Zimbabwean dollars for each and every single one of them.

The Center for Computational Sciences (CCS) was founded in 1992 at Oak Ridge National Laboratory to advance the state of the art in high-performance computing by bringing a new generation of parallel computers out of the laboratory and into the hands of the scientists who could most use them. It began with an Intel Paragon supercomputer, and over time expanded to contain many including an IBM system based on the POWER3, an IBM system based on the POWER4, SGI Altix, and more recently, the Cray X1E, Cray XD1, Cray XT3-5, and Titan.

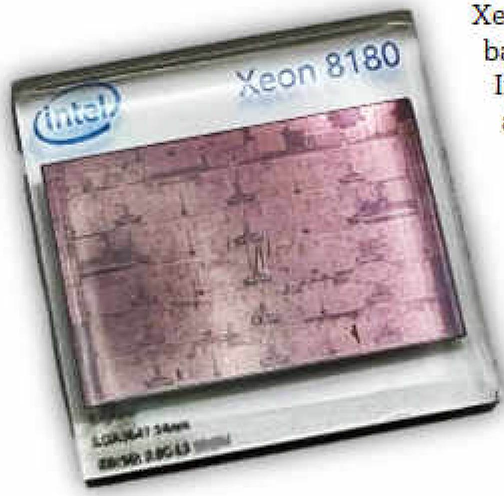
In the fall of 2008, Cray delivered the "Jaguar" XT5 supercomputer to the CCS. The Cray XT5 was a development from the Cray XT4 supercomputer, and operated with a version of Linux called the Cray Linux Environment.

The system boasted over 150,000 x86-based AMD Opteron processor cores such as the one in this Lucite, each with ~450 million transistors, and was the second fastest system in the world for the LINPACK benchmark, the fastest system available for open science, and the first system to exceed a petaflop (a unit of computing speed equal to one thousand million million floating-point operations per second) sustained performance on a 64-bit scientific application. Originally operating at a speed of 1.3 petaflops, Jaguar underwent an upgrade to 224,256 cores in 2009, after which its performance jumped to 1.75 petaflops. This is the kind of power you need to model things like the lifecycle of a nuclear reactor, or complex weather patterns.

In both November 2009 and June 2010, TOP500, the semiannual list of the world's top 500 supercomputers, named Jaguar as the world's fastest computer. In late October 2010, the BBC reported that the Chinese supercomputer Tianhe-1A had taken over the top spot, achieving over 2.5 quadrillion calculations per second, thereby bumping Jaguar to second place. The November 2010 TOP500 list confirmed the new rankings.

In 2012, the Cray XT5 Jaguar was upgraded to the Cray XK7 Titan hybrid supercomputing system by adding the Gemini network interconnect, and fitting all of the compute nodes with Kepler generation Nvidia GPUs.

Lucite with Intel Xeon 8180 (8,000,000,000 Transistors), 2017



Xeon (/ˈziːɒn/ ZEE-on) is a line of x86 microprocessors, still based on the basic architecture of the first PC, designed, manufactured, and marketed by Intel. The Xeon line is targeted at the non-consumer workstation, server, and embedded system markets and was first introduced in June 1998.

Xeon processors are based on the same architecture as regular desktop-grade CPUs, but have advanced features such as higher core counts, support for larger amounts of RAM, larger cache memory, extra provisions for reliability, and availability and serviceability features responsible for handling hardware exceptions. Advanced processors such as these are often capable of safely continuing execution where a normal processor cannot due to these extra features, depending on the type and severity of the exception. Some also support multi-socket systems with two, four, or eight sockets.

The Quad Intel Xeon Platinum 8180 in this small Lucite was available from July 11, 2017, and as of this writing is still near the top end of the Intel Xeon Scalable Processor Family. The list price for the CPU itself begins at $10,000, totaling $50,000 and up for a fully configured system.

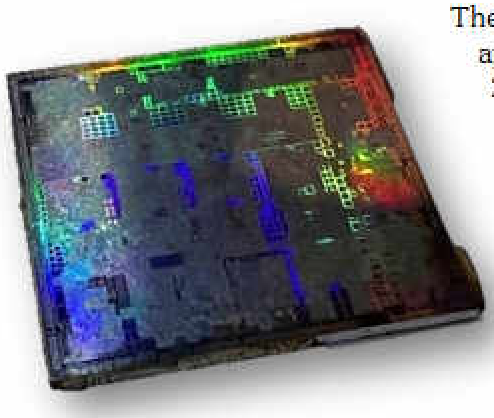
To illustrate the journey upon which Moore's law has taken us, consider that this chip contains around eight billion transistors. If you laid that number of Sylvania 7AK7 computer tubes shown at the beginning of this chapter end to end, they would reach to the moon.

Intel bunny men.
© *Walden Kirsch/Intel Corporation*

The United States fell far behind in processor innovation and production in the latter half of the 2010's. More than half of the world's advanced computer chips are now made by Taiwan Semiconductor Manufacturing Co. (TMSC). The U.S. Government and chipmakers are now playing catch-up by re-investing in boosting domestic chip production after allowing hubris, competitive pressure, and finally COVID-19 pandemic-related shortages and supply chain disruptions to degrade our capabilities.

Semiconductor "fabs" are the most complex factories on earth and cost around $10 billion to construct over the course of three to five years.
© *Walden Kirsch/Intel Corporation*

NVIDIA GPU (220,000,000 Transistors), 2010s

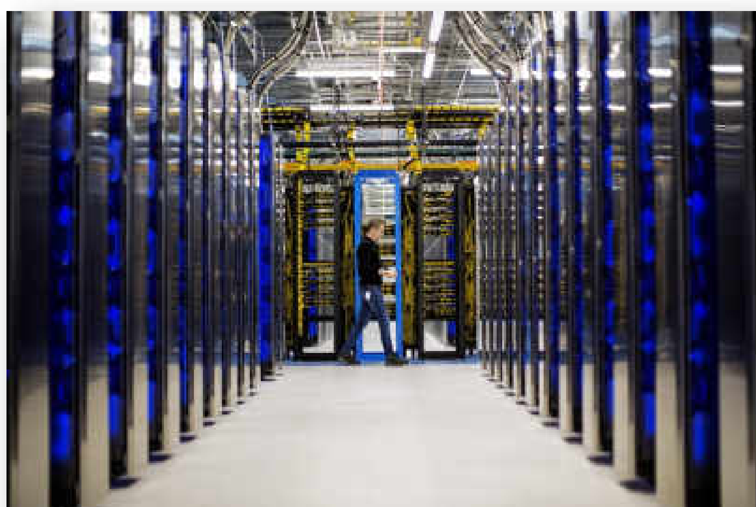


The exposed chip die you see here is a vintage midrange Nvidia GPU with approximately 220,000,000 transistors. Although this example is from the 2010's, the GPU has become the primary workhorse of modern computing much more recently. The recent rise of GPUs (Graphics Processing Units) can be attributed to several converging trends, foremost among them being the proliferation of machine learning and artificial intelligence (AI) applications.

Unlike traditional CPUs (Central Processing Units) which are designed for general-purpose computation and excel in task-switching and managing diverse processes, GPUs are tailored for parallel processing. This makes them particularly apt for the kind of repetitive and parallelizable calculations encountered in deep learning, large-scale simulations, and artificial intelligence. As deep learning models, especially neural networks, have grown in size and complexity, the parallel processing capabilities of GPUs have proven indispensable. The immense computational demands of training these models on massive datasets have shifted the focus from CPUs to GPUs, with the latter demonstrating significant speed-ups and efficiency gains. By using GPUs, artificial intelligence data centers can train more complex models faster, experiment with larger datasets, and deploy AI services to a large number of users simultaneously.

This scalability is crucial for applications such as cloud-based AI services, where demand can fluctuate widely, and computational resources need to be allocated dynamically. The importance of GPUs in AI has now led to the development of specialized AI chips, including those designed specifically for neural network processing. These chips, often referred to as Tensor Processing Units (TPUs) or AI accelerators, offer further optimizations for AI tasks, improving upon the general-purpose GPU architecture for specific AI and ML algorithms.

While GPUs are more power-intensive than CPUs, their ability to handle more calculations per watt of power consumed makes them more energy-efficient for AI workloads. This efficiency is critical in data centers, where energy consumption is a significant operational cost and environmental concern.



A Microsoft AI datacenter.
© *Microsoft*

Along with the rise of AI, there has been an increasing demand for real-time, high-quality graphics in various fields, from gaming to virtual and augmented reality (VR and AR). GPUs, originally designed to accelerate rendering in computer graphics, have naturally found their place in this space. With the progression in technologies like ray tracing, which mimics the real-world behavior of light to produce highly realistic visuals, the demand for powerful GPUs has skyrocketed.

Furthermore, the synergy between advanced graphics and AI, for instance in real-time game physics or AI-driven character animations, has further entrenched GPUs as a cornerstone of modern computing. The rise of GPUs has consequently spurred significant investments and innovations in this domain, resulting in a vibrant ecosystem of hardware and software solutions optimized for a wide range of applications.

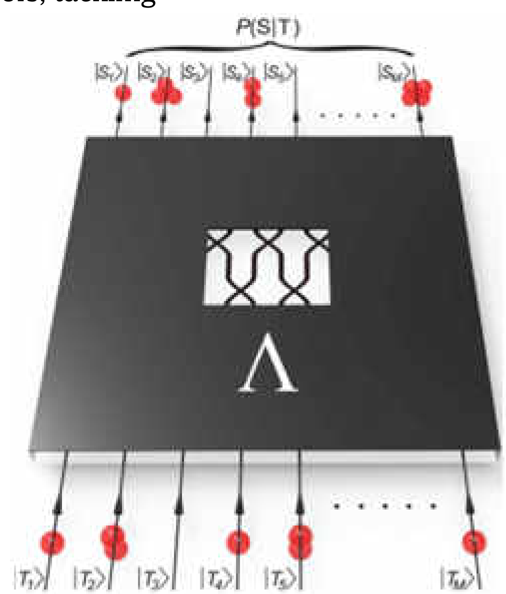
In 2024, Nvidia, the leading manufacturer of GPUs including the one shown here, became the world's most valuable company, over tech giants such as Microsoft, Amazon, and Google.

Silicon Quantum-Optics Keychain, 2016

Like the NVIDIA GPU, this too isn't the newest item in this chapter, but it feels logical to follow the progression from CPU to GPU, and that from digital to quantum computing, in the order in which they are occurring rather than by the age of the artifacts.

Quantum computing is an approach to information processing that stores data in qubits – physical systems such as trapped ions, superconducting circuits, or photons that can exist in a blend of "0" and "1" at the same time. Thanks to this property, called superposition, and a related phenomenon known as entanglement, groups of qubits can explore many possible solutions to a problem simultaneously instead of one after another as in classical machines. When a quantum algorithm ends, careful measurement collapses those possibilities into a result that, for tasks like factoring large numbers, modeling molecules, or optimizing complex logistics networks, can in principle outpace even the fastest supercomputer. The field is still experimental – today's prototypes hold tens to a few hundred noisy qubits – but steady advances in error-correction, materials, and control electronics suggest that practical quantum accelerators could one day sit alongside classical processors, tackling specialized problems that were once beyond reach.

The 5 mm square of oxidized silicon inside this plastic keychain began life in the Optoelectronics Research Centre at the University of Southampton as part of "Building Large Optical Quantum States" (BLOQS), a U.K. research program that explored how photons can be routed and interfered with on a chip for quantum-information experiments. More than a thousand spare test dies from that work were pressed into inexpensive key fobs and distributed at science festivals and school visits to spark public conversations about quantum technology.



Model of quantum boson sampling. Given a specified initial number state |T⟩ = |T1...TM⟩ and linear transformation Λ, a QBSM efficiently samples from the distribution P(S|T) of possible outcomes |S⟩ = |S1...SM⟩.
Do you understand?

Chromium mask used for photolithography.

The pale tracks on the surface are waveguides – hair-thin glass channels that confine light the way copper traces confine electrons. Two of those tracks form a Mach–Zehnder interferometer. light entering the first splitter is divided, travels along paths of slightly different length, and is then recombined. By adjusting that path-length difference researchers can direct single photons to one output or the other, demonstrating controlled quantum interference, the basic switching operation behind many photonic-quantum algorithms.

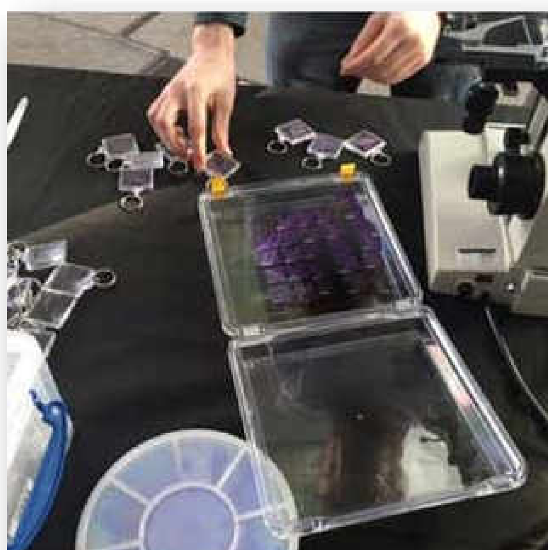
The Quantum Photonics Lab at the University of Southampton, furnished with three ultralow-vibration optical tables surmounted by an overhanging rack for electrical equipment. The tables are equipped with various lasers, and a confocal microscope is devoted to the study of color centers and their coupling to optical devices. Three waveguide characterization setups can be used for non-linear and quantum measurements (including single photon counting).

Fabrication followed standard integrated-circuit practice. A 150 mm crystalline-silicon wafer was oxidized at 1,060 °C for about 12 hours to grow a 400 nm silica layer. Photolithography defined the circuit in positive photoresist; hydrofluoric acid etched the exposed glass to create buried trenches that guide light. One £35 chromium mask and one £20 wafer yield roughly 29 good chips; even allowing for edge breakage and 80–90 % process yield, the material cost works out to £2.38 per die before labor. A trained operator can process sixteen wafers (about 400 chips) in three working days. Each die is snapped into a 29-pence clear plastic carrier, turning laboratory hardware into a robust pocket souvenir.

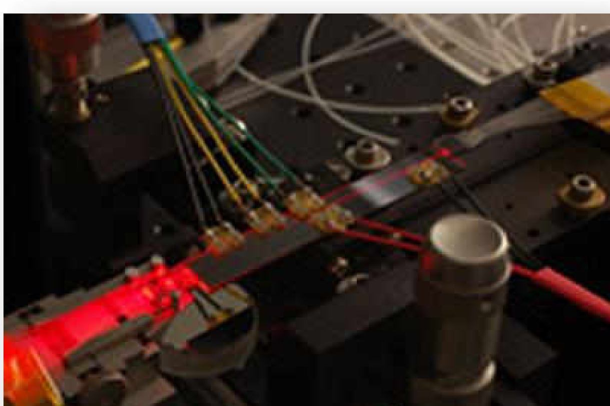
The visible diffraction colors come from shallow Bragg gratings etched at the input and output ports. They serve two purposes: coupling light into and out of the buried guides during experiments, and giving the public an immediate visual cue that something optical is happening on the surface. When visitors tilt the keychain under a lamp, the color shift neatly illustrates the wavelength-scale precision required to engineer quantum photonic circuits.

Diced chips.

We began this chapter with vacuum tubes and transistors, microscopic versions of which were formed into integrated circuits, which allowed for the creation of the microprocessors that probably fill your house by the hundreds or even thousands. The fabrication of this chip uses the same lithographic steps that gave us those classical integrated circuits, yet its function – manipulating individual photons – may well usher in an entirely new sixth generation of computing.



Packaging of chips into acrylic snap-in key chains.

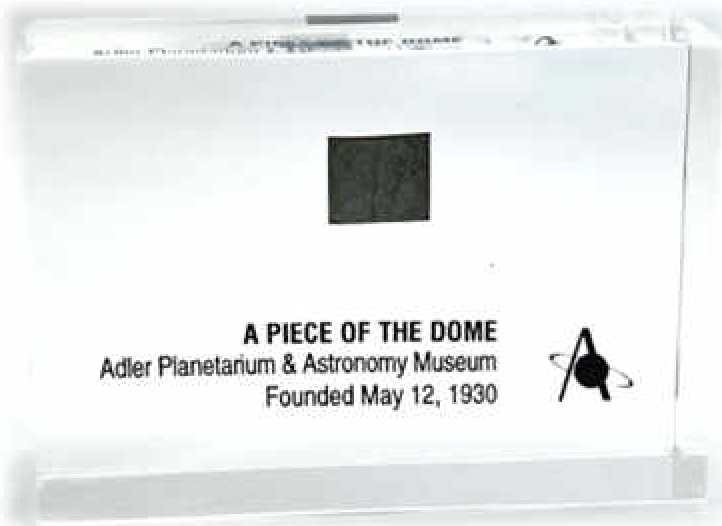


An "optical chip" in action.

Other Computing Lucites

Conquest of Space

Lucite with Piece of Adler Planetarium Dome Cladding, 1930 – 2021



Since the first ape gazed up at the night sky, we have yearned to unlock the mysteries held by the stars and planets. This innate human need to comprehend our universe has fueled any number of innovations, from ancient astronomers who aligned their sacred structures with celestial bodies, to modern explorers using telescopes and spacecraft to broaden our cosmic perspective.

In 1913, the Deutsches Museum's Oskar von Miller initiated a groundbreaking project with Carl Zeiss Works, leading to the creation of the planetarium – a new device, capable of projecting images of celestial bodies onto a dome. Designed by Walther Bauersfeld, it was first showcased in 1923. Its appeal was immediate, and by 1929, planetariums dotted the landscape of Europe.

Inspired by a visit to Munich's planetarium, Max Adler, a philanthropist with a vision for enhancing Chicago's cultural landscape, envisioned a planetarium on the city's Museum Campus. With architect Ernest Grunsfeld Jr., Adler set about creating such an attraction. His acquisition of the Mensing Collection and a generous $500,000 contribution led to the opening of the Adler Planetarium in 1930, the first of its kind in the Western Hemisphere. This institution, dedicated as a "classroom under the heavens", quickly became a center of astronomy education in America. The Planetarium's design, courtesy of Grunsfeld, earned accolades for its beauty, and was designated a National Historic Landmark in 1987.

© DroneRB / Reddit

Over the following decades, the Adler's significance continued to grow, with the Century of Progress World's Fair, drawing 12 million visitors to the Planetarium over its two years, and the USSR's launch of Sputnik heralding the advent of the Space Age.

Perched on the shores of Lake Michigan, the Adler Planetarium now serves as a portal to the universe for the curious and the scholarly alike. Its mission transcends the display of celestial phenomena, and serves to inspire visitors of all ages through viewing events, exhibits, immersive theater experiences, and extensive educational outreach.

A notable milestone was reached in 2019 when the Adler launched a ThinSat, marking its entry into space exploration. Other initiatives like the "Chicago's Night Sky" exhibition aim to reconnect urban dwellers with the wonders above, and highlight the challenges posed by light pollution.

Over time, the copper of the new dome will develop a fine blue green patina called verdigris.

© Adler Planetarium

Today, The Adler has three theaters, space science exhibitions, including the Gemini 12 space capsule, and a collection of antique scientific instruments and print materials. In addition, the Adler Planetarium hosts the Doane Observatory, a research-active public observatory.

In 2021, after pandemic related delays, the Adler's historic copper dome was replaced. The aging and leaky structure was thoroughly refurbished, and the old copper tiles were removed and replaced with new, 20-ounce copper tiles.

This Lucite contains a fragment of the old dome's cladding.

© Adler Planetarium

Lucite with Piece of V-2 Rocket Steering Rudder, 1944

The V-2 (German: Vergeltungswaffe 2, "Retaliation Weapon 2"), with the technical name Aggregat 4 (A4), was the world's first long-range guided ballistic missile. The missile, powered by a liquid-propellant rocket engine, was developed during the World War II in Nazi Germany as a "vengeance weapon" and assigned to attack Allied cities as retaliation for bombings against German cities. The V-2 rocket also became the first artificial object to travel into space by crossing the Kármán line (edge of space) with the vertical launch of MW 18014 on June 20, 1944, and thus was the forerunner of modern space rockets and long-range missiles.

Research into military use of long-range rockets began when the graduate studies of Wernher von Braun attracted the attention of the Wehrmacht. A series of prototypes culminated in the A-4, which went to war as the V-2. It was first successfully launched on October 3, 1942, and was fired against Paris on September 6, 1944. Two days later the first of more than 1,300 V-2s was fired against Great Britain, gouging a crater 10 m across, killing three people and injuring 22 (the last was fired on March 27, 1945). Belgium was also heavily bombarded.

About 9,000 people died in V-2 attacks, and it is estimated that at least 12,000 prisoners from the Mittelbau-Dora concentration camp died when used as forced labor in building V-2s at the underground Mittelwerk factory.

The V-2 was 14 meters long, weighed 12,700–13,200 kg at launch, and developed about 60,000 pounds of thrust, burning alcohol and liquid oxygen. The payload was about 725 kg of high explosive, horizontal range was about 320 km, and the peak altitude usually reached was roughly 80 km. The rockets travelled at supersonic speed, impacted without audible warning, and proved unstoppable.

London bound, 1942.
Bundesarchiv, Bild 141-1875A / CC BY-SA 3.0

Damage caused by a V2, Chinatown, Limehouse, East London, 1945.
A man inspects the propulsion unit of a "V" rocket bomb.

At the end of the war, teams from the Allied forces raced to seize key Nazi manufacturing facilities, procure the Nazi's missile technology, and capture the V-2's launching sites. Von Braun and over 100 key personnel surrendered to the Americans, and many of the original V-2 team ended up working at the Redstone Arsenal. The U.S. also captured enough hardware to build approximately 80 of the missiles. After the war, the Soviets gained possession of the V-2 manufacturing facilities, re-established production, and moved it to the Soviet Union.

Both the United States and the Soviet Union used the captured V-2s in research that led to the development of their missile and space exploration programs.

Lucite with Fragments of X-15 #3, 1959 – 1967

When we think of space exploration, we sometimes forget about the winged vehicles in which men first "slipped the surly bonds of Earth", before the gigantic ICBM-based rockets that first spring to mind. In fact, it took many years for pilots of such winged craft to be recognized as astronauts and retroactively be awarded their wings. The X-15 was such a craft, a joint research program sponsored by the National Advisory Committee for Aeronautics, the U.S. Air Force, the Navy, and private industry. It was designed to explore the upper limits of supersonic flight above Mach 2 and hypersonic flight beyond Mach 5. It first flew on June 8, 1959, and was introduced to the public shortly thereafter.

Over the course of its extensive test program, the three X-15s built set numerous records, becoming the fastest and highest-flying aircraft in the world, reaching a maximum speed of Mach 6.72 on one flight and an altitude of 354,000 feet (67 miles) on another flight. These records still stand.

Eight X-15 pilots actually flew into space in an X-15; surprisingly, Neil Armstrong was not one of them. He flew seven of the X-15's 199 flights, including the first flight of X-15 #3. His fastest flight occurred in X-15 #1 when, on July 26, 1962, he reached Mach 5.74 (3,989 miles per hour). In fact, Armstrong flew hypersonically (i.e. above Mach 5) three out of his seven flights and reached a maximum altitude of 207,000 feet on his sixth flight.

X-15 Flight 3-65-97, also known as X-15 Flight 191 (due to being its 191st free flight), was planned as a high-altitude flight and had eight primary science objectives, including boost guidance evaluation, solar spectrum and plume measurement experiments, a "traversing probe experiment", micrometeorite collection, ablative materials testing, and several instrumentation tests. It took place on November 15, 1967 and was piloted by Michael J. Adams. It ended in tragedy when the aircraft broke apart minutes after launch due to technical difficulties, killing the pilot and destroying the plane. This Lucite was produced by a private individual who collected debris from the wreckage.

Transcript of the cockpit communications during the doomed flight:

10:29:06	NASA-1:	"One minute now, Mike, one minute."
	Adams:	"Rog."
:09	Adams:	"Experiment, camera. Give me a 45-second call."
:22	B-52:	"Forty-five seconds now, zero-eight."
:26	Adams:	"Rog."
:30	Adams:	"Prime, igniter ready."
:36	Adams:	"And precool, igniter, and tape. And give me 15 seconds Joe, will you? I missed that."
:51	B-52:	"Fifteen seconds, zero-eight."
:54	Adams:	"Pump—good igniter."
10:30:02	B-52:	"Five seconds, zero-zero-eight."
:03	NASA-1:	"Looks good here, Mike."
:07	Adams:	"Rog, two, one, launch."
:11	NASA-1:	"Rog, we got a good light here, Mike. Check your alpha and your heading."
:21	NASA-1:	"Right on track, Mike, you're coming up on profile."
:29	NASA-1:	"Standby for theta."
:33	NASA-1:	"How do you read, Mike?"
:39	NASA-1:	"Check your boost guidance null, Mike, and how do you read?"
	- -	[squelch break]
:44	NASA-1:	"OK, Mike, we have you right on the track, on the profile."
:45	B-52:	"You're on track and profile, Mike."
:52	Adams:	"Roger."
:54	B-52:	"I'll relay, Pete."
	NASA-1:	"OK."
10:31:01	NASA-1:	"Standby for 83,000, Mike."
:04	B-52:	"Standby for 83,000."
:09	NASA-1:	"Do you read us at all, Mike?"
:12	NASA-1:	"OK, you're right on the track."
	B-52:	"Right on the track, Mike."
:19	NASA-1:	"Coming up on 110,000."
	B-52:	"Coming up on 110,000."
:22	NASA-1:	"On the profile, on the heading."
:24	B-52:	"On profile, on heading."
:26	NASA-1:	"Standby for shutdown."
:27	B-52:	"Standby for shutdown."
:33	NASA-1:	"Precision attitudes, Mike."
:35	B-52:	"Precision attitudes, Mike."
:39	NASA-1:	"Alpha to 0."
:40	B-52:	"Alpha to 0."
:42	NASA-1:	"And rock your wings and extend your experiment, Mike."
:45	B-52:	"Extend your experiment, Mike."
:50	NASA-1:	"On the heading, on the profile."
:52	NASA-1:	"Have you going a little bit high, that's all right."
:54	B-52:	"On the heading, on the profile, maybe a little bit high."
:58	Adams:	"I am reading him now. I got a computer and instrument light now."
10:32:03	NASA-1:	"OK, Mike."
:08	NASA-1:	"We'll go ahead and try computed alpha at 230, Mike."
:14	NASA-1:	"Check your computed alpha now."
:18	NASA-1:	"And you're right on track, Mike."
:27	Adams:	"I lost my pitch and roll dampers."
:31	NASA-1:	"OK, Mike, let's try and get them on."
:32	Adams:	"They reset."
:34	NASA-1:	"Did they reset?"
:35	Adams:	"Yep."
:36	NASA-1:	"OK."
:37	NASA-1:	"And I'll give you a peak altitude, Mike."
:42	NASA-1:	"Have you coming over the top. You're looking real good. Right on the heading, Mike."
:51	NASA-1:	"Over the top at about 261, Mike."
:54	NASA-1:	"Check your attitudes."
10:33:02	NASA-1:	"You're a little bit hot, but your heading is going in the right direction, Mike."
:09	NASA-1:	"Real good."
:11	NASA-1:	"Check your attitudes. How do you read, Mike?"
:14	NASA-1:	"OK, let's check your dampers, Mike."
:17	Adams:	"They're still on."
:18	NASA1:	"OK."
:24	NASA-1:	"A little bit high, Mike, but real good shape."
:33	NASA-1:	"And we got you coming downhill now. Are your dampers still on?"
:37	Chase-1:	"Dampers still on, Mike?"
:39	Adams:	"Yeah, and it seems squirrely."
	- -	[squelch break]
:44	NASA-1:	"OK, have you coming back through 230, ball nose, Mike."
:50	NASA-1:	"Let's watch your alpha, Mike."
:58	NASA-1:	"Let's not keep it as high as normal with this damper problem. Have you at 210. Alpha, beta, and check your alpha, Mike."
10:34:02	Adams:	"I'm in a spin, Pete."
:05	NASA-1:	"Let's get your experiment in and the camera on."
:13	NASA-1:	"Let's watch your theta, Mike."
:16	Adams:	"I'm in a spin."
:18	NASA-1:	"Say again."
:19	Adams:	"I'm in a spin."
:21	NASA-1:	"Say again."
:27	NASA-1:	"OK, Mike, you're coming through about 135 now."
:34	NASA-1:	"Let's get it straightened out."
:37	- -	[two squelch breaks]
:42	NASA-1:	"OK, you got theta 0 now."
:44	NASA-1:	"Get some angle of attack up."
:50	NASA-1:	"Coming up to 80,000, Mike."
:53	NASA-1:	"Let's get some alpha on it."
:57	NASA-1:	"Get some *g* on it, Mike."
:59	NASA-1:	"Let's get some *g* on it."
10:35:02	NASA-1:	"We got it now. Let's keep it there. Coming around."
:09	NASA-1:	"OK, let's keep it up, Mike."
:14	NASA-1:	"Keep pulling up. Do you read, Mike?"
:20	NASA-1:	"Let's keep pulling it up, Mike."
:27	NASA-1:	"OK, 130 let's head down that way."
:37	NASA-1:	"He was abeam Cuddeback, 130, three-five-eight."
:42	NASA-1:	"Chase-4, do you have anything on him?"
:44	Chase-4:	"Chase-4, negative."
:47	NASA-1:	"OK, Mike, do you read?"
:52	Chase-4:	"Pete, I got dust on the lake down there."
:55	NASA-1:	"What lake?"

Lucite with Bolt from Liberty Bell 7, Recovered from 16,043ft Depth in the Atlantic Ocean, 1961 & 1999

In the late 2010's, as Elon Musk's SpaceX worked towards crewed commercial flights to orbit, his fellow 21st century billionaires Jeff Bezos, with his company Blue Origin and its New Shepard rocket and capsule, and Richard Branson's firm Virgin Galactic, with its VSS Unity spaceplane, focused on making less-ambitious suborbital tourist flights – short, arcing journeys just beyond the sensible atmosphere – safe enough to sell seats to people wealthy enough to afford it. The efforts of both Blue Origin and Virgin Galactic finally paid off in 2021 when both Bezos and Branson launched themselves into space aboard their respective pleasure craft, months after SpaceX launched its first crewed flight to orbit. Accelerating someone to over 2,000 mph and then bringing them down unharmed is no trivial feat though.

Sixty years earlier, the U.S. government made the first of such suborbital flights as part of the Space Race with the Soviet Union, and on May 5, 1961, Alan Shepard – the eponym of the Blue Origin launch vehicle and spacecraft – became the first American in space. This accomplishment was overshadowed however by the Soviets launching Gagarin into orbit three weeks earlier. Hurled by an Army Redstone ballistic missile, Wernher von Braun's Alabama-designed evolution of the V-2, Shepard's Mercury capsule went higher and faster than the crews of the 2021 flights, but likewise did not orbit the planet.

Less than three weeks later, on May 25, President John F. Kennedy declared that America must take the lead in the space race and spoke the fateful words "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth". Military and space development went hand in hand, as the suborbital Mercury missions using Redstone rockets, one evolution away from the V-2, gave way to orbital flights using modified Atlas ICBMs, which in turn led to the Gemini program which launched using Titan II missiles. Finally, bespoke rockets were purpose-built during the Apollo program to reach the moon.

On July 21, 1961, Virgil I. "Gus" Grissom flew the second NASA Mercury-Redstone mission. But that trip, nearly identical to Shepard's, almost ended in disaster. Grissom's capsule, Liberty Bell 7, sank after splashing down in the Atlantic, and Grissom came close to drowning. The six Mercury flights from 1961 – 1963 produced several nerve-racking moments, but Grissom's was the only one that came close to killing an astronaut.

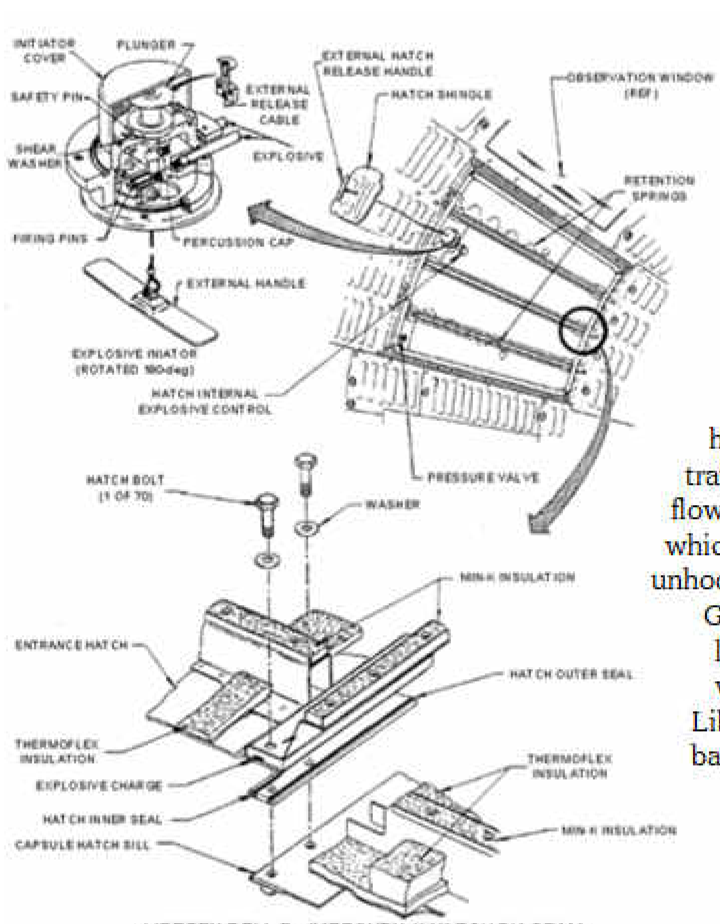
Gus Grissom suits up for his spaceflight. Note the oxygen inlet on the lower right of his spacesuit. That was where water began leaking into his suit after he was forced to leave the capsule after splashdown.

Gus Grissom was a gruff, compact, working-class kid from Mitchell, Indiana, who used the GI Bill to become an engineer, fighter pilot, and test pilot. He flew 100 combat missions in Korea. Picked as one of the first seven astronauts in 1959, he made the further cut to the three who would make the initial flights. Project Mercury head Robert Gilruth picked Alan Shepard to be first and Gus Grissom second – much to the frustration of John Glenn, who became the backup for both of them. All were expected to make suborbital Mercury-Redstone flights. The space agency wanted to gain space experience before putting an astronaut in orbit with the larger Atlas missile, the core objective of Mercury – a mission Glenn famously ended up doing, instead of another suborbital trip.

In mid-July 1961, after three weather-related postponements, Grissom finally got to fly. There were two major differences between the Mercury capsule he piloted and the one flown by Shepard: Liberty Bell 7 had a window over the astronaut's head instead of two small portholes, and a hatch that could be explosively separated for a quicker escape. Lifting off from Cape Canaveral, Florida, about 8:20 am on July 21, he reached a velocity of 5,134 mph when his Redstone shut down as planned. Liberty Bell 7 then separated. Grissom coasted in weightlessness up to an altitude of 118 miles before his capsule began to descend. Riding backwards, he was fascinated and distracted by the beautiful view of Florida through the bigger window. Once the capsule began reentering the atmosphere, the deceleration was brutal, reaching 11 times the force of gravity. Everything worked, his capsule's parachutes deployed, and he landed in the ocean 15 minutes and 37 seconds after liftoff.

It was not long after splashdown that things suddenly went bad. A Marine helicopter from the carrier USS Randolph came in to pick up Grissom and his capsule. The plan was to hook on to the capsule, lift it out of the water a little so Grissom could blow off the hatch, climb out, and get into a "horse collar" sling to be pulled up to the aircraft. To hook on, the helicopter crewman had to snip off a long recovery radio antenna that had deployed from the cylindrical nose section of the capsule. As the crewman reached down with an extension cutter like those used to trim tree branches, the hatch of the spacecraft below suddenly blew off. Seawater began pouring over the hatch rim. Grissom, who had armed the hatch and removed the restraint on the plunger to trigger it, claims he did nothing to initiate the explosion. He had his helmet off and had rolled up the neck dam to keep water from getting down his spacesuit, but had forgotten, or did not have the time, to close the oxygen vent on his suit torso – the attachment point for the capsule oxygen supply.

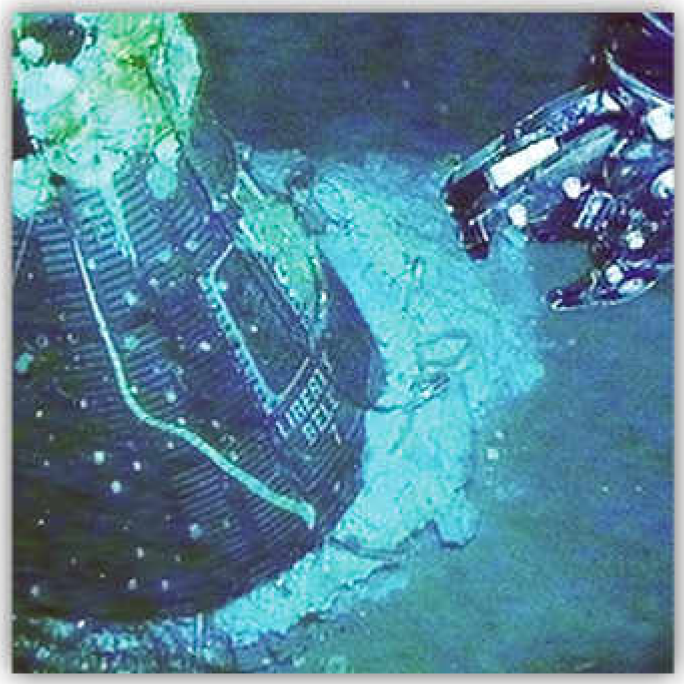
Grissom instantly threw himself out of the hatch and swam away from the sinking spacecraft. The helicopter crew, thinking he was ok and following their training, moved in to hook on to Liberty Bell 7. But the water flowing into the capsule made it too heavy for the helicopter, which at one point had all three wheels in the water. Forced to unhook, the crew watched the capsule slip beneath the waves. Grissom, meanwhile, found himself sinking too as water leaked in through the oxygen inlet. Blasted by the rotor wash, Grissom waved frantically to the helicopter. After Liberty Bell 7 sank, but before Grissom did, the crew came back and lowered the sling. The wet and exhausted astronaut was taken back to the carrier.



LIBERTY BELL 7 - (MERCURY 4) HATCH DIAGRAM

Almost immediately afterward, rumors circulated that Gus had panicked and triggered the hatch himself. He repeatedly testified that he was lying in his couch waiting for the helicopter when it "just blew." The space agency's investigations, notably lacking the capsule resting at the bottom of the ocean, provided no other evidence. Given that hitting the plunger hard enough to trigger the hatch often caused a nasty bruise on the hand, something Grissom did not have, NASA leadership was inclined to believe him.

Because Shepard was sidelined with an inner-ear problem from 1964 to 1969, Gus went on to command the first two-astronaut mission in 1965. With a wink, he named Gemini 3 Molly Brown, after a contemporary Broadway musical, The Unsinkable Molly Brown. (A humorless NASA banned further spacecraft names in Project Gemini.) He then was to command the first crewed Apollo mission, but was tragically killed in the Apollo 1 launch-pad fire in January 1967, along with Ed White, the first American to walk in space, and Roger Chaffee.



© *Kansas Cosmosphere*

In 1978, The Kansas Cosmosphere began looking for a Mercury spacecraft for the Cosmosphere's Hall of Space Museum. The only "unclaimed" flown Mercury at the time was Liberty Bell 7, but it lay more than 16,000 feet below sea level – deeper than the Titanic – and the technology needed to recover the spacecraft from that depth was not commercially available yet. In the meantime, the Cosmosphere found a different Mercury spacecraft for display, but still held on to the dream of someday recovering Liberty Bell 7.

In 1986, the Cosmosphere joined forces with deep-sea salvage expert Curt Newport, enlisting the help of hundreds of engineers, scientists, historians and oceanographic technicians. The team of experts studied ship logs and conducted interviews with people involved in the flight and recovery to determine its resting place.

They looked at weather and tide data and computer models to determine how the craft sank and where it might be. They studied the unique metals of the Mercury capsule to calculate the corrosion occurring in salt water at 16,000 feet. The variables were numerous, but searchers were confident that they had narrowed the area to approximately one mile in diameter and would find the spacecraft in good condition.

Because of the expense of the project – and the fact that the exact location of the spacecraft was still unknown – the project was shelved until 1999, when the Discovery Channel underwrote a large expedition dedicated to finding and recovering Liberty Bell 7. A deep-sea salvage team funded by the Discovery Channel left Cape Canaveral on April 16, 1999. After days of meticulously exploring the 24-square-mile search area 300 miles off the coast of Florida with side-scan sonar, the crew had mapped 88 potential targets. They narrowed their search to 18 targets on which they would dive with a Remote Operated Vehicle (ROV) outfitted with high-definition cameras.

© Kansas Cosmosphere

The first target they dove on was Liberty Bell 7. But their excitement was short-lived when the tether of the ROV was severed in rough sea conditions and the ROV fell to the bottom of the ocean, ending the expedition. A new ROV was built and a second expedition mounted on July 1, 1999.

The spacecraft was recovered from the ocean floor and returned to Port Canaveral on July 21, exactly 38 years after its flight into space. The drama of the expedition was captured in the two-hour Discovery Channel documentary “In Search of Liberty Bell 7”. Upon its arrival the spacecraft was continuously flushed with fresh water to begin the long process of cleaning the salt from the entire system. The meticulous six-month restoration took place in full view of the public, and a live webcam allowed millions of people around the world to watch the historic restoration.

To ensure that all the salt and corrosive elements were gone from the spacecraft, every one of the approximately 25,000 parts was removed, disassembled, cleaned, and then put back together. The goal of the project was not to make the craft look new, but to preserve it so that it would be available for generations to come. If the salt and corrosive elements remained, the spacecraft would have rapidly deteriorated when exposed to natural air.

Liberty Bell 7 is owned by the Cosmosphere, and some pieces which were too corroded to be salvaged were embedded in Lucites such as this one and sold in the gift shop. The Cosmosphere is among only four museums worldwide to have a flown set of manned Mercury, Gemini, and Apollo spacecraft.

Liberty Bell 7 at the Kansas Cosmosphere.
© Kansas Cosmosphere

Lucite with Piece of Mercury-Atlas 7 Flown EaglePicher Battery, 1962

In the early hours of May 24, 1962, Scott Carpenter strapped into the Aurora 7 spacecraft, ready to embark on a mission that would make him the sixth human and second American to orbit Earth. This mission, known as Mercury-Atlas 7, using Mercury spacecraft No. 18 and Atlas launch vehicle No. 107-D, was essentially a repeat of John Glenn's Mercury-Atlas 6, involving three Earth orbits.

The selection of Carpenter for this mission came after Deke Slayton, originally chosen for the flight, was grounded due to a heart condition. This angered Flight Director Christ Kraft, who would later sharply criticize Carpenter. Meanwhile, Carpenter, eager and prepared, renamed his spacecraft Aurora 7, a name reflecting his optimistic outlook and the dawn of a new era in space exploration.

Among his duties was the first-ever study of liquids in a zero-gravity environment. This experiment was a small but significant step in understanding how fluids behave in space, laying the groundwork for future space travel where liquid handling would be essential.

One of the more curious observations during the mission was the appearance of what John Glenn had previously described as "fireflies" outside the spacecraft. Carpenter accidentally solved the mystery when he bumped against the capsule wall and released a cloud of them, eventually determining that they were not cosmic particles or mysterious space beings, but rather ice particles dislodged from the spacecraft's exterior. This discovery, while not groundbreaking, was a moment of genuine wonder.


Astronaut Scott Carpenter in a pressure suit

Not all of Carpenter's experiences were as pleasant or straightforward. The mission's food supply, for instance, was a lesson in the unexpected challenges of space travel. Unlike previous missions where astronauts consumed paste-like food from tubes, Carpenter had been provided with freeze-dried food cubes stored in a plastic bag.

These cubes, meant to be a more palatable alternative, posed their own problems. The food cubes had been coated with an anti-crumbling agent, but were apparently accidentally crushed prior to launch, breaking the coating. This caused the cubes to

Cmdr. Carpenter being helped into his Aurora 7 spacecraft on May 24, 1962.

shed crumbs that floated freely in the zero-gravity environment. Carpenter quickly realized that these crumbs could become a serious hazard, potentially clogging ventilation systems or even being inhaled, causing choking. As if that wasn't enough, a candy bar included in his food supply melted due to the high cabin temperatures, which reached up to 102°F. By the end of his second orbit, Carpenter had decided to avoid the food altogether, noting that it was more trouble than it was worth. Later in this chapter, you will see Doritos optimized for a zero-gravity environment with a special oil coating, proof positive that floating crumbs are still a challenge.

As the mission progressed, the demands on Carpenter grew. Serious trouble arose when the equipment controlling the way the capsule was facing malfunctioned, requiring him to determine the capsule's proper attitude visually. Human error also delayed Carpenter's preparations for reentry, and a combination of attitude errors and a late firing of the retrorockets caused Aurora 7 to deviate from its planned trajectory.

The spacecraft splashed down 250 miles off course in the Atlantic Ocean, sparking immediate concern at NASA and among the American public. For 39 minutes, there was no confirmation of Carpenter's safety, leading to tense moments as rescue teams searched for him. Finally the voice of mission control, Shorty Powers, announced, "An aircraft in the landing area has sighted the capsule and a life raft with a gentleman by the name of Carpenter riding in it." Carpenter spent three hours in his bright orange life raft before being picked up by a helicopter and taken aboard the USS Intrepid.

Earth and sky view taken with handheld camera.

Carpenter being recovered from the ocean after his MA-7 Flight.

"The flight experience itself is incredible," he said. "It's addictive. It's transcendent. It is a view of the grand plan of all things that is simply unforgettable."

However, "the last 30 minutes of the flight, in retrospect, were a dicey time," he recalled in his memoir, "At the time, I didn't see it that way. […] I was trained to avoid any intellectual comprehension of disaster – dwelling on a potential danger, or imagining what might happen. I was also too busy with the tasks at hand."

The aftermath of the mission was mixed. President Kennedy greeted Commander Carpenter and his family at the White House in June 1962 after they had been hailed at parades in Denver and Boulder and honored at City Hall in New York. A few days after Mr. Carpenter's mission, the University of Colorado gave him a long-delayed degree in aeronautical engineering at its commencement, citing his "unique experience with heat transfer during his re-entry". He had missed out on his degree by not completing a course in heat transfer as a senior in 1949.

Carpenter and his family visit the White House.
Left to right: Rene, President John F. Kennedy, Kristen, Carpenter, Scott, Candace and Jay.

But while Carpenter had successfully completed his orbits and returned safely to Earth, his performance during the mission drew sharp criticism, particularly from Chris Kraft, NASA's flight director. Kraft argued that Carpenter had become too absorbed in conducting scientific experiments, neglecting his primary responsibility as a pilot. Mr. Kraft's criticism was not just a professional rebuke but a public one, leading to Carpenter's removal from future space missions "He was completely ignoring our request to check his instruments," Kraft wrote in his memoir. "I swore an oath that Scott Carpenter would never again fly in space. He didn't."

Kraft's criticism fueled NASA engineers' simmering resentment of the astronauts' status as pop-culture heroes, and word spread within NASA that Mr. Carpenter had panicked, the worst sin imaginable. However, even though one might argue that Carpenter had mishandled the re-entry, accusing him of panic made no sense in light of the telemetered data concerning his heart rate and his respiratory rate. The suspicions and rumors were similar to those surrounding Gus Grissom's hatch incident, and jealousy may well have played a part.

Despite the controversy, Carpenter's contributions to space exploration were significant. After leaving NASA, he joined the Navy's SEALAB program, becoming the first astronaut to also become an aquanaut, living and working on the ocean floor at a depth of 205 feet and helping develop underwater training techniques that would later be used to prepare astronauts for spacewalks. He also wrote two novels involving underwater adventures, and, among his many projects, joined with fellow astronauts to create the Astronaut Scholarship Foundation (ASF). You will see several artifacts later in this chapter that were produced by the ASF and sold to raise money for their scholarship programs.

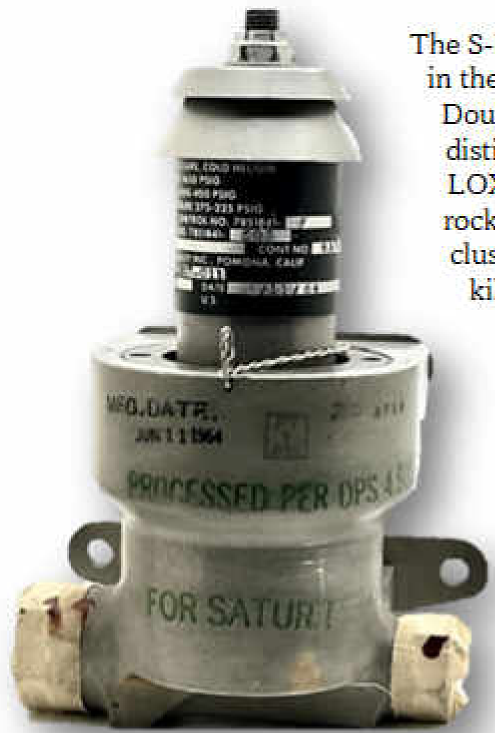
Scott Carpenter in 2011.
collectSPACE.com

"I volunteered for a number of reasons," Carpenter wrote in "We Seven," a book of reflections by the original astronauts published in 1962. "One of these, quite frankly, was that I thought this was a chance for immortality. Pioneering in space was something I would willingly give my life for." When he passed away in 2013 at the age of 88, Scott Carpenter left behind a legacy that reached both the stars and the ocean floor – just like Liberty Bell 7 a few pages back. Aurora 7 is now on display at the Museum of Science and Industry in Chicago.

Aurora 7 is just a bike ride away from home!

EaglePicher was a battery supplier to the U.S. Government. By 1947 they were among the first to adapt a purification system for germanium for commercial use in the transistor industry, playing a key role in the development of solid state electronics. In 1958, EaglePicher created batteries to power Explorer 1, the first U.S. satellite in space, and their silver-zinc batteries powered the Mercury capsules as well. When an explosion later crippled the Apollo 13 spacecraft, its return depended heavily upon the EaglePicher batteries on board the spacecraft, and 33 EaglePicher batteries remain on the Moon.

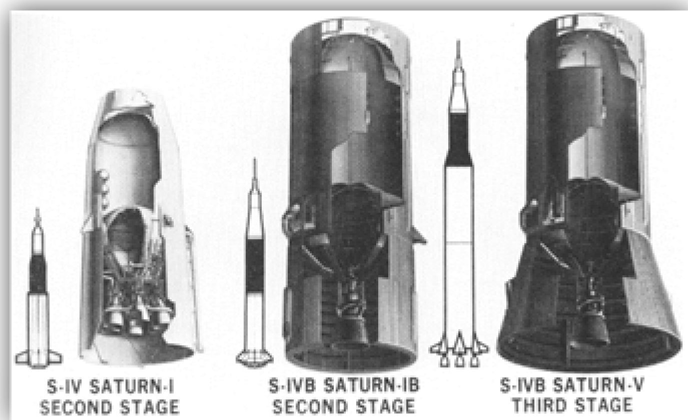
Apollo Saturn 1 Second Stage S-IV Cold Helium Pressure Regulator, c. 1964

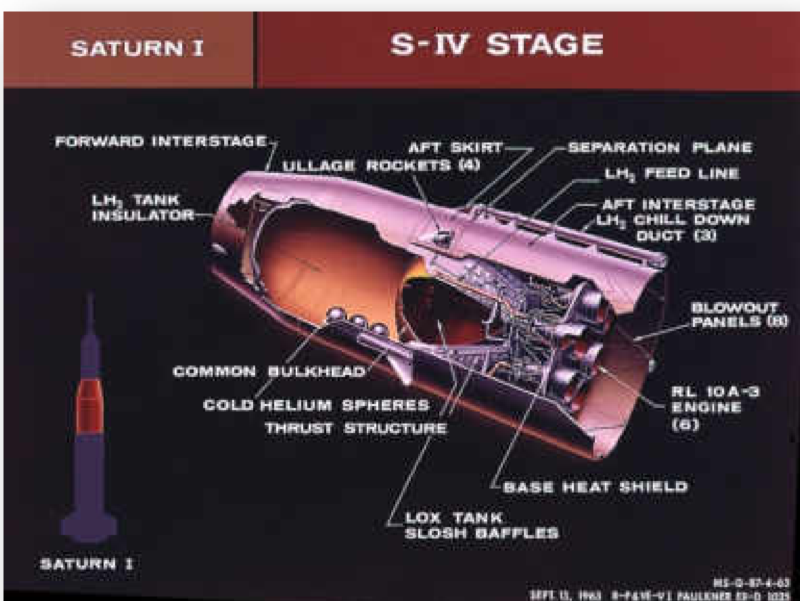


The S-IV was the second stage of the Saturn I rocket used by NASA for early flights in the Apollo program, the final push for the moon. It was manufactured by the Douglas Aircraft Company and later modified by them to the S-IVB, a similar but distinct stage used on the Saturn IB and Saturn V rockets. The S-IV was a large LOX/LH2-fueled rocket stage used for the early test flights of the Saturn I rocket. It formed the second stage of the launch vehicle and was powered by a cluster of six RL-10A-3 engines. Each one of the engines supplied 66.7 kilonewtons (15,000 lbf) of thrust for a total of about 400 kilonewtons (90,000 lbf). Cryogenic LH2 (liquid hydrogen) and LOX (liquid oxygen) tanks were separated by a common bulkhead. The forward bulkhead of the LOX tank formed the aft bulkhead of the LH2 tank. This saved up to 20% of structural weight.

Attached to the LH2 tank interior were, among other components, nine cold helium spheres. The fuel tank was pressurized by the gaseous helium stored in these spheres. They were initially filled to 1,660 psig, but once LOX was loaded and the bottles were cold, helium pressure was raised to about 3,100 psig. Cold helium was heated by engine heat exchangers before entering the fuel tank via a pressure regulator like this one, which would reduce the pressure from 3,100 to 275-225 psig. Tank pressurization ensured sufficient head pressure for engine start and operation.

A January 20, 1967 S-IVB-503 acceptance test in Douglas' Sacramento Operations Test Stand Beta III proceeded normally until 11 seconds before ignition when the stage exploded. The stage was blown completely out and away from the test stand, leaving jagged metal hanging in the test stand structure. Nearby structures and windows, along with the Beta II test stand, were damaged.





An extensive investigation revealed that one of the high-pressure titanium helium storage spheres had exploded, rupturing the LOX and LH2 fill lines, which allowed the fuel and oxidizer to mix and explode. The helium sphere vendor had substituted pure titanium fill wire for the specified fill wire alloy when the helium hemispheres were joined. The resulting weld was weak and failed after a few pressurization cycles. DAC built the remaining helium spheres in-house.

McDonnell Lucite with Heat Shield Cutting from Gemini VII, 1965

"Souvenir cut from the Gemini VII heat shield which was recovered from the Atlantic on 18 December 1965 After the first space rendezvous and the longest space flight of 14 days. This heat shield protected Astronauts Borman and Lovell from reentry temperatures of 3100 degrees Fahrenheit."

McDonnell Aircraft Company manufactured this heat shield for the Gemini VII spacecraft, launched into space on a mighty Titan II rocket which you will encounter elsewhere in this book. Gemini VII was a 1965 manned flight in NASA's Gemini program, the next stepping stone to the moon, and an important proving ground for future Apollo innovations. It was the 4th manned Gemini flight, the 12th manned American flight and the 20th spaceflight of all time (includes X-15 flights over 100 kilometers).

Gemini VII capsule.
Smithsonian NASM.

The crew of Frank F. Borman, II and James A. Lovell, Jr spent nearly 14 days in space making a total of 206 orbits and were joined on orbit by the Gemini-6A flight, which performed the first rendezvous maneuver of manned spacecraft. Its mission priorities were to demonstrate a 2-week flight, to perform station keeping with the Gemini launch vehicle stage 2, to evaluate the 'shirt sleeve' environment and the lightweight pressure suit, to act as a rendezvous target for Gemini 6, and to demonstrate controlled reentry close to the target landing point. The crew members had three scientific, four technological, four spacecraft, and eight medical experiments to perform.

This artifact is a Lucite presentation piece containing a flown heat shield core from the Gemini VII spacecraft. McDonnell was the prime contractor for the Gemini spacecraft. On the front of the Lucite imprinted in gold letters is the company name. Gemini artifacts are very rare; at the time few unnecessary pieces of spacecraft were retained as the future historical and commercial value was not yet understood.

Jim Lovell would later utter the famous words "Houston, we've had a problem" during the harrowing voyage of Apollo 13, featured a little farther along in this chapter.

Lucite with Flown AS-201 Heatshield Fragment, 1966

AS-201, launched on 26 February 1966, was the first test flight of both the Saturn IB rocket and the Apollo Block I command-and-service module. NASA used the sub-orbital mission to verify that the new launch vehicle could lift an Apollo spacecraft, that the launch-escape tower would separate cleanly, that the service module's big AJ10-137 engine could start and restart in space, and – most critically – that the command module's heat shield could survive a high-energy re-entry comparable to a return from lunar orbit.

The flight reached 486 km in altitude, accelerated the capsule to nearly 8.3 km/s, then splashed down 37 minutes after launch. Telemetry showed the Saturn IB performed as designed and the heat shield came through with comfortable temperature margins, giving NASA confidence to press on toward crewed flights. Engineers did uncover issues with helium pressurization in the service-propulsion system and with spacecraft electrical wiring, prompting fixes before the next test. Overall, AS-201 proved the basic Saturn IB–Apollo stack worked together, clearing a major milestone on the path to Apollo 7 and, ultimately, to the Moon.

Avcoat is the ablative material that formed the orange-brown outer layer of every Apollo command module. The code "5026-39 HC" breaks down like this:

5026-39 – the specific epoxy-novolac resin formulation developed by Avco Corporation; it mixed the resin with silica fibers and tiny phenolic micro-balloons to control density and char behavior.

HC – "honeycomb cast." Instead of being machined from a block, the compound was injected as a putty into the individual cells of a pre-bonded fiberglass honeycomb that had already been attached to the spacecraft's aluminum skin. Each cell was then cured and machined flush, giving the heat shield its familiar quilted appearance.

During re-entry the surface layer of Avcoat charred, melted, and gradually ablated away, carrying heat with it and keeping the underlying aluminum structure of the command module well below its melting point. The same recipe – slightly tweaked for modern environmental regulations – is still being used on NASA's Orion capsules today.

Closeups. The honeycomb structure can be seen in the top photo. Compare it to the main photo for a sense of scale.

AS-202 PSA Screws from the First Flown Apollo Guidance & Navigation System, 1966

Without the computers on board the Apollo spacecraft, there would have been no moon landing, no great leap for mankind, no pinnacle of human space travel. A pilot could never have navigated the way to the moon, as if a spaceship were simply a more powerful airplane. The calculations required to make in-flight adjustments and the complexity of the thrust controls far outstripped human capacities.

The Apollo Guidance Computer, or AGC, in both its guises – one on board the core spacecraft, and the other on the lunar module – was a triumph of engineering. Computers had been the size of rooms and filled with vacuum tubes, and if the Apollo computer, at 70 pounds, was not exactly miniature yet, it began "the transition between people bragging about how big their computers are […] and bragging about how small their computers are", the MIT aerospace and computing historian David Mindell once joked.

The trends that this computer foretold kept spinning out for decades: From big to small, from vacuum tubes to silicon, from hardware to software. Now, if you compare the computing power that NASA used with any common device, from a watch to a greeting card to a microwave, it induces technological vertigo. Michio Kaku, the physicist and popular author, put it like this: "Today, your cell phone has more computer power than all of NASA back in 1969, when it placed two astronauts on the moon". But these just-so sayings obscure the real power of the Apollo computer. Of course, any contemporary device has vastly more raw computational ability than the early machine, but the Apollo computer was remarkably capable, reliable, and up to the task it was given. You could not actually guide a spaceship to the moon with a smart doorbell.

Margaret Hamilton led a team of 350 people to design the software behind the Apollo 11 mission.

The Apollo Guidance Computer in the command module had two main jobs. First, it computed the necessary course to the moon, calibrated by astronomical measurements that the astronauts made in flight, with a sextant not unlike that used by oceanic navigators. They'd line up the moon, Earth, or the sun in one sight, and fix the location of a star with the other. The computer would precisely measure those angles and recalculate its position. Second, it controlled the many physical components of the spacecraft. The AGC could communicate with 150 different devices within the spacecraft – an enormously complicated task.

Conceptually, the MIT Instrumentation Laboratory, which designed the system, built it atop the work they'd done for the Polaris guided-missile system, made to launch nuclear weapons from American submarines. The Apollo computer's hardware was fairly well understood in the world of military avionics. Building this hardware dominated the project at first, because the lab had heavily underestimated the complexity of the software engineering task.

My screws came from this specific G&N System.

An Apollo Guidance Computer and DSKY.

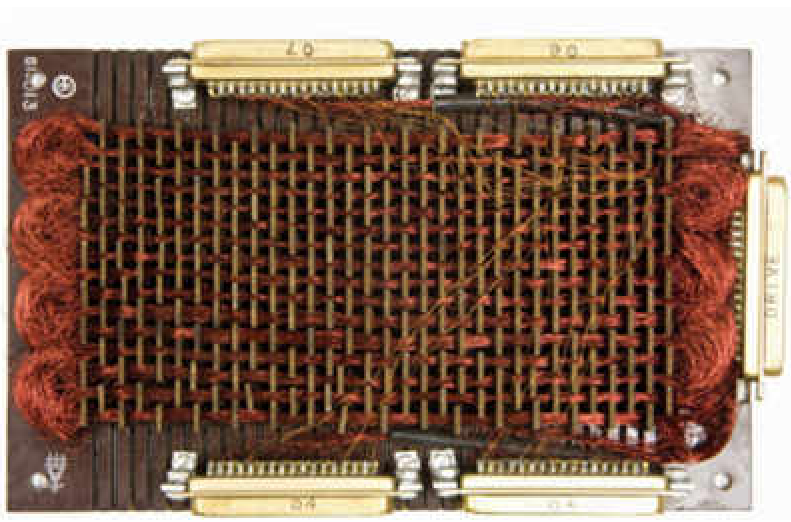
At that time, programmers were still using punch cards to run programs sequentially. But the necessity of having Apollo astronauts and NASA engineers “in the loop,” making decisions in real time, required a different kind of software. There had to be an interface. Multiple operations had to run at once.

Margaret Hamilton with her code that took us to the moon.

The initial overfocus on hardware opened space for Margaret Hamilton, a woman in the heavily male Apollo program, to lead software design. As it became clear that the software was truly where the mission would be made, Hamilton’s team expanded to 350 people at its peak. The system they built was remarkably advanced. To maximize the built-in architecture, Hamilton and her colleagues came up with what they named “The Interpreter” – we’d now call it virtualization. It allowed them to run five to seven virtual machines simultaneously in 2K of memory. It was terribly slow, but gave the computer all the capabilities it needed.

The astronauts communicated with the computer through the DSKY, short for “display and keyboard”. They’d punch in numbers and get responses. It’s not easy to describe the user-interface system, but it relied on a series of program codes, as well as “verb” and “noun” codes. Verbs were things the computer could do (“78 UPDATE PRELAUNCH AZIMUTH”). Nouns were numerical quantities or measurements (“33 TIME OF IGNITION”). It was a long way from point-and-click simplicity.

Most of the system’s memory had been woven, literally, into “core rope memory”, but some could be written, both by the astronauts and remotely from Mission Control. Perhaps the most brilliant software-engineering feat was the software designed by J. Halcombe Laning that prioritized the system’s computational tasks. This turned out to be a mission-saving advance for Apollo 11. As the lunar module descended, noise from one of its radars began to feed bad data into the system. The guidance computer understood it had a problem, but was able to stay functional throughout the descent, dumping the bad information and continuing its more important operations, saving the mission.



A core rope memory module, note the hardwired connections. These represented software code.

Apollo Flight AS-202, in CSM-011, was the second uncrewed, suborbital test flight of a production Block I Apollo command and service module launched with the Saturn IB launch vehicle. It was launched on August 25, 1966, and was the first flight which included the AGC and fuel cells. The success of this flight enabled the Apollo program to judge the Block I spacecraft and Saturn IB ready to carry men into orbit.

A decal with the emblem of the "Lunar Test Article" Jimmie worked on, also in my collection.

My screws holding the PSA module in place before removal.

The two 6/32" Removable Socket Head machine screws in this artifact were part of this guidance computer, and with its friends held the Block 1 Power and Servo Assembly (PSA) Modules of the AGC in their trays. The PSA, located just below the display and control panel in the lower equipment bay, served as a central mounting point for most of the guidance system's electronic units such as power supplies and amplifiers. It consisted of 10 removable trays mounted adjacent to each other and connected to a junction box.

Unflown PSA modules, AS-202 flight spares, also in my collection.

These two screws were removed from Flown PSA Serial #1 Tray #8 by, and purchased from, Jimmie Loocke. During the Apollo program, Jimmie worked at the NASA Manned Spacecraft Center (now Johnson Space Center). Part of the work he and his colleagues did was to human-rate the Lunar Module in the thermal vacuum chamber, simulating the environment of outer space by piping out most of the air in the chamber and fluctuating the temperature. The human-rating of the LEM was a landmark development in Apollo, as it helped prove the vehicle's flightworthiness.

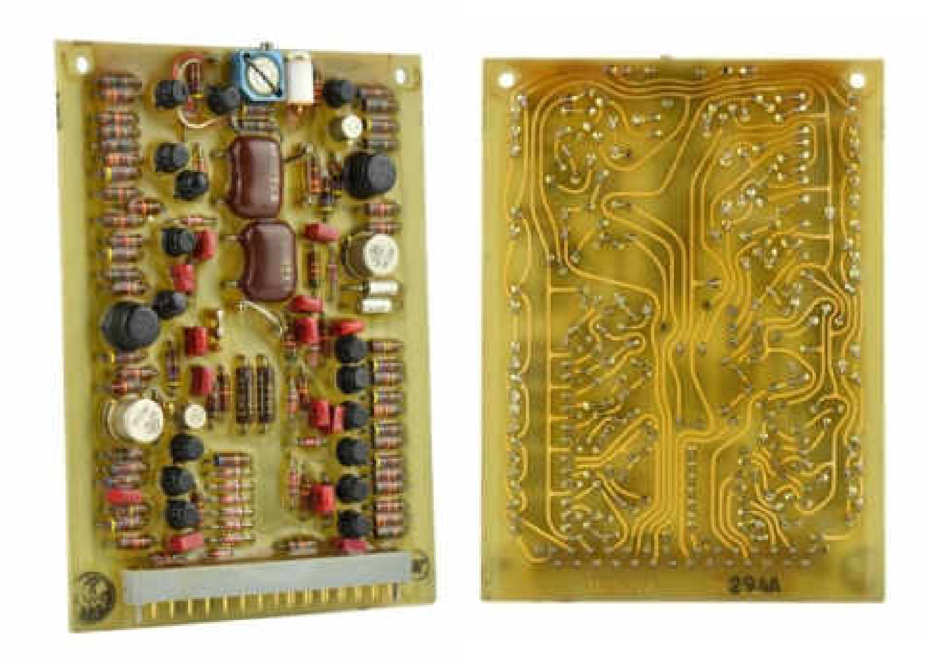
In 1976, Loocke was working on a new and unrelated project. Looking for components, he heard about a warehouse filled with hardware. Upon digging through the equipment, he began to recognize Apollo components. Specifically, Lunar Module components. The man who owned the warehouse, Virgil Redgate, had acquired the surplus hardware at NASA auctions and intended to extract precious metals and then scrap the rest. Upon seeing the Apollo components, Loocke knew he had to save them. The boxes of equipment also included pieces from Mercury, Gemini, and Surveyor. Loocke was able to obtain over two tons of hardware.

The crown jewel is his Block II Lunar Module Apollo Guidance Computer, which, in synchronicity, came out of the same test vehicle he had worked on, Lunar Test Article 8 (LTA-8). The computer was in such good condition that he has been collaborating ever since with experts, astronauts, and fellow collectors to bring the AGC and its history back to life. Yes, they were able to boot it.

The story of Jimmie's AGC is too long for this book, but it's easy to find, there's a great video on WSJ.com.


Jimmie Loocke.

Apollo Saturn IB / V Moon Rocket S-IVB Multiplexer Circuit Board, c. 1966



The S-IVB (pronounced "S-four-B") was an evolution of the S-IV earlier in this chapter, serving as the second stage on the Saturn IB and third stage on the Saturn V heavy launch vehicles. Built by the Douglas Aircraft Company, it had one J-2 rocket engine. For lunar missions it was fired twice: first for Earth orbit insertion after second stage cutoff, then for translunar injection (TLI).

This board was designed as part of the data multiplexing equipment aboard the S-IVB. It consists of various NASA "Man Rated" space components, such as Kovar canned tantalum capacitors, Kovar canned gold header transistors, and variable trim potentiometers. Gold, silver, palladium, and tantalum are used throughout this device. All the beautiful hand-drawn interconnecting traces on the back are gold, with an environmentally protective coating on all vital components.

NASA flight box data plate from the multiplexer assembly which once housed this circuit board.

© ApolloManiacs apollomaniacs.com

Saturn-IVB after separation.

Lucite with Flown Piece of Kapton Foil from Apollo 9 Lunar Module “Spider”, 1969

Apollo 9 (March 3–13, 1969) was the third manned spaceflight in NASA’s Apollo program. Flown in low Earth orbit, it was the second crewed Apollo mission that the United States launched via a Saturn V rocket, and the first flight of the full Apollo spacecraft: the command and service module (CSM) with the Lunar Module (LM). The mission was flown to qualify the LM for lunar orbit in preparation for the first Moon landing by demonstrating its descent and ascent propulsion systems, showing that its crew could fly it independently, then rendezvous and dock with the CSM again, as would be required for the first lunar landing. Other objectives of the flight included firing the LM descent engine to propel the spacecraft as a backup (as would be required on Apollo 13), and use of the portable life support system backpack outside the LM cabin.

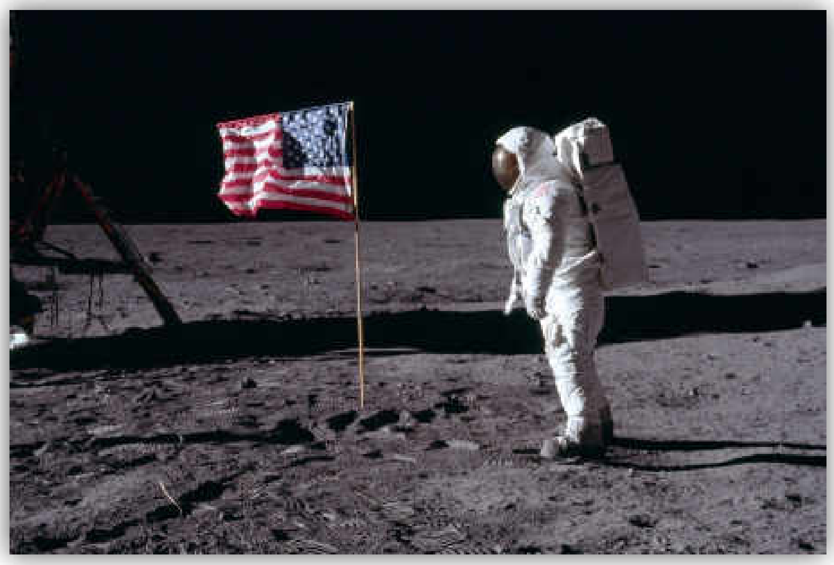
The three-man crew consisted of Commander James McDivitt, Command Module Pilot David Scott, and Lunar Module Pilot Rusty Schweickart. During the ten-day mission, they tested systems and procedures critical to landing on the Moon, including the LM engines, life support systems, navigation systems and docking maneuvers. The mission was a complete success. It proved the LM worthy of crewed spaceflight, setting the stage for the dress rehearsal, Apollo 10, before the ultimate goal, landing on the Moon.

In the photo, Apollo 9 Command/Service Modules (CSM) “Gumdrop” and Lunar Module (LM) “Spider” are shown docked together as Command Module pilot David R. Scott stands in the open hatch. Astronaut Russell L. Schweickart, Lunar Module pilot, took this photograph of Scott during his EVA as he stood on the porch outside the Lunar Module, and was the one who removed the piece of foil embedded in this Lucite.

Lucite with Apollo 11 Command Module "Columbia" Flown Cold Plate Fragment, 1969

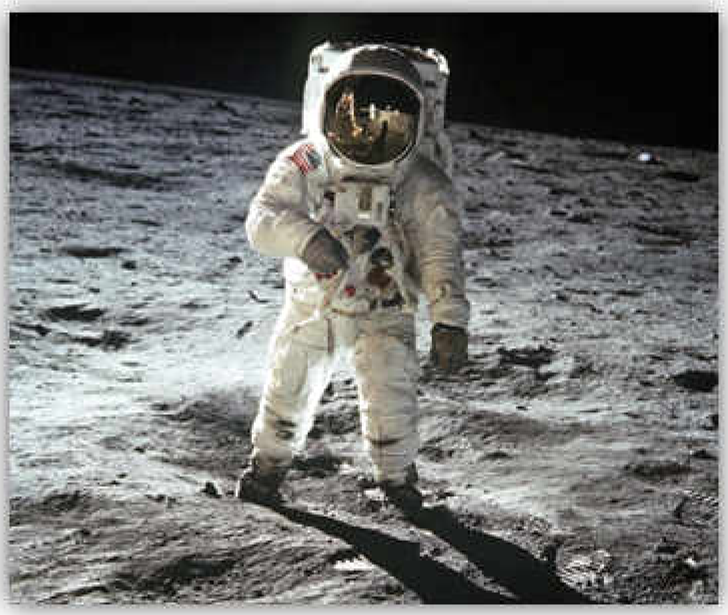
On July 20, 1969, a man stepped out of a small and ungainly looking spacecraft, and set foot on Earth's moon. His mission had really begun on May 25, 1961, when President Kennedy, amidst the tensions of the Cold War and the space race with the Soviet Union, issued the directive "to send a man to the Moon and safely return him to Earth", by the end of that decade. This ambitious goal had galvanized the nation and set in motion Project Apollo, the effort to plant mankind's first footprints on another celestial body.

The Mercury and Gemini programs had laid the groundwork for human spaceflight, demonstrating the feasibility of manned orbital missions and refining techniques needed for rendezvous, docking, and spacewalks. In parallel, development of the powerful Saturn V rocket provided the vehicle necessary to propel astronauts to the Moon. This behemoth 63 feet tall, with a liftoff thrust of 7.5 million pounds-force, making it most powerful rocket ever built until SpaceX launched a full stack Star ship more than fifty years later.



After four crewed Apollo missions, each testing different hardware and mission components, the first to finally send humans to the surface of the moon blasted off from the Kennedy Space Center in Florida on July 16, 1969. The Apollo spacecraft had three parts: a Command Module (CM) with a cabin for the three astronauts, the only part that returned to Earth; a Service Module (SM), which supported the command module with propulsion, electrical power, oxygen, and water; and a Lunar Excursion Module (LEM) that had two stages – a descent stage for landing on the Moon and an ascent stage to place the astronauts back into lunar orbit.

In command was Neil A. Armstrong, Michael Collins was the CM pilot, and Edwin E. Aldrin Jr. would pilot the LEM. After traveling 240,000 miles, the astronauts entered into orbit around the moon on July 19. Astronauts Neil Armstrong and Buzz Aldrin entered the LEM, which they named the Eagle, and began their descent to the moon's surface, while Michael Collins continued to orbit the moon in the CM.



As the Eagle approached the moon, the astronauts encountered several issues, including a computer error and limited fuel. However, Margaret Hamilton's fault tolerant code, Armstrong's piloting skills, and Aldrin's calculations allowed them to land safely on the moon's surface at the Sea of Tranquility with just 20 seconds of fuel left.

At 10:56 p.m. EDT, Armstrong opened Eagle's hatch and stepped onto the lunar surface as the world watched in awe on live television. His words do not need repeating here. Aldrin followed, and the two astronauts spent over two hours conducting experiments, taking photographs, and collecting samples of the moon's surface.

After completing their tasks, Armstrong and Aldrin returned to the LEM and the ascent stage lifted off to rendezvous with Collins in orbit.

Apollo 11 returned to Earth on July 24, 1969, and the three astronauts were hailed as heroes. Kennedy's directive had been fulfilled. The mission not only demonstrated the technological prowess of the United States, but also its economic might. The Soviets were never to catch up again. By putting footprints on the moon America had effectively won the space race, and captured the imagination of all mankind

Lucite with Piece of Couch Backing from Apollo 13 Command Module "Odyssey", 1970

Apollo 13 was to be NASA's third moon-landing mission, but never made it to the lunar surface, and in fact almost didn't come home.

During the mission's dramatic series of events, an oxygen tank explosion almost 56 hours into the flight forced the crew to abandon all thoughts of reaching the moon. The spacecraft was damaged, but the crew was able to seek cramped shelter in the lunar module for the trip back, before returning to the command module for an uncomfortable splashdown.

The mission is another example of the dangers of space travel, and of NASA's innovative minds working together to save lives on the fly. The Apollo 13 mission celebrated its 50th anniversary on April 11, 2020, and a statue to commemorate their survival was unveiled.

The Apollo 13 astronauts were commander James Lovell, lunar module pilot Fred Haise, and command module pilot John "Jack" Swigert. At age 42, Lovell was the world's most traveled astronaut when he joined the mission, with three missions and 572 spaceflight hours under his belt. Lovell participated in Apollo 8, the first mission to circle the moon, and flew two Gemini missions – including a 14-day endurance run.

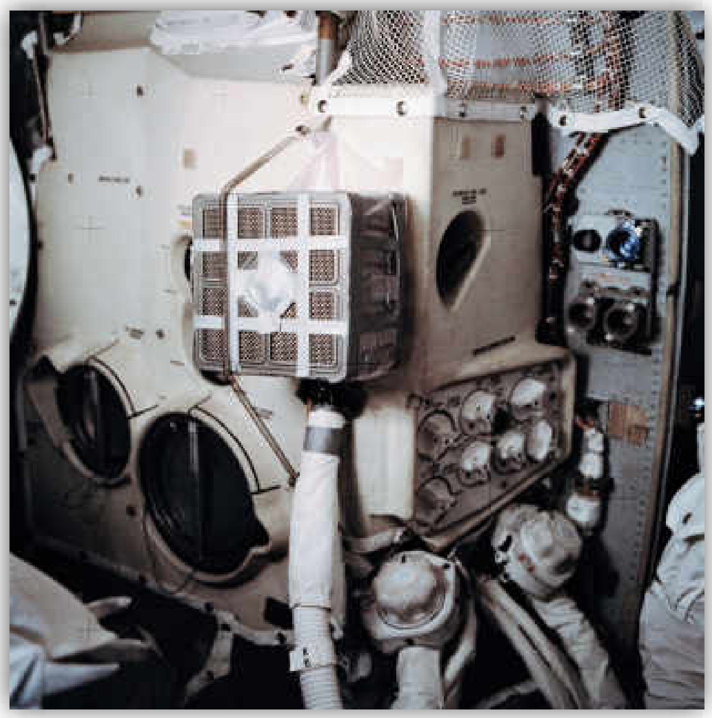
Prior to Apollo 13, 36-year-old Haise served as the backup lunar module pilot for Apollo 8 and Apollo 11. Haise was a fighter pilot in the U.S. Marine Corps before joining NASA as a test pilot. He was selected for the manned space program in 1966, at the same time as Swigert. Apollo 13 was Haise's only trip to space.

Apollo 13 was Swigert's first trip to space, at age 38. He had been part of the support crew for Apollo 7 and was initially Apollo 13's backup command module pilot. He was asked to join the crew 48 hours before launch time after the original command module pilot, Ken Mattingly, was exposed to German measles.

The mission was launched on April 11, 1970. The Apollo spacecraft was made up of two independent spacecraft joined by a tunnel: orbiter Odyssey, and lander Aquarius. The crew lived in Odyssey on the journey to the moon.

On the evening of April 13, when the crew was nearly 322,000 kilometers (200,000 miles) from Earth and closing in on the moon, mission controller Sy Liebergot saw a low-pressure warning signal on a hydrogen tank in Odyssey. The signal could have shown a problem, or could have indicated the hydrogen just needed to be resettled by heating and fanning the gas inside the tank. That procedure was called a "cryo stir" and was supposed to stop the super cold gas from settling into layers.

Swigert flipped the switch for the routine procedure. A moment later, the entire spacecraft shook. Alarm lights lit up in Odyssey and in Mission Control as oxygen pressure fell and power disappeared. The crew notified Mission Control, with Swigert famously saying, "Houston, we've had a problem." (Note that the 1995 movie "Apollo 13" took some creative license with the phrase, changing it to "Houston, we have a problem" and having the words come from Apollo 13 commander James Lovell).


The famous hack – failure is not an option.

Much later, a NASA accident investigation board determined wires were exposed in the oxygen tank because of a combination of manufacturing and testing errors before flight. That fateful night, a spark from an exposed wire in the oxygen tank caused a fire, ripping apart one oxygen tank and damaging another inside the spacecraft.

Since oxygen fed Odyssey's fuel cells, power was reduced as well. The spacecraft's attitude control thrusters, sensing the venting oxygen, tried to stabilize the spacecraft through firing small jets. The system wasn't very successful given several of the jets were slammed shut by the explosion.

Fortunately for Apollo 13, the damaged Odyssey had a healthy backup: Aquarius, which wasn't supposed to be turned on until the crew was close to landing on the moon. Haise and Lovell frantically worked to boot Aquarius up in less time than designed. Aquarius didn't have a heat shield to survive the drop back to Earth, so as Lovell and Haise got the lunar module up and running, Swigert remained in Odyssey to shut down its systems to conserve power for splashdown.

The crew had to balance the challenge of getting home with the challenge of preserving power on Aquarius. After they performed a crucial burn to point the spacecraft back towards Earth, the crew powered down every nonessential system in the spacecraft. Without a source of heat, cabin temperatures quickly dropped down close to freezing. Some food became inedible.

The crew also rationed water to make sure Aquarius – operating for longer than it was designed – would have enough liquid to cool its hardware down. And Aquarius was pretty cramped as it was designed to hold two people, not three.

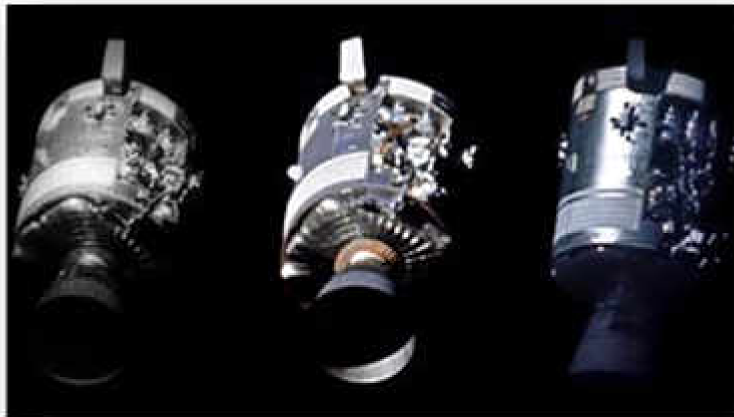
On Earth, flight director Gene Kranz pulled his shift of controllers off regular rotation to focus on managing consumables like water and power.


Jim Lovell selects music on a tape player; you'll find a space flown cassette tape later in this chapter.

Other mission control teams helped the crew with its daily activities. Spacecraft manufacturers worked around the clock to support NASA and the crew.

It was a rough journey home. The entire spaceflight crew lost weight, and Haise developed a kidney infection. But the small vessel protected and carried the crew long enough to reach Earth's atmosphere.

In the hours before splashdown, the exhausted crew scrambled back over to the Odyssey and powered it up. The craft had essentially been in a cold-water soak for days, and could have shorted out, but thanks to safeguards put in place after the Apollo 1 disaster, there were no issues.



The damaged Service Module.

Lovell, Haise and Swigert safely splashed down in the Pacific Ocean near Samoa, on April 17.

© Universal

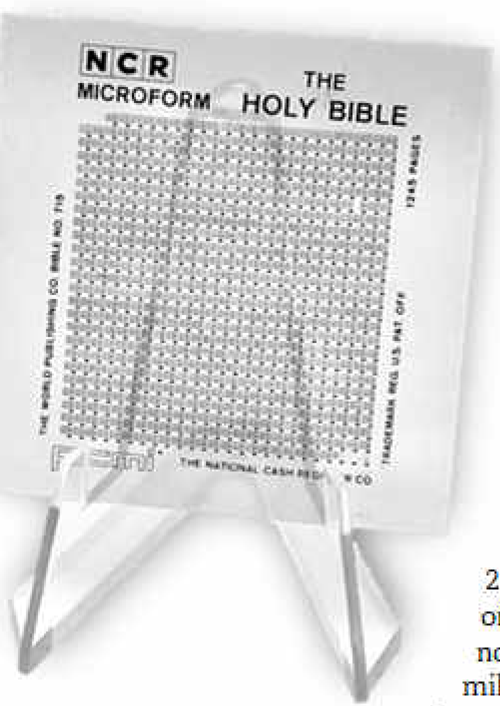
Apollo 13 was made into a 1995 American docudrama film directed by Ron Howard. The film stars Tom Hanks, Kevin Bacon, Bill Paxton, Gary Sinise, Kathleen Quinlan and Ed Harris. The screenplay by William Broyles, Jr. and Al Reinert, that dramatizes the mission, is an adaptation of the book Lost Moon: The Perilous Voyage of Apollo 13 by astronaut Jim Lovell and Jeffrey Kluger.

Enclosed inside this Lucite is a piece of couch fabric, approximately 0.875" square in size, and a color mission insignia for Apollo 13. On the bottom of the mission insignia is the text: "2009 Space Artifact Series - This fabric flew to the moon aboard Apollo 13 as the backing material of the astronauts' couches in the Command Module, Odyssey. The April 11-17, 1970, mission epitomized a nation's strength as the U.S. brought the crew and their crippled spaceship home safely", as well as a facsimile of Fred Haise's signature.

Fred Haise catches some sleep.

Jack Swigert and Jim Lovell at the LEM controls.

NCR Microform "Lunar Bible" (Not Flown to Moon), 1971



Let me preface this by stating I am not a religious man; I submit to no higher power and kneel before the altar of no false god. It is said though that just like there are no atheists in foxholes, there are no atheists in space. I will let you know when I get back, but for now I staunchly remain so.

In 1966 the Research and Development department of National Cash Register (NCR) of Dayton, Ohio produced an edition of all 1245 pages of the World Publishing Company's No. 715 Bible on a single 2" x 1-3/4" photochromatic microform (PCMI). The microform contained both the Old and New Testaments, and was issued in a paper sleeve with the title on the cover and information about the process.

On the microform each page of double column Bible text was about 0.5 mm wide and 1 mm high. Each text character was 8 um high (ie 8/1,000ths of a millimeter). NCR noted on the paper wallet provided with the microform that this represented a linear reduction of about 250:1 or an area reduction of 62,500:1. This would correspond to the original text being circa 2 mm high. To put this into perspective, NCR also noted that if this reduction was used on the millions of books on its 270+ miles of shelving, the entire Library of Congress as it existed in 1966 could be stored in six standard filing cabinets.

The origins of both the "Lunar Bibles", and the "Apollo Prayer League" which created them, can be found in the ashes of a national tragedy. On January 27, 1967, astronauts Virgil "Gus" Grissom, Edward White II, and Roger Chaffee were killed in the Apollo 1 fire at Cape Kennedy. Apollo 1 was meant to be the first manned Apollo flight, and the tragedy was all the more shocking given that it occurred during a routine test.

As the world looked on in horror, one man in particular made a personal commitment to bring meaning to an otherwise senseless tragedy. During his tenure at NASA, Reverend John M. Stout came to know many of the pioneer astronauts personally, including Edward White, II. Astronaut White became the first American space-walker on Gemini IV, and was also a devoutly religious man who often prayed with Stout. As Stout watched his friend die in the Apollo 1 fire, he was moved to do something as a tribute to White and his fellow crew members. Prior to the official formation of the Prayer League, Reverend Stout had led a group that informally prayed with and for the astronauts.

However, after the fire, Reverend Stout desired to create a broader and more permanent religious organization. Reverend Stout envisioned a global organization that would not only pray for the astronauts, but also engage in humanitarian efforts. Discussions with his wife Helen, brother James W. Stout, and others led Reverend Stout to launch the "Apollo Prayer League" in 1968.

In 1971 Apollo 14 lunar module pilot Edgar D. Mitchell carried 100 of the microform bibles aboard the Lunar Module "Antares", along with microfilm copies of several newspapers – which we will see in the next article – as confirmed by NASA's official manifests. Launched January 31, 1971, Mitchell and the bibles reached the Fra Mauro formation of the Moon on February 5 aboard the Antares before returning to the command module for the voyage back to Earth. This was the first edition of the Bible to reach the Moon, and probably the first book of any kind to reach the moon and return. A second parcel containing 200 microform Bibles flew in Edgar Mitchell's Command Module "PPK" bag in lunar orbit, and did not land. These 200 copies represented extra Bibles to be used if something happened to the Lunar Module copies.

Lucite Globe with Alan Shepard's Apollo 14 Lunar Surface Flown Microfilm, 1971

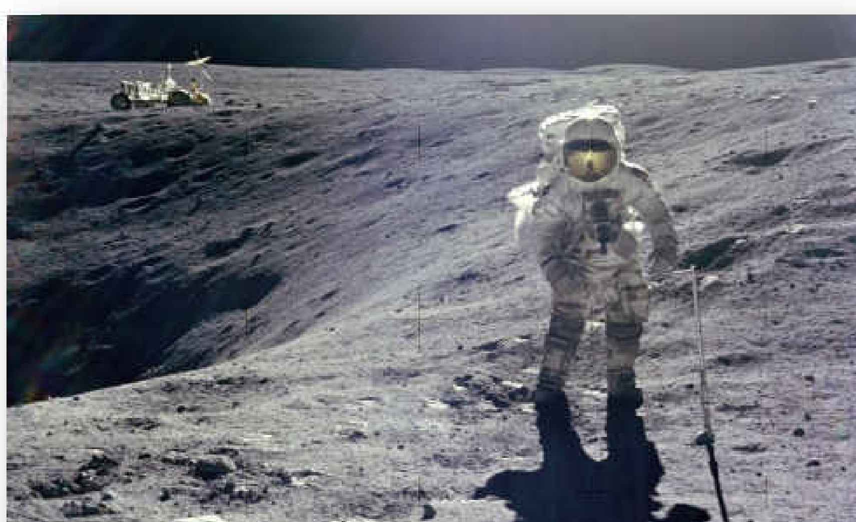
This Lucite sphere, just large enough to fit in the palm of a hand, holds a strip of 35 mm microfilm. Enlarged under magnification the frame reveals the Christian Science Monitor's very first front page from 25 November 1908 – which opened with the boldly curious headline "LIFE ON MARS MAY BE SHOWN." In January 1971, Commander Alan B. Shepard stowed one hundred of these tiny negatives, plus a full microfilmed copy of the inaugural issue, in a metal canister in his Lunar Module personal-preference kit (PPK) aboard Apollo 14. On February 5, he and Edgar Mitchell landed their lunar module Antares, with in it this microfilm, in the Fra Mauro highlands of the Moon. After spending over nine hours on the Moon's surface, the ascent module of the LM left the surface, docked with the Command Module, the PPK holding the canister of film was transferred from spacecraft to spacecraft, and it began the quarter-million-mile journey home before splash-down nine days after launch.

The idea to bring this newspaper along originated not with NASA publicity staff but with Joyce Becker, a Christian Science Monitor advertising representative and fellow congregant of Shepard's wife Louise at Third Church of Christ, Scientist in Houston. Shepard had already promised to carry two other newspapers, yet he welcomed the addition of the Monitor since the microfilm added almost no weight. The publishing society in Boston duplicated the front page one hundred times, sealed everything in a half-dollar-sized can, and – well aware of the promotional potential – planned in advance to suspend each returned fragment in a Lucite display like this.

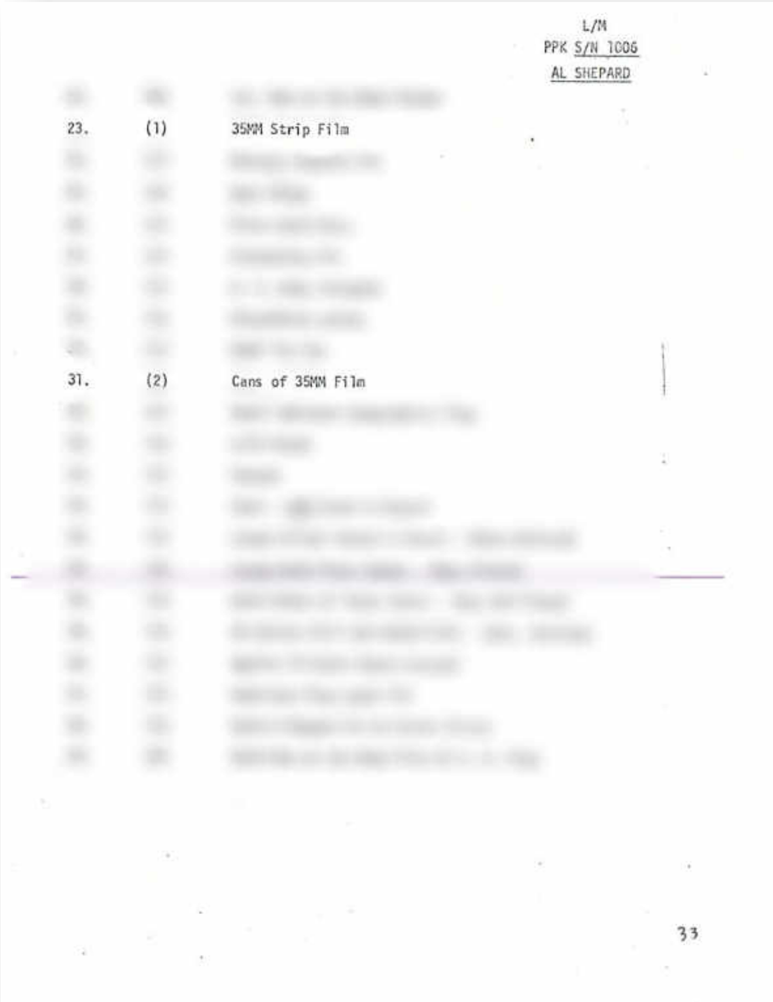
The exact disposition of all the microfilms has been a matter for debate; early news reports quoted editors who believed Shepard might leave the full first-edition microfilm on the Moon alongside a microfilmed copy of Cocoa Today (precursor to Florida Today) and seven historic front pages of the Houston Post. Later internal memos and the Monitor's own archives state that every copy made the round-trip and none were left among the rocks.

The label doesn't explicitly state that the film traveled to the lunar surface.

The best Apollo 14 artifact.



Alan Shepard famously practicing his golf swing on the Moon.



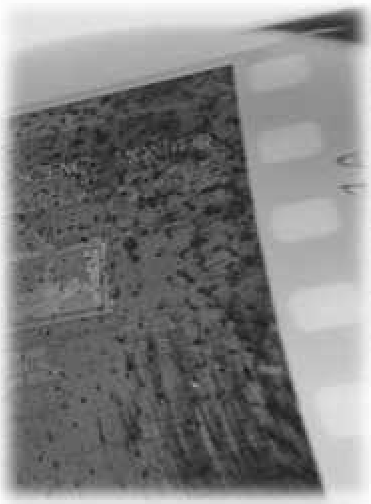
L/M
PPK S/N 1006
AL SHEPARD

23.	(1)	35MM Strip Film
31.	(2)	Cans of 35MM Film

33

Al Shepard's Lunar Module PPK manifest.

Stu Roosa (left), Al Shepard (center), and Ed Mitchell (right) in an official publicity shot, and in the isolation van where Roosa is using the microphone to talk to bystanders.

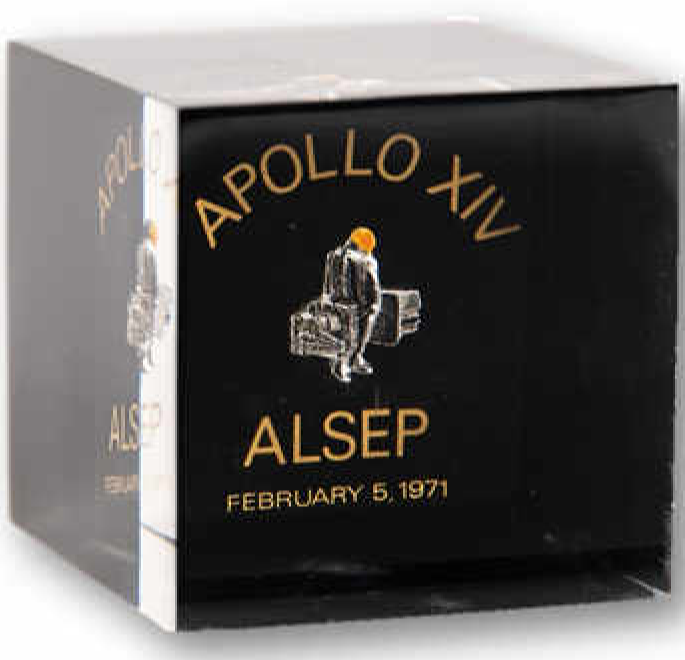


Several of the negatives went to Monitor archives; more were presented to dignitaries or employees; and a handful have since surfaced in space-collectible auctions. They are among the very few lunar-surface artifacts personally carried by Shepard that private collectors can still obtain – rarer than flown flags or medallions because, at most, ninety-odd survive.

This and the following two artifacts will serve to illustrate the collector's plight. Seen through the Lucite today the film's emulsion is peppered with dark specks that look tantalizingly like lunar dust. A film expert was quick to disappoint me: the flecks are chemical scars where the film's gelatin binder has begun to break down, either during the initial casting process or after decades of fluctuating temperature, a well-known form of silver-gelatin deterioration that eventually produces spots, stickiness, and fading in archival microfilm. I had hoped I'd found dust where there were nothing but spots of deteriorating gelatin. It's the eternal hope that the thing we have is in actuality incrementally better. Not some mundane a NASA artifact, but "possibly flown," not just lunar flown but surface flown, not just surface flown, but used outside of the Lunar Module, not just a roll of film that went to the moon, but film covered in Moon dust. Whatever vanishingly rare treasure we hold, it could always be rarer.

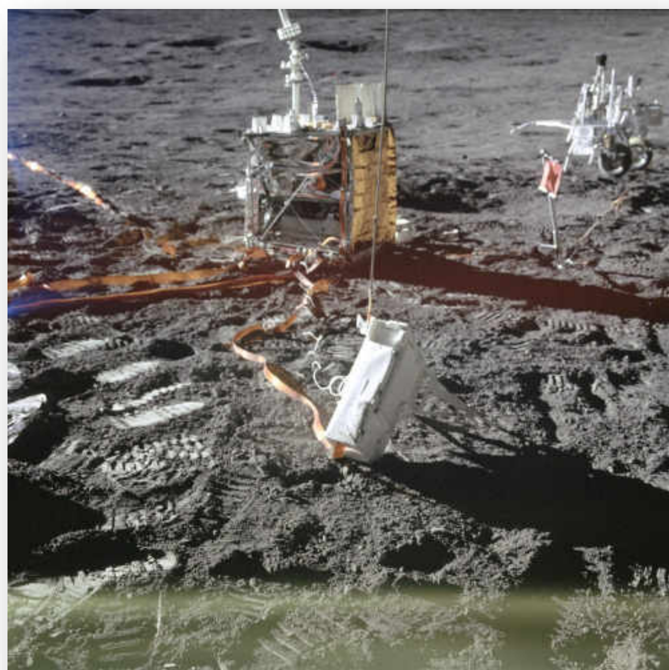
Closeups of the film. YOU try taking pictures through a sphere.

Lucite with Edgar Mitchell's Apollo 14 Purportedly Lunar Surface Flown ALSEP Emblem, 1971



This Lucite cube from Bendix Aerospace houses a nickel-silver badge that shows an astronaut carrying the Apollo Lunar Surface Experiments Package (ALSEP). Text on the back of the object – complete with NASA and Bendix logos – proclaims confidently that the emblem "was taken to the surface of the moon and returned to Earth". That claim has been repeated dozens of times in auction listings, museum labels, and even letters of authenticity accompanying this artifact and others just like it. Yet NASA paperwork contradicts it. The manifest for Edgar Mitchell's Command Module personal-preference kit (PPK S/N 1098) lists forty-seven "ALSEP emblems". No corresponding entry appears on the inventory for Lunar Module Antares, which alone touched down at Fra Mauro. Unless a last-minute swap went undocumented – mission logs show none – these badges rode nine days to the Moon and in lunar orbit aboard Kitty Hawk, rather than traveling to the surface.

The mismatch illustrates how easily enthusiastic presentation wording can out-run provenance. Bendix had produced a similar run of Lucite blocks for Apollo 12 and, at the time, widely referred to them as lunar-surface keepsakes. Recent scrutiny of Alan Bean's Apollo 12 flight manifests, however, suggests those earlier emblems may have remained in the Command Module as well. Someone at Bendix must have crafted the inscription, based either on incomplete information, plans that changed, or a little bit of wishful thinking, hoping and pretending that the thing they had was just a little bit better than it was. We'll never know for sure.

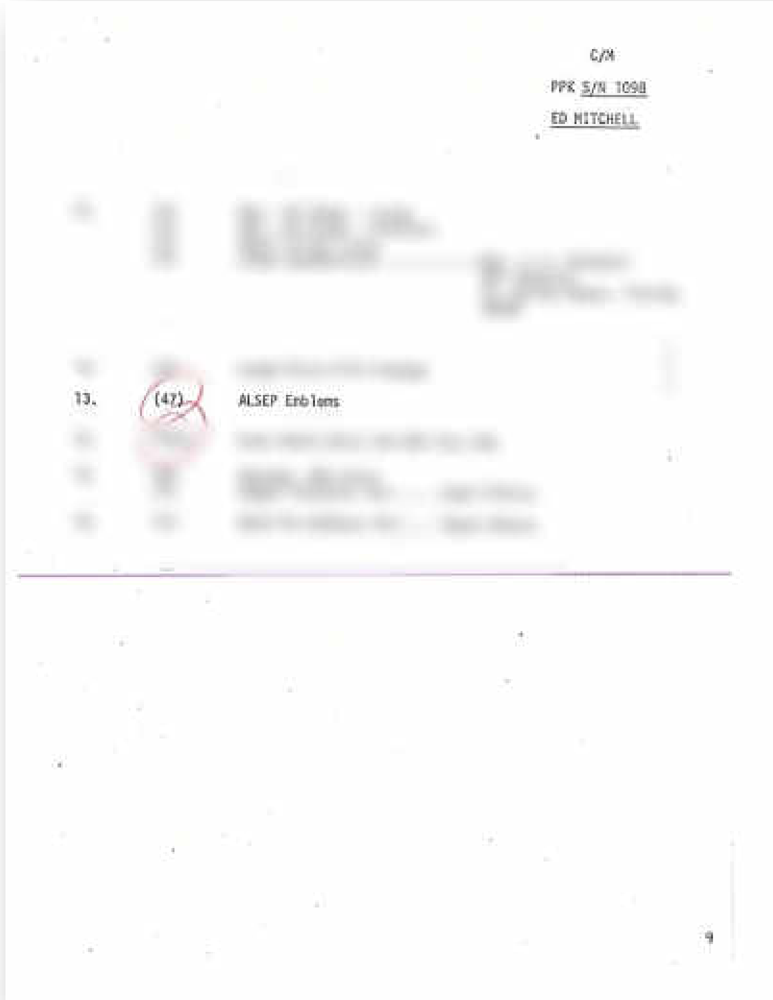


The Apollo 14 ALSEP deployed.

The prior artifact, the Christian Science Monitor microfilm sphere, suffers from the opposite problem, bearing a display label identifying it as moon-flown rather than surface-flown, even though the consensus amongst the collecting community is that these artifacts did reach the surface.

Whatever its journey, the emblem commemorates an important piece of lunar science. ALSEP was a suitcase-sized laboratory every Apollo crew after 11 dropped onto the Moon. The Apollo 14 station, deployed by Mitchell and Alan Shepard on their second EVA, combined a passive seismic experiment, an active seismic array, the Suprathermal Ion Detector, the Charged-Particle Lunar Environment Experiment, a cold-cathode pressure gauge, and a dust monitor. A plutonium-238 radio-isotope generator powered the package, and its transmitters returned data until September 1977 – long after the program itself had ended. The seismic receivers, in particular, helped map the thickness of the lunar crust and detect scores of tiny "moonquakes," fundamental measurements still cited in modern planning for Artemis landers.

Bendix embedded most of the badges in Lucite for distribution to NASA managers, senior engineers, and the three Apollo 14 crewmembers. Each bears the same optimistic text, but the paper trail causes us to conclude that "lunar orbit flown" is the accurate description.


C/M
PPK S/N 1098
ED MITCHELL

13. (47) ALSEP Emblems

9

Ed Mitchell's Command Module PPK manifest. PPK S/N 1098 most likely did not travel to the surface of the Moon.

PPK S/N 1099 did.

The story evolved over time. Some Bendix retirees recalled that the company planned to remake the inscription after Apollo 14 but never did because the program ended sooner than expected. Others point to the rush of public-relations requests that followed the successful deployment – NASA's first fully functional geophysical station after the Apollo 13 stand-down – and note that the wording simply echoed the heroic narrative of the day. The manifests of PPKs have always been intensely private. An astronaut might have included personal religious symbols, a gift for his wife, and one for his girlfriend too, and so the lists of these mementoes are not part of the public record. When detailed questions started being asked about the ALSEP pins, decades after the frantic weeks of training when such gifts were packed, Mitchell had to refer back to his own PPK lists to determine their path – which is why we know their history today.

This small plastic cube forms a cautionary counterweight to the certainties often attached to space memorabilia. Display plaques, family recollections and even manufacturer's brochures can be sincere yet incomplete. Only dry, bureaucratic documents – packing lists and stowage ledgers – are immune to wishful thinking.

Placed next to the Monitor microfilm sphere and the artifact we will explore next, this ALSEP block reminds us that the boundary between "lunar-flown" and "lunar-surface-flown" hinges on a single line item, or lack thereof, on a manifest page. When I purchased this object, based on the inscription and auction site description, I assumed it had been surface-flown – and I paid a commensurate price for it.

Lucite with Stuart Roosa's Apollo 14 Lunar Orbit Flown Weyerhaeuser Flag, 1971

This Lucite, our final Apollo 14 artifact, contains one of two flown Weyerhaeuser mini-flags carried to lunar orbit aboard the Command Module "Kitty Hawk" during the Apollo 14 mission. The story begins with an elk hunt on the Weyerhaeuser's Company's enormous Millicoma Tree Farm, centered around four of America's astronauts who had been invited to the Coos Bay, Oregon area by two local men.

The businessmen who set up the trip were Bob Perkins, owner of the Timber Inn Restaurant, and Phil Waters, who owned radio station KYNG. The two had many things in common, including a great love of the outdoors. Several years earlier, when a number of the Apollo astronauts were going through simulated moonscape walking on some rugged lava beds in Central Oregon, Bob and Phil had decided to go over and see what was happening. Soon they were swapping stories over cocktails with several of the like-minded young men.

Bob was invited to Cape Canaveral by some of his new acquaintances on the Apollo 7 crew to watch their launch. He and Phil then returned the favor, issuing invitations to Charlie Duke, Gordon Cooper, Stu Roosa, and Joe Engle to come west for some elk hunting on the 210,000 acres of the Millicoma Tree Farm. A call to a friend at the company secured everything they needed, including a flight on the company plane from Portland down to Coos Bay, along with gear, food, and guides.

Rocks rattled in the clearing below, and everyone's pulse jumped. Stu Roosa and Ovie Coleman, rifles ready, tip-toed carefully to the edge of the steep bank and searched the brush in a clearing below for what had to be elk on the move. The sky was overcast, and it was still so dark one would have had trouble reading. Fog drifted back and forth through the valley, further obscuring sight.

The company plane flew the astronauts from Portland to the Coos Bay-North Bend airport. From left to right, Charlie Duke, Gordon Cooper, Stu Roosa, chief pilot Bill Gilbert, pilot Don Booth and Joe Engle.

Then the fog parted briefly and they could be seen, a herd of eight or ten elk, their brown sides visible against the surrounding brush. Stu, "eyes sharpened by space training", raised his binoculars but even with those, it was impossible to see if any of the animals had antlers. Ovie, logging foreman for Weyerhaeuser at Coos Bay, peered intently through the scope of his rifle, trying to "put horns" on at least one of the animals. Just because it was legal shooting time on the opening day of elk season that didn't mean there was enough light to see.

The rattle of rocks grew louder as the herd, seeming to sense it was being observed, started moving toward a stand of old-growth timber nearby. Without a word, Stu and Ovie slipped over the side of the steep, wooded hillside into the thick brush in an attempt to get closer for a better look. Trying to keep quiet in the dim light of dawn in the Western Oregon brush is not easy, for the ground is covered with twigs and branches. It's also easy to slip and slide noisily or kick loose a rock as the elk were doing. Ovie and Stu continued stalking the herd, which was getting more restless each moment. There's a

Ovie Coleman, chief guide (left), and astronaut Stu Roosa examine the elk Ovie downed on the opening morning of the hunt.

lot of blind luck in an elk hunt. If the animals zig one way, the hunter on the left gets the shot; if they move the other way, the person on the right gets the good view. As luck would have it, when the elk were only a few steps from the tall timber, they took the turn which put them in front of Ovie. "I knew Stu couldn't get a shot", Ovie said later. He fired and down the elk went as the rest of the herd disappeared into the timber. The season was only minutes old and the hunt was a success. As they moved through the brush to their prize, Stu remarked, "This is amazing. Shooting an elk before daylight. I just can't get over it". Later, by the campfire, the astronauts proved themselves accomplished storytellers – and capable of taking the kind of ribbing that men in a hunting camp can hand out. Many stories and friendly insults were traded. Gordon Cooper said later, "I don't know when I've been in a better hunting camp. Everyone got along so well together".

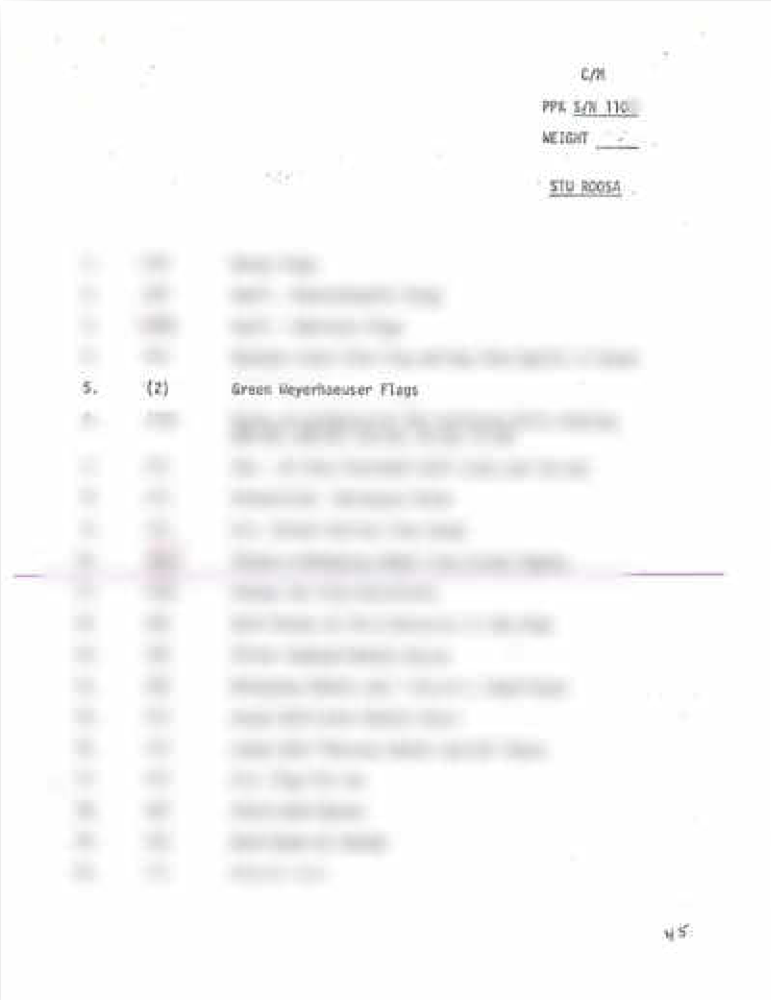
The trip and the friendships forged there made such an impression on Stu Roosa that before he flew to the moon, he had two tiny Weyerhaeuser flags made and stashed them in his Command Module Personal Preference Kit (PPK) to bring back as gifts. Upon his return, Stu had the two small green-and-white swatches encased in Lucite and gave them to Phil Waters and Weyerhaeuser Coos Bay Area Manager Oscar Weed. Why Oscar and not Ovie or Bob? Perhaps Stu brought Bob something else mission flown. Bob would later give a shotgun that had been passed down in his family to Stu to give to his son, Chris, so that the boy could learn to appreciate hunting, guns, and the outdoors, as he had done with his own children.

My Weyerhaeuser flag Lucite is the one given to Oscar Weed, and came with an attestation from his wife. The only other extant Lucite like mine is on the market accompanied by a certificate of provenance from Phil Waters' son, claiming that the flag traveled to the surface of the Moon. Another case of wishful thinking, of wanting to believe that an artifact is just a little bit better than it is; not lunar-flown but surface-flown. The manifest once again tells the real story.

A report of the Astronauts' elk hunt on the Weyerhaeuser tree farm was published in the August 1969 Field & Stream magazine.

Tents on an old landing were home for three days. In the picture on the right, Harry Morgan (left), senior vice president—wood products, and Coos Bay area manager Oscar Weed laugh at one of many camp jokes.

The Apollo 14 forest connections don't end with the hunt and these flags; Stu's background and the "Moon Trees" also tie Apollo 14 to the woods. The idea of growing trees from seeds taken into orbit around the Moon was first proposed by Edward P. Cliff, then the Chief of the United States Forest Service, who had known Stu Roosa since before his career as an astronaut, when he worked as a smokejumper for the Service. Edward convinced Stu to bring a small canister containing about 500 seeds aboard the Apollo 14 CM, chosen from five species of tree: loblolly pine, sycamore, sweetgum, redwood, and Douglas fir. After the flight, nearly all the seeds germinated successfully, and after a few years, the Forest Service had about 420 seedlings.



C/M

PPK S/N 110

WEIGHT

STU ROOSA

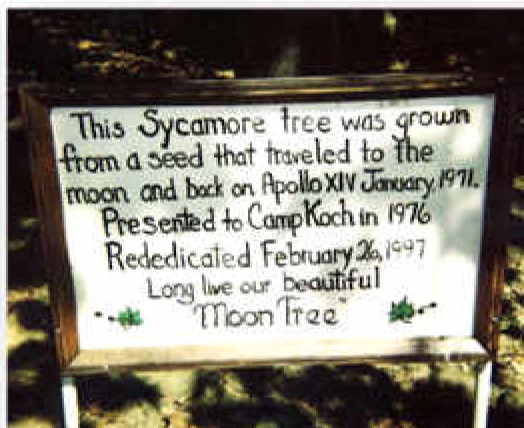
5. (2) Green Weyerhaeuser Flags

Stu Roosa's Command Module PPK manifest

Some of these were planted alongside their Earth-bound counterparts, which were specifically set aside as controls. Soon, there is no discernible difference between the two classes of trees. Most of the Moon trees were given away in 1975 and 1976 to state forestry organizations in order to be planted as part of the nation's bicentennial celebration. Since the trees were all of southern or western species, not all states received trees. A Loblolly Pine was planted at the White House, and trees were planted in Brazil and Switzerland, and presented to Emperor Hirohito among others.

The locations of many trees planted from these seeds were largely unknown for decades. In 1996, a third-grade teacher, Joan Goble, and her students found a tree in their local area with a plaque identifying it as a Moon tree. Goble sent an email to NASA, and reached employee Dave Williams, who was unaware of the trees' existence, as were most of his colleagues. Upon doing some research, Williams found old newspaper clippings describing the initial actions taken by Roosa to bring these seeds to space and home to be planted, and posted on NASA's website asking for public help to find the trees.

Dave began to hear from people around the country who had seen trees with plaques identifying them as Moon trees. Williams began to manage a database listing details about such trees, including their location and species. In 2011, an article in Wired magazine described the effort, and provided Williams' email address, encouraging anyone to write who might have data on existing Moon trees. As of this writing, efforts were continuing to identify and locate existing trees.



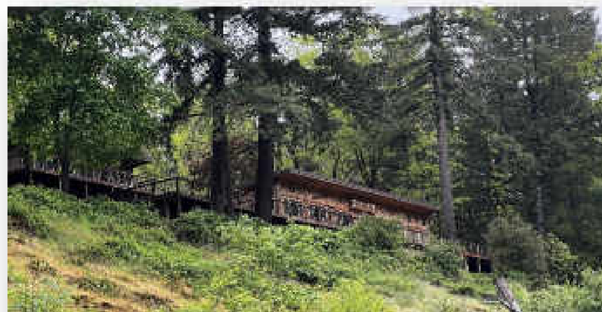
As NASA prepares to return humans to the Moon as part of the Artemis program, understanding the effects of deep space on plant growth is critical – a foundation the Apollo 14 mission helped lay. Astronauts on the Moon and Mars will be too far from Earth for regular resupply missions carrying fresh food, so they must be able to grow their own.

Experiments on the International Space Station are studying the growth of various plants and crops, which could be used as food for spacefaring astronauts.

In November 2020, the Expedition 64 crew harvested a crop of radishes. Other crops grown on the space station include red romaine lettuce, Mizuna mustard greens, and zinnia flowers.

In 2022, NASA revived the Moon tree program. More than 1,000 seeds of five different species of tree were flown 40,000 miles beyond the moon as part of the official flight kit (OFK) on the 26-day uncrewed test flight of the Artemis I Orion spacecraft – which you will find later in this chapter. Upon their return, the seeds were germinated and grown into seedlings Forest Service in preparation for their new roles as Artemis moon trees.

Oregon is insanely beautiful, it's no wonder Stu fell in love with it.



Paradise Lodge.

All future crops grown in space, as they nourish astronauts and feed our continued ambition to explore the cosmos, will have Apollo 14 in their roots. And five decades after the mission that first took seeds to the Moon, the trees that grew from them stand here as grounded, living, leafy testaments to humanity's first voyages beyond the planet that birthed us.

The crew of STS-108 rafted the Rogue River as well.

A sliver of an Apollo 14 Moon Tree is included in my Mini Museum Second Edition, towards the end of this book.

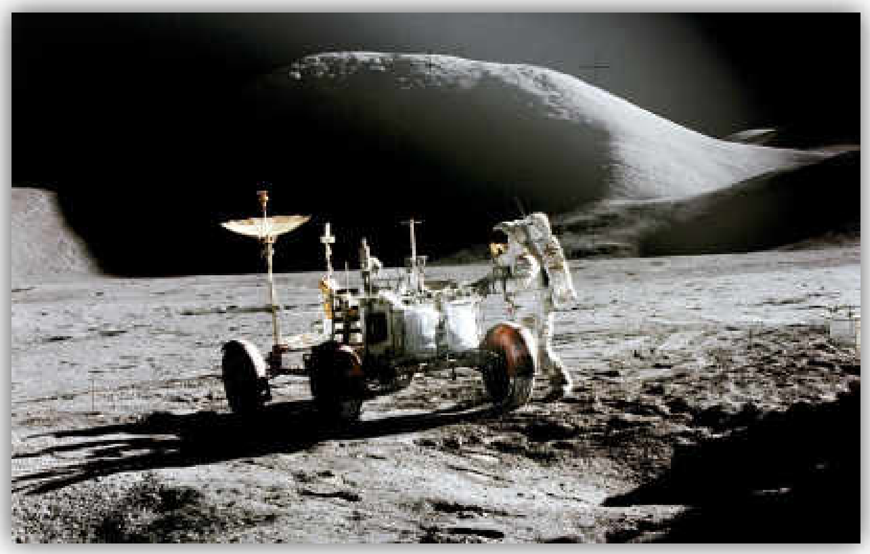
The final connection between Apollo 14 and the wilderness is personal. In May 2024 a small group of us rafted the Rogue River in southern Oregon, at one point staying at the remote Paradise Lodge, only accessible by boat. While attempting to warm up by the stove, imagine my surprise when I spotted a signed picture of Stu Roosa on the wall, dedicated to the lodge's former owner. Though the story is probably lost to time, Stu obviously took the same trip we did, and it was cool to think about sharing the experience. The crew of STS-108, whose picture adorns the same wall, must have felt the same way.

Fallen Astronaut / Man in Space, 1971 & 2019

One crisp March morning in 1969, artist Paul van Hoeydonck was visiting his Manhattan gallery when he stumbled into the middle of a startling conversation. Louise Tolliver Deutschman, the gallery's director, was making an energetic pitch to Dick Waddell, the owner. "Why don't we put a sculpture of Paul's on the moon," she insisted. Before Waddell could reply, van Hoeydonck inserted himself into the exchange: "Are you completely nuts? How would we even do it?" Deutschman stood her ground. "I don't know," she replied, "but I'll figure out a way." She did.

© Callewaert-Vanlangendonck Gallery

At 12:18 a.m. Greenwich Mean Time on Aug. 2, 1971, Commander David Scott of Apollo 15 placed a 3.5-inch-tall aluminum sculpture onto the dusty surface of a small crater near his parked lunar rover. At that moment the moon transformed from an airless ball of rock into the largest exhibition space in the known universe.



Apollo 15 Commander David Scott.

Scott regarded the moment as a tribute to the heroic astronauts and cosmonauts who had given their lives in the space race. Van Hoeydonck was thrilled that his art was pointing the way to a human destiny beyond Earth and expected that he would soon be "bigger than Picasso."

In reality, van Hoeydonck's lunar sculpture, called Fallen Astronaut, inspired not celebration but scandal. Within three years, Waddell's gallery had gone bankrupt. Scott was hounded by a congressional investigation and left NASA on shaky terms. Van Hoeydonck, accused of profiteering from the public space program, retreated to a modest career in his native Belgium. Now both in their 80s, Scott and van Hoeydonck still see

themselves unfairly maligned in blogs and Wikipedia pages – to the extent that Fallen Astronaut is remembered at all.

And yet, the spirit of Fallen Astronaut is more relevant today than ever. Private adventurers are sending robots to the moon; companies such as SpaceX and Virgin Galactic are creating a new for-profit infrastructure of human spaceflight; and David Scott is grooming Brown University undergrads to become the next generation of cosmic adventurers.

Governments come and go, public sentiment waxes and wanes, but the dream of reaching the stars lives on. Fallen Astronaut does, too, hanging eternally 238,000 miles above our heads. The figure represents all space travelers and all mankind. As such it has no ethnic or gender characteristics whatsoever.

© Breckner Gallery/Danny van Hoecke

The statuette's aluminum build enables it to withstand large temperature fluctuations on the moon. Initially, Van Hoeyndonck had it embedded in an acrylic block, only to find out that this material was at risk of burning during flight. Because of that, it did not meet NASA's strict requirements, and the artist had to change his approach. Almost fifty years later, the astronaut figure floats in his original blue acrylic, and was made available in 2019 on the occasion of Apollo 15's 50th anniversary in a limited edition of 1971.

Ad Astra:

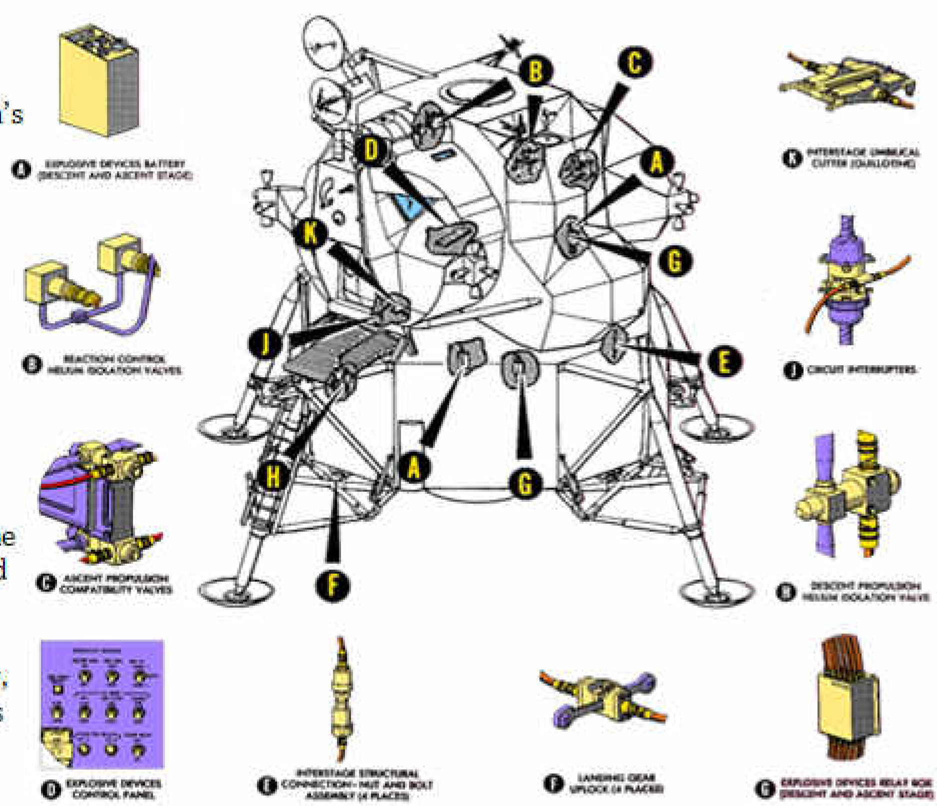
Charles A. Bassett II
Pavel I. Belyayev
Roger B. Chaffee
Georgi Dobrovolsky
Theodore C. Freeman
Yuri A. Gagarin
Edward G. Givens Jr.
Virgil I. Grissom
Vladimir Komarov
Viktor Patsayev
Elliot M. See Jr.
Vladislav Volkov
Edward H. White II,
Clifton C. Williams Jr.

Lucite with Apollo 16 Lunar Surface Flown Pyro System Schematic Piece, 1972

Apollo 16 was the tenth crewed mission in the program, and the fifth and next-to-last to land on the Moon. It was the second of Apollo's "J missions", with an extended stay on the lunar surface, a focus on science, and the use of the Lunar Roving Vehicle (LRV). The landing and exploration were in the Descartes Highlands, a site chosen because scientists expected it to be an area formed by volcanic action, though this proved to not be true.

The mission was crewed by Commander John Young, Lunar Module Pilot Charles Duke and Command Module Pilot Ken Mattingly. Launched on April 16, 1972, Apollo 16 experienced a number of minor glitches en route to the Moon. These culminated with a problem with the spaceship's main engine, resulting in a six-hour delay of the Moon landing as NASA managers contemplated having the astronauts abort the mission and return to Earth. Although they permitted the lunar landing, NASA had the astronauts return from the mission one day early.

After flying the lunar module to the Moon's surface on April 21, Young and Duke spent 71 hours – just under three days – on the lunar surface, during which they conducted three extra-vehicular activities or moonwalks, totaling 20 hours and 14 minutes. The pair drove the lunar rover, the second used on the Moon, for 26.7 kilometers. On the surface, Young and Duke collected 95.8 kilograms of lunar samples for return to Earth, including Big Muley, the largest Moon rock collected during the Apollo missions. During this time Command Module Pilot Mattingly orbited the Moon in the command and service module (CSM), taking photos and operating scientific instruments. Mattingly, in the command module, spent 126 hours and 64 revolutions in lunar orbit.



Pyrotechnic devices were used as actuators throughout the LEM.

Big Muley

After Young and Duke rejoined Mattingly in lunar orbit, the crew released a subsatellite from the service module (SM). During the return voyage, Mattingly performed a one-hour spacewalk to retrieve several film cassettes from the exterior of the service module.

This Lucite contains a piece of Pyro System Schematic taken from the Lunar Module Data Book used aboard the Lunar Module "Orion". From the collection of Charlie Duke.

Lucite with Apollo 16 Lunar Surface Flown Beta Cloth with Moon Dust and Command Module Metal Ring, 1972

Not "just" another lunar surface flown artifact, this artifact actually is lunar surface. The moon has no atmosphere and no water. That means rocks don't erode in the same way as they do on earth. Instead, the moon is continually being bombarded by meteorites and micro meteorites, some the size of a mote of dust, but travelling at tens of thousands of miles per hour. With no atmosphere to stop them, they hit the moon and instantly vaporize the underlying rock. Over the years, the moon has become covered in a fine powder or dust, the result of the continual micro impacts. Some of the sand and dust looks like dark, basaltic lava. Other grains are clearly crystallized minerals of different sorts. Some are tiny sphere-like objects that are formed when a tiny bit of rock vaporizes and cools into a microscopic sphere.

The most unique grains are called agglutinates, colored particles formed when tiny molten droplets bind together pre-existing grains of sand.

This lunar surface flown strap fragment was used in the same Apollo 16 Lunar Module "Orion" as the artifact on the previous page. It also came from the collection of Charlie Duke, from whom Florian Noeller acquired it. The fabric is coated with real lunar dust that can be seen with the naked eye as greyish smudges compared to plain white regular beta cloth, and even better under a microscope where tons of grains are easily visible. I took the microscopic images on the left with an inexpensive consumer device.

Yes, these are actual little bits of the moon. They are my most precious possession and will be until I go collect more myself.

Lunar dust from the Apollo mission as part of a legally obtained artifact is legal to own. Look up the Florian Noeller lawsuit.

The metal ring in the Lucite is from a bungee strap used onboard the command module, from the personal collection of John Young.

30 such acrylics were made.

But there is another part of the Apollo 16 story, and another story about an object left behind on the moon. While Charlie Duke was on the moon, he snapped a photo of a family portrait of him, his two sons, and his wife, which remains on the lunar surface to this day.

On the back of the photo Duke wrote:
"This is the family of astronaut Charlie Duke from planet Earth who landed on the moon on April 20, 1972."

Below is a clearer copy of the photo. On the far left is his oldest son, Charles Duke III, who had just turned seven. In the front in red is his youngest son, Thomas Duke, who was five. Duke and his wife, Dorothy Meade Claiborne, are at the back:

"I'd always planned to leave it on the moon," Duke told an interviewer. "So when I dropped it, it was just to show the kids that I really did leave it on the moon." The photo has since been featured in numerous popular photo books and is a great example of the "human side of space exploration," Duke said.

When Duke was training to be an Apollo astronaut, he spent most of his time in Florida. But his family was stationed in Houston. As a result, the children didn't get to see much of their father during that time. "So just to get the kids excited about what dad was going to do, I said 'Would y'all like to go to the moon with me?'" Duke said. "We can take a picture of the family and so the whole family can go to the moon."

At the time of this writing more than 43 years have passed since Duke walked on the moon. And while the footprints that he made in the lunar soil are relatively unchanged, Duke suspects the photo is not in very good shape at this point. "After 43 years, the temperature of the moon every month goes up to 400 degrees [Fahrenheit] in our landing area and at night it drops to almost absolute zero", Duke said. "Shrink wrap doesn't turn out too well in those temperatures. It looked OK when I dropped it, but I never looked at it again and I would imagine it's all faded out by now."

Unfortunately, there is no way to determine just how faded the photo is because it's too small for lunar satellites to spot. Regardless, the photo "was very meaningful for the family," Duke said. In the end, that's all that matters, right?

Unlike Fallen Astronaut, which is meant as a permanent memorial, this was a beautiful and ephemeral moment in space history.

Lucite with Piece of the Pressure Equalization Valve Decal from the Hatch of the Apollo 17 Command Module "America", 1972

Front. Reverse.

Apollo 17, launched on December 7th, 1972, marked the end of NASA's Apollo program and – for now – the last time humans have set foot on the moon. The mission was notable for many reasons, including being the longest lunar landing mission, the first to include a scientist-astronaut, and the first nighttime launch of a Saturn V rocket.

In command was Eugene A. Cernan, a veteran astronaut who had previously flown on the Gemini 9 and Apollo 10 missions. Cernan was joined by Harrison H. Schmitt, a geologist who became the first scientist to ever walk on the moon, and Ronald E. Evans, who stayed in orbit around the moon while Cernan and Schmitt explored the lunar surface.

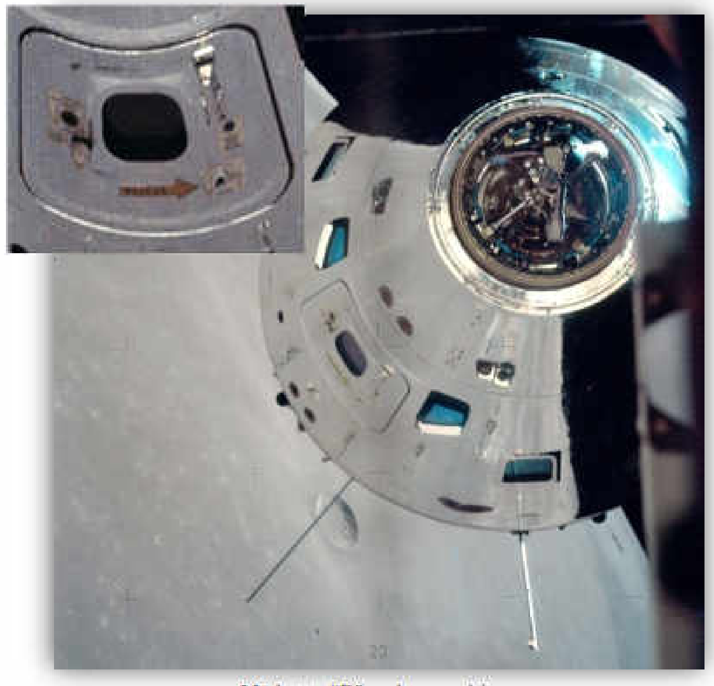
The Apollo 12 Pressure Equalization Valve decal was removed and survived intact, not in my collection.

Apollo 17 was tasked with exploring a region of the moon known as the Taurus-Littrow valley, which had been selected for its geological significance. The lunar module, named Challenger, touched down on the moon's surface on December 11, and Cernan and Schmitt immediately got to work. They spent a total of 22 hours on the lunar surface, conducting experiments, collecting samples, and taking photographs.

"America" aboard the USS Ticonderoga after recovery, still sporting "P", "R", and "E".

One of the most memorable moments of the mission occurred when Cernan and Schmitt discovered a large orange rock that turned out to be a piece of the moon's mantle, the first time such a sample had ever been collected. The astronauts also drove a Lunar Roving Vehicle (LRV) for the third time on the moon, covering a total distance of 35 kilometers.

After the conclusion of their third and final excursion on the surface, Cernan and Schmitt placed all unneeded materials in a bag, and along with the Portable Life Support System backpacks they no longer needed pushed them out the hatch. They had collected 40 more pounds of lunar samples than they expected, and they needed to lighten the LM's load for takeoff. They took photographs through the LM windows of their landing site, now forever altered by their boot prints and Rover tracks. They removed their spacesuits, debriefed the spacewalk with Mission Control, ate dinner, and humans went to sleep for the last time on the lunar surface.



My letter "P" on lunar orbit.

The crew was woken by Mission Control playing "Also Sprach Zarathustra". After a quick – and cold – breakfast, in a brief moment of levity and with the upcoming Christmas holiday in mind, Schmitt radioed to Mission Control the first poem ever read from the surface of the Moon:

My letter "P" on lunar orbit.

"It's the week before Christmas
And all through the LM,
Not a commander was stirring,
Not even Cernan.
The samples were stowed in their places with care,
In hopes that with you, they soon will be there.
And Gene in his hammock and I in my cap,
Had just settled our brains for a short lunar nap.
But up on the comm loop there rose such a clatter,
I sprang from my hammock, to see what was the matter.
The Sun on the breast of the surface below,
Gave the luster of objects, as if in snow.
And what to my wondering eyes should appear,
But a miniature Rover and eight tiny reindeer.
And a little old driver so lively and quick,
I knew in a moment, it must be St. Nick.
I heard him exclaim as over the hills he did speed.
Merry Christmas to all and to you all Godspeed."

Cernan counted down the seconds, and as the count reached zero, Schmitt called out "Ignition", the last word spoken from the Moon. During the three-day voyage home, Evans conducted a deep-space spacewalk to retrieve film cassettes from cameras located in the Scientific Instrument Module (SIM) bay in the spacecraft's Service Module. The astronauts held an inflight press conference to provide their views of the mission for reporters, and prepared their spacecraft for reentry and splashdown.

Apollo 17 after splashdown, decal intact.

Apollo 17 was the sixth and final American mission to the moon, and it left a lasting legacy on both the scientific and cultural communities. The mission was a triumph, and the scientific data collected by the crew has been invaluable in helping us understand the geology and history of the moon.

The most enduring legacy of the Apollo program though is the sense of wonder and inspiration it has provided to generations of people around the world. Cernan's last words as he climbed back into the Lunar Module ("We leave as we came and, God willing, as we shall return, with peace and hope for all mankind"), will finally come true in the next few years as the Artemis program returns us to our celestial neighbor.

Apollo 17 was a remarkable achievement and marked the end of an era in human space exploration. The crew's bravery, dedication, and scientific contributions have been recognized and celebrated for decades, and their legacy continues to inspire new generations of scientists, engineers, and explorers to reach for the stars.

This Lucite is unique, one of three created by a gentleman who, in addition to being a manager at Harrods, served as the UK host or "proctor" for visiting astronauts such as Cernan, Armstong, Aldrin, Collins, and McDivitt. Proctors are unpaid, but a member of the Apollo support staff, probably during a Cernan or Schmit visit, gave our man three decal letters – "PRE" – from the Apollo 17 Command Module that had been removed from the hatch after recovery. The proctor made three Lucites, using one letter in each.

Apollo 8 hatch, subjected to less re-entry and trophy hunting abuse.

He then sold one to a close friend, a respected space model restorer, fellow collector, and Lunar Module expert, from whom it was in turn purchased by me.

One of the unusual aspects of this particular Lucite is that the artifact is encapsulated between two separate blocks rather than being embedded in one solid cast piece, and could therefore be removed for future examination.

"America" at the Johnson Space Center in Houston, missing "P", "R", "E", and part of the first "S". Excuse crappy zoom quality in downloaded picture.

Apollo 18 or 19 Lunar Module Ground Test Equipment Data Plate

After the successful Apollo 11 moon landing in July 1969, public and political interest in moon landings began to wane. The enormous cost of the Apollo program, which at its peak consumed more than 4% of the federal budget, became increasingly difficult to justify. The Vietnam War and domestic programs also demanded significant financial resources, leading to a reallocation of funds away from NASA. Apollo 18, 19, and 20 were all scrubbed in 1970 as part of budget cuts. NASA's focus shifted towards developing space stations in low Earth orbit, a direction that would eventually lead to the Skylab program, the Space Shuttle program, and participation in the International Space Station.

This artifact was intended for one of those canceled missions, and was attached to Ground Support Equipment used to test the Lunar Module (LEM).

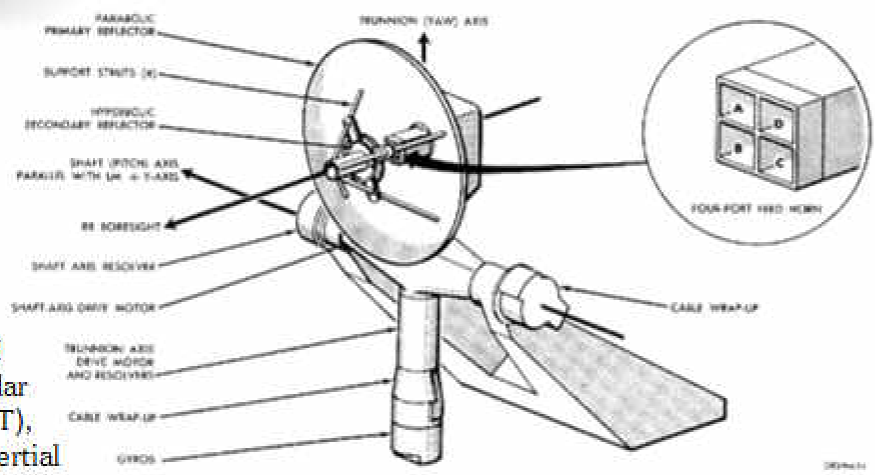


Figure 2.2-24. Rendezvous Radar Antenna Assembly

The primary guidance and navigation section (PGNS) provided all guidance, navigation, autopilot stabilization, and control computations necessary to complete the LEM mission. The PGNS comprised the landing radar (LR), the rendezvous radar/transponder (RR/T), the alignment optical telescope (AOT), the inertial measurement unit (IMU), five coupling data units (CDU's), the LEM guidance computer (LGC), and the power and servo assembly (PSA), which we saw earlier in this chapter.

During descent to the lunar surface, the LR sensed LEM altitude and velocity with respect to the lunar surface. During the coasting, descent, lunar shy, and rendezvous and docking phase of the mission the rendezvous radar (RR) tracked its transponder in the Command Module (CM) to derive range, range rate, and angle rate measurements with respect to inertial space. Using inputs from the LR, the IMU, the rendezvous radar (RR), the thrust translation control assembly (TTCA), the attitude controller assembly (ACA), and manually entered data derived from star sightings with the AOT, the LGC solves the necessary guidance, navigation, steering,

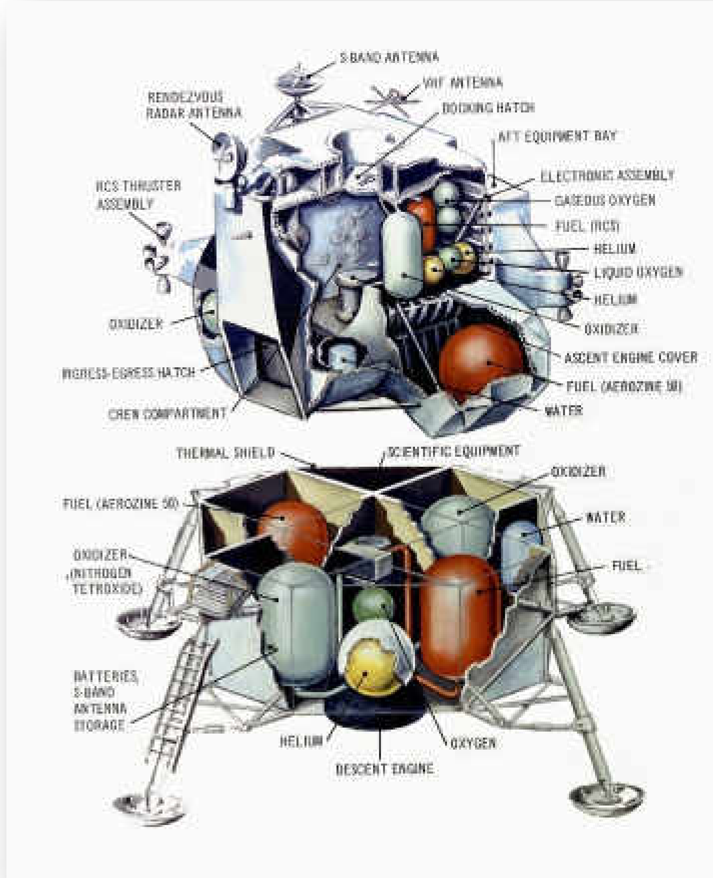
LMA790-1

5-12. RENDEZVOUS RADAR AND LANDING RADAR MICROWAVE CHECKOUT ADAPTER, PART NO. 410-310-30.

The rendezvous radar and landing radar microwave checkout adapter (MCA), controlled by the Radar Section Checkout Station (RSCS), couples and routes microwave signals to the radar equipment during system checkout. The MCA is connected to the other radar section checkout adapters. The solenoid-operated waveguide switches and attenuators of the MCA are controlled by the RSCS to couple landing radar transmitter outputs from the landing radar checkout adapter to the RSCS for special display and measurement, to couple rendezvous radar transmitter outputs to the RSCS for measurement and provide receiver stimuli to check the rendezvous radar modes, and to couple rendezvous radar transmitter outputs directly to the corresponding transponder and transmit the transponder output to the receiver during RR/T compatibility tests.

and stabilization equations to initiate engine-on and engine-off commands for the descent and ascent engines, throttle commands and trim commands for the descent engine, and thruster-on and thruster-off commands for the selected Reaction Control Subsystem (RCS) jets.

During ground testing of the LEM, a hat was placed over the microwave radar antennas which allowed outputs to be read at the Radar Section Checkout Station.

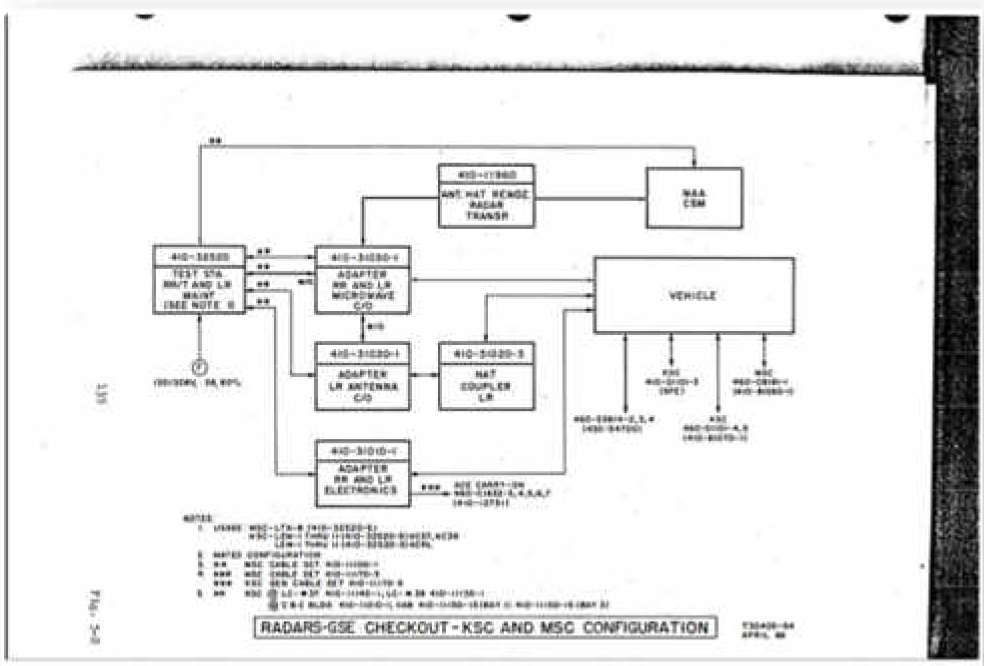


Antenna hat.
© *RR Auction*

The adapter (note the spelling error on the data plate, these were very common) which this plate belonged to allowed those signals to be properly captured and routed for performance and compatibility testing.

In existing Apollo LEM documentation, this part is referred to with number LDW410-31030. My data plate carries a part number of LDW410-31121, indicating it was intended for a later mission. I don't have enough knowledge about the contract numbers to determine if it was 18 or 19.

As for the other hardware that was built for these canceled missions, the remaining Saturn V rockets initially intended for Apollo 18, 19, and 20 were repurposed or displayed in museums. One of the Saturn V rockets was used to launch the Skylab space station into orbit in 1973. Some of the Lunar Modules built for the canceled missions were used for testing or training purposes. Others are on display in museums across the United States. Like the Lunar Modules, some CSMs were repurposed for other missions, such as the Apollo-Soyuz Test Project in 1975.



Lucite with Skylab Oxygen Tank Fragment Recovered after Re-Entry, 1973 – 1979

Skylab was the very first space station for the US, made largely out of leftover Apollo hardware, and was a steppingstone for the International Space Station. Skylab was launched in 1973 and was occupied for nearly 24 weeks between May of 1973 and February 1974. Unable to be re-boosted into a more sustainable orbit by the Space Shuttle, which was not ready until 1981, Skylab's orbit decayed, and on July 11, 1979, it disintegrated in the atmosphere. The debris was strewn across the Indian Ocean and Western Australia.

The target NASA had been trying to hit is a place known as Point Nemo, 3,000 miles off the coast of New Zealand and 2,000 miles north of Antarctica. Point Nemo is so far from land that the closest humans are often the astronauts on board the ISS orbiting 227 nautical miles above Earth. It's this remoteness that explains why the ISS, once it's retired in 2030, will end its days here, plummeting to Earth to join other decommissioned space stations, satellites and assorted space debris. Welcome to the world's space graveyard.

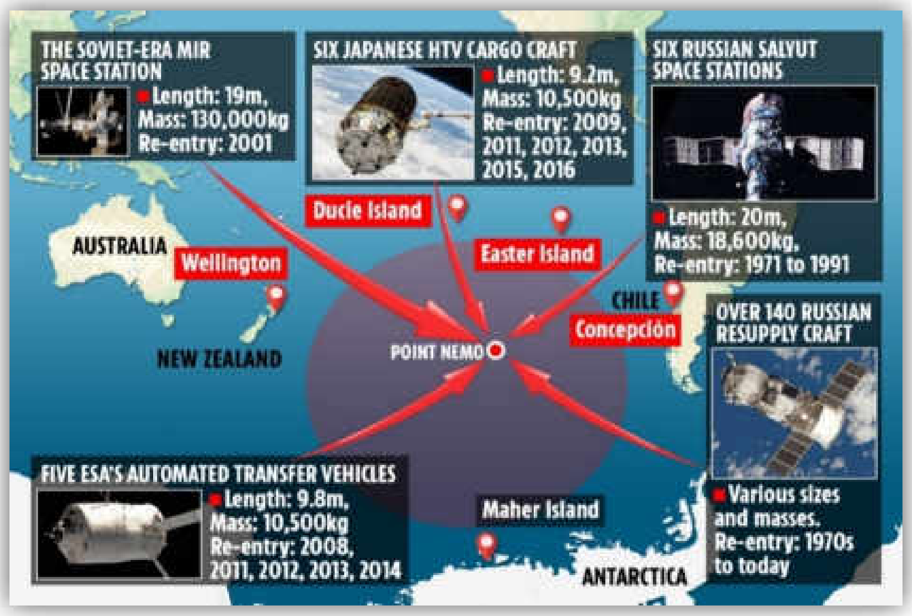
Spacefaring nations have been dumping their junk in the area around Point Nemo, named after Captain Nemo from Jules Verne's novel "Twenty Thousand Leagues Under the Sea", since the 1970s.

Also known as the Oceanic Pole of Inaccessibility or South Pacific Ocean Uninhabited Area, the exact coordinates of the world's most remote spot were calculated by Canadian-Russian engineer Hrvoje Lukatela in 1992.

More than 263 pieces of space debris have been sunk in this area since 1971, including Russia's Mir space station and most of NASA's first space station Skylab – at least the portion that did not rain down on Australia – according to a 2019 study.

A tank in the bush.

They're not intact monuments to the history of space travel but are likely fragmented debris scattered over a large area. Note the six Japanese HTV cargo craft in the graphic, we will encounter one later in this chapter.



© The Sun

"This is the largest ocean area without any islands. It is just the safest area where the long fall-out zone of debris after a re-entry fits into", said Holger Krag, Head of the Space Safety Program Office at the European Space Agency. Point Nemo is beyond any state's jurisdiction and is devoid of any human life – although it's not free from the traces of human impact. In addition to the space junk on the seafloor, microplastic particles and trash were discovered in the waters when yachts in the Volvo Ocean Race passed through the region in 2018.

Space junk such as old satellites reenter the Earth's atmosphere on a daily basis, although most of it goes unnoticed because it burns up long before it can hit the ground.

It's only larger space debris - such as spacecraft and rocket parts - that pose a very small risk to humans and infrastructure on the ground. Space agencies and operators must plan well in advance to ensure that it falls to Earth in this far-flung bit of ocean.

In the case of the International Space Station, NASA said the ISS will begin maneuvers to prepare for deorbit as early as 2026, lowering the altitude of the space lab, with it expected to crash back to Earth in 2031. The exact timings of the maneuvers depend on the solar cycle activity and its effect on Earth's atmosphere.


This is also headed to Point Nemo.

I like that this artifact mimics the shape of the ground observations being made from Skylab.


Point Nemo.

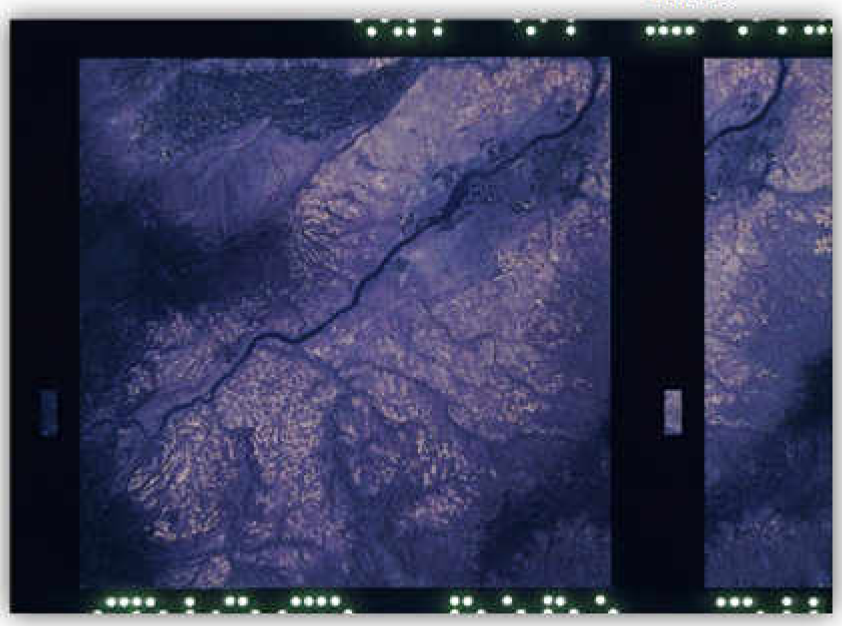
Lucite with 70mm Frame from Skylab 3 (SL3-22-96), 1973

Skylab's mission was to "Look at Earth, take measurements, and decide how man can improve life thereon".

This artifact contains a frame of onboard photography, showing Southern Washington and northern Oregon, including the Columbia River, Yakima Valley, The Dalles, and a little part of Mount Hood.

NASA Photo ID	SL3-22-096
Focal Length	152mm
Date taken	1973.08.04
Time taken	17:16:21 GMT
Camera	Skylab Multispectral (S190A)
Camera Tilt	0 degrees
Format: SO356:	Unknown SkyLab

Image of the same frame from an online NASA photo archive.

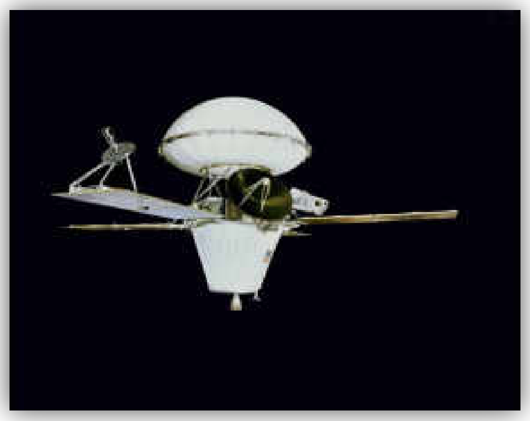


Spacecraft nadir point	45.6° N, 120.3° W
Photo center point	45.6° N, 120.3° W
Nadir to Photo Center	0
Spacecraft Altitude	239 nautical miles

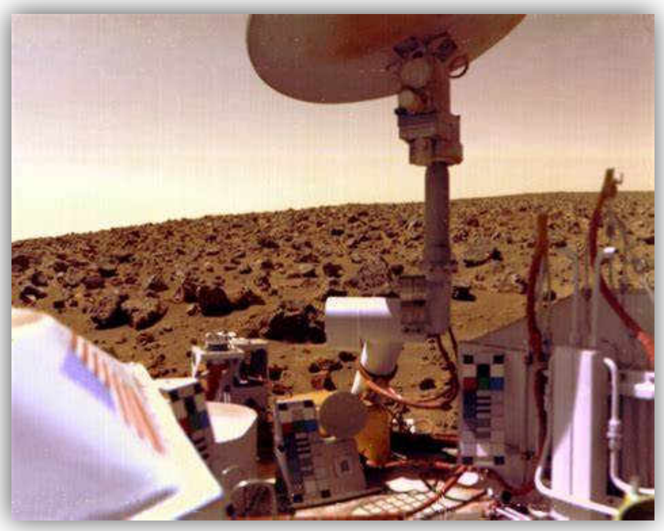
Lucite with Unflown (Obviously) Material Shavings from the Viking Mars Landers, 1976

NASA's Viking Project found a place in history when it became the first U.S. mission to land a spacecraft safely on the surface of Mars and return images of the surface. Two identical spacecraft, each consisting of a lander and an orbiter, were built. Each orbiter-lander pair flew together and entered Mars orbit; the landers then separated and descended to the planet's surface. The Viking 1 lander touched down on the western slope of Chryse Planitia (the Plain s of Gold), while the Viking 2 lander settled down at Utopia Planitia.

Besides taking photographs and collecting other science data on the Martian surface, the two landers conducted three biology experiments designed to look for possible signs of life. These experiments discovered unexpected and enigmatic chemical activity in the Martian soil, but provided no clear evidence for the presence of living microorganisms in soil near the landing sites. According to scientists, Mars is self-sterilizing. They believe the combination of solar ultraviolet radiation that saturates the surface, the extreme dryness of the soil and the oxidizing nature of the soil chemistry prevent the formation of living organisms in the Martian soil.



The Viking mission was planned to continue for 90 days after landing. Each orbiter and lander operated far beyond its design lifetime. Viking Orbiter 1 continued for four years and 1,489 orbits of Mars, concluding its mission August 7, 1980, while Viking Orbiter 2 functioned until July 25, 1978. Because of the variations in available sunlight, both landers were powered by radioisotope thermoelectric generators – devices that create electricity from heat given off by the natural decay of plutonium, discussed elsewhere.



First Mars selfie, note the camera calibration marks at the base of the antenna mast.

That power source allowed long-term science investigations that otherwise would not have been possible. Viking Lander 1 made its final transmission to Earth on November 11, 1982. The last data from Viking Lander 2 arrived at Earth on April 11, 1980.

This cylindrical paperweight contains two shavings from the manufacture of 1976 Viking lander 1 or 2. This memento was produced by Martin Marietta.

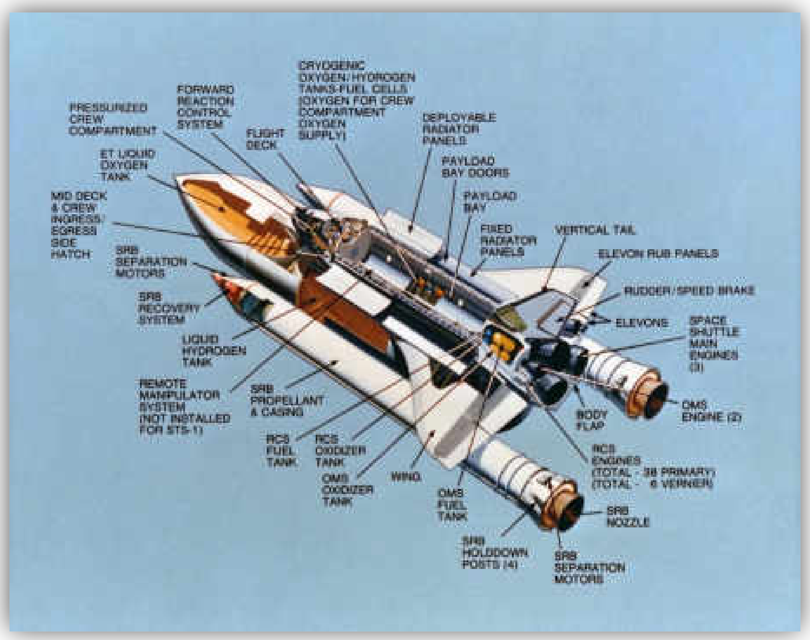
Lucite with STS-1 (First Space Shuttle Mission) Flown Thermal Insulation Tile, 1981

Early 1981 was an eventful time in U.S. history. On the day of the inauguration of Ronald Reagan as the country's 40th president, 52 American hostages were released from captivity in Iran. Blondie and Hall and Oates blared from the stereos of Oldsmobile Cutlasses. The Oakland Raiders won the Super Bowl. The new president was shot outside a Washington, DC, hotel. The voice of the Apollo program on television, Walter Cronkite, retired from hosting CBS Evening News. MTV was gearing up for a summer launch that would change the landscape of cable television. An exciting new action film, Raiders of the Lost Ark, loomed as a summer blockbuster. The country was a scant few months from finally having a woman seated on the Supreme Court. Popular culture, politics, and technology were amidst dramatic changes when a March 19, 1981, test of the Space Shuttle Columbia again threatened to delay the dawn of a new phase of human spaceflight.

Looking majestic on the launchpad. Note the white external tank, this paint job was omitted on later flights to save weight

The reusable spaceplane, the Space Shuttle, embarked on a maiden voyage with the launch of STS-1 on April 12, 1981, after a 7-year hiatus in American manned spaceflight. Commanded by space veteran and moonwalker John Young and piloted by Robert Crippen, the launch slipped two years from its originally scheduled launch in 1979 because of problems with its powerful engines and the fragile thermal protection system. The delays and concerns meant that the first launch would be the first full test of the Space Transportation System, the completely assembled unit of solid rocket boosters, external tank, and orbiter.

This was truly a new beginning for spaceflight and NASA, with the realization of a decades-old dream of a reusable spaceplane that could deploy large objects from a payload bay, serve as a scientific base for orbital research, and open up space to new professionals and industries interested in the unique offerings of low-Earth orbit for science and technology.



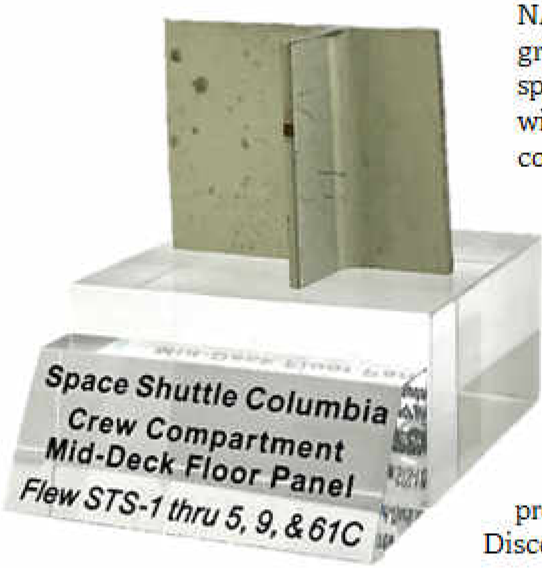
STS-1 coincided with the anniversary of another first in spaceflight, launching twenty years to the day after Yuri Gagarin's mission that made him the first human to fly in space. But the Space Shuttle program was on an entirely different technological level from Gagarin's single orbit in a tiny capsule. After 20 years, rockets and spacecraft were viewed by many as expensive, disposable, and lacking the capacity for real science and technology research. They were not the path to develop lasting in-space capabilities for humans. As the first of several test flights for the shuttle, STS-1 offered NASA a preview of the program in terms of successes and difficulties.

Young and Crippen had room to spare in the spacious crew compartment. The flight deck included aircraft-like seats for them both with windows forward, overhead, and into the payload bay to make visual observations. The mid-deck offered plenty of storage and space for sleeping, but the space only reached its full intended potential on later missions as science experiments and crewmembers were added. To make space for their seats, panels were removed from the mid-deck, a small piece of one is pictured on the next page.

Despite those positives, STS-1 also indicated the troubles ahead: Crippen noticed foam loss from the external tank during launch and missing thermal tiles, both of which later contributed to the loss of Columbia and her crew during STS-107 in 2003. Other damage over the two-day mission, approximately 70 problems both foreseen and underestimated in potential effect by engineers, meant Columbia required numerous repairs before the next planned mission could launch and prove the reusability of the orbiter.

STS-1 commander John W. Young, left, and pilot Robert L. Crippen.

Sadly, not every problem seen on the first mission would ever be solved entirely, making the risks of the system deeply disconcerting to many but never forcing a full cancelation of the program before it completed a plethora of scientific and technical goals, but also led to the loss of fourteen astronauts.



Section of Columbia floor panel removed after STS-61C to make room for extra crew seating, also in my collection.

NASA's ambitions for the vehicle were inflated by a desire to achieve great things, but also preserve a waning sense of enthusiasm for spaceflight mined over a decade earlier. When many adults who witnessed moon landings as children moved on to more grown-up concerns over the economy or politics, something dynamic could capture the attention of a new generation. In that respect, the program was largely successful. Gen X, born from 1965 to 1980, bore witness to the entirety of the Space Shuttle's roller coaster trajectory over 30 years and 135 missions.

We were crushed as young people to see the Challenger tragedy live, celebrated an American hero's return to space when we were young adults (John Glenn on STS-95 in 1998), and devastated again just a few years later with the loss of Columbia. By the shuttle program's end in 2011 we could relish seeing the remaining fleet; Discovery, Atlantis, and Endeavour complete the International Space Station.

There is a beautiful and moving memorial to the crews of Challenger and Columbia on their last flights at the Kennedy Space Center. The picture on the right shows the recovered flight deck windows from Columbia.

Richard E. Gray, to whom this memento was presented, was the prime television chase plane pilot following Columbia home as she returned safely from her maiden voyage. The following year, Dick was tragically killed at 37, when his T-37B jet aircraft crashed after entering a spin while making a proficiency flight.

Columbia coming home, with Dick Gray following.

Richard E. Gray at Dryden Flight Research Center, 1982.

Lucite Presentation with Soviet Cosmos 1403 Flown Solar Battery Cell, 1982

This flown solar battery cell from the Cosmos 1403 satellite, returned to the USSR in 1982, was presented to cosmonaut Andriyan Nikolayev, who retired that same year. The battery cell is engraved in gold writing “To Andrey Grigorievich from the collective. Kusta 1403” Dated 09/24/782. The plate above the engraving says “Solar Battery” and lists Rated Voltage and Output Power, as well as declaring it was Made in USSR.

The other side of the display.

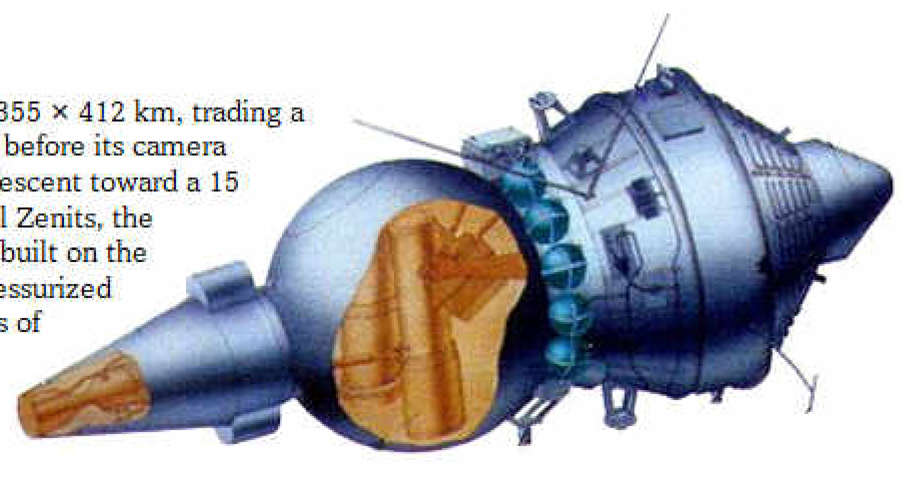
Zenit was a series of military photoreconnaissance satellites launched by the Soviet Union between 1961 and 1994. The basic design of the Zenit satellites was similar to the Vostok crewed spacecraft, sharing the return and service modules. The satellite weighed roughly 6.3 tons and the total length in orbit was a little over 16 ft, with a spherical re-entry capsule 7.5 ft in diameter with a mass of around 2.5 tons. The. This capsule contained the reusable camera system, its film, recovery beacons, parachutes and a destruct charge. In orbit, this was attached to a service module that contained batteries, electronic equipment, an orientation system and a liquid fueled rocket engine that would slow the Zenit for re-entry, before the service module detached. Most Zenits flew in a slightly elliptical orbit with a perigee of around 120 miles and an apogee between 160 and 220 miles; the missions usually lasted between 8 and 15 days.

Back side of the cells.

Cosmos 1403 was a Zenit-6-class satellite launched from Baikonur on 1 September 1982 atop a Soyuz-U booster. The spacecraft, catalogued as 1982-085A, entered an initial 208 × 356 km orbit inclined 70 degrees – typical for Zenits that needed high-latitude coverage of North America, Europe, and China.

The display opened, showing the solar cells themselves.

Over the first day it was trimmed to about 355 × 412 km, trading a little image sharpness for longer orbital life before its camera packages began the deliberate two-week descent toward a 15 September recovery in Kazakhstan. Like all Zenits, the satellite weighed roughly 6.3 tons and was built on the proven Vostok manned-capsule shape: a pressurized return module carrying thousands of meters of 70-mm film, attitude-control gyros, and a recoverable camera cluster, mated to an expendable service section holding propellant and solar-orienting panels, a segment of which is inside this display.



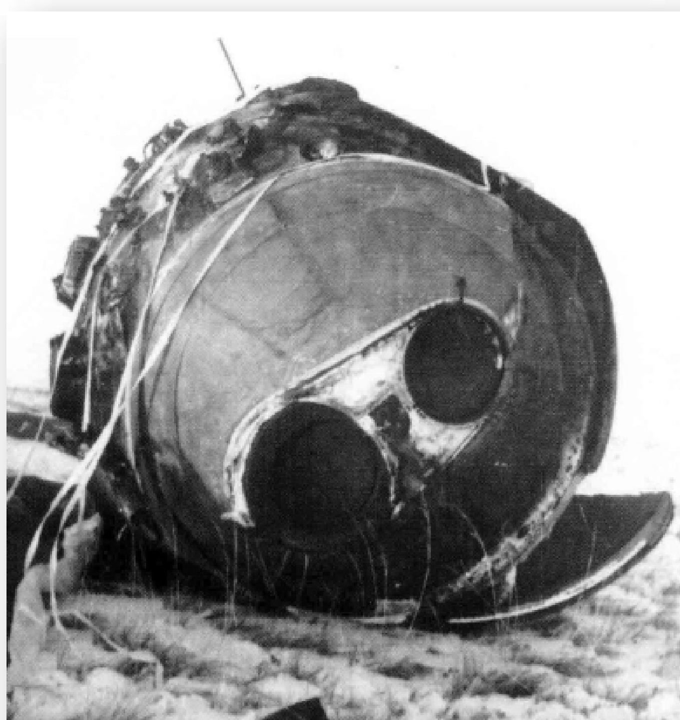
Zenit-6 Cutaway
Credit: TsSKB

Preserved in a museum, presumably unflown.

In 1982 the Cold War's temperature was rising again. The Soviet invasion of Afghanistan had dragged into its third year; martial law in Poland had just entered its ninth month; and the Reagan administration was accelerating deployment of Pershing II missiles and BGM-109G cruise missiles in Western Europe.

Both blocs depended on space reconnaissance not only for tactical warning but for arms-control diplomacy: although the unratified SALT II treaty was on life support, Moscow and Washington still exchanged accusatory notes citing "national technical means" of verification. Where the United States had already fielded near-real-time electro-optical KH-11 satellites, the USSR continued to rely on film-return craft like Cosmos 1403; their orbital perigee – at first a low 208 km – signaled a push for the best resolution the Zenit optics could deliver, probably on the order of half a meter. (As Soviet manuals noted, "image quality is inversely proportional to perigee altitude.")

The Argon-coded payload (GRAU index 11F645) carried both a high-resolution narrow-angle camera and a lower-resolution wide-angle mapper, allowing analysts to locate NATO armor concentrations in West



Soviet and Russian spacecraft come down hard sometimes, like this Zenit-6U.

Germany one pass and revisit missile-test ranges in the Pacific the next. After each exposure a strip of film was automatically processed, dried, and wound into a light-tight cassette inside the descent capsule. Near the end of the 14-day mission, small solid-propellant retro-motors braked the return module, which re-entered over Siberia protected by an ablative shield derived from the Vostok heat-shield recipe. A parachute unfurled at about 5 km altitude; a recovery beacon on 19.990 MHz guided Soviet Il-14 search aircraft to the landing zone; and Spetsnaz troops secured the canister for rail shipment to the imagery labs at Krasnogorsk.

Cosmos 1403 was one entry in a steady drumbeat of Zenit flights – roughly three per month – that kept the Kremlin supplied with fresh photography during a particularly uneasy year. While the West watched Yuri Andropov replace the ailing Leonid Brezhnev that November, satellites like 1403 documented American carrier groups in the Arabian Sea, Pakistani supply corridors into Afghanistan, and the Pershing dispersal sites being surveyed in the forests of West Germany. The mission underlined both the strengths and limitations of Soviet space surveillance: excellent optical quality, but a built-in 10- to 15-day latency while the film crossed half a continent by rail. That lag would eventually drive t he USSR to field its own electro-optical Yantar-4KS1 in 1984, yet in 1982 the sturdy, camera-equipped Zenit remained the workhorse – one that still bore the unmistakable silhouette of Gagarin's Vostok even as it peered down on a world bracing for Able Archer '83 and the next chill in East–West relations.

The recipient of this handsome display, containing solar cells from Cosmos 1403, was Andriyan Grigoryevich Nikolayev. Nikolayev was born on September 5, 1929, in the Chuvash Autonomous Soviet Socialist Republic, and would be the third cosmonaut to orbit the Earth, following Yuri Gagarin and Gherman Titov. Before enrolling in a group of cosmonauts, Andriyan Grigorievich Nikolaev for 3 years worked as a logging master of the Yuzhkarelles trust in the Derevyanskiy Lespromkhoz, and as an air gunner. Nikolaev made two space flights, piloting Vostok 3 as it flew in formation with Vostok 4, and as commander of Soyuz 9. In 1982, Nikolaev was expelled from the cosmonaut group with the retention of the post of first deputy head of the CPC.

Notably, Nikolayev was married to Valentina Tereshkova, the first woman in space, and to this day the only solo female space traveler. They were married in November 1963, shortly after Tereshkova's historic spaceflight, in a highly publicized event. The couple had a daughter, Elena Andriyanovna Nikolaeva-Tereshkova, born in 1964. Elena was notable for being the first person in the world both of whose parents had flown in space. Presumably he somehow disgraced himself either with the party or through alcoholism; Nikolayev and Tereshkova divorced in 1982 shortly after his "retirement" as a cosmonaut, at which time he was presented with this award. According to her, he was "difficult".

Valentina Tereshkova

Replica Pepsi Can from Coke Wars in Space, 1985

When Coca-Cola first reached out to NASA with the idea of testing a soda dispenser in space, it marked the beginning of an slightly frivolous challenge: creating a can that could function in the microgravity of Earth's orbit. Traditional soda cans and bottles, which rely on gravity, were unsuitable for space. Coca-Cola's solution involved investing approximately $250,000 in designing a can that contained a laminated plastic bag of soda and a pressurized bladder of carbon dioxide to expel the drink on demand, thus preventing any mess in the cabin.

Upon learning of Coca-Cola's space mission, Pepsi promptly sought NASA's permission to participate. NASA agreed, with the condition that Pepsi could prepare a dispenser in time. Pepsi's response was a redesigned can, based on technology that originally cost $14 million to develop. This can used a carbon dioxide-filled pouch activated by chemicals to propel the soda, resembling the mechanics behind spray cheese or whipped cream dispensers but with a simpler, less sophisticated design.

NASA, keen to minimize the perception of commercialism in the space mission, dubbed the project the "Carbonated Beverage Container Evaluation" and scheduled it as a secondary activity during the STS-51F mission. The mission's goal was primarily focused on advancing solar, atmospheric, and astrophysical studies.

Payload Specialist Loren Acton.

Rules were established pre-launch: only two astronauts would taste test the beverages from four cans provided by each company, avoiding any taste comparisons. Despite some initial reluctance due to the overt commercial aspect, the crew agreed, focusing on the cans' functionality rather than the soda taste.

The Pepsi can, albeit designed in haste, delivered its soda in a frothier state compared to Coca-Cola's, leading to playful experiments with fizzy Pepsi balls among the astronauts. The major issue was the beverage being evaluated, said astronaut Tony England, and its ability to bring on "wet burps". "The problem was with carbonated beverages. When you open a bottle on Earth, the bubbles come up and they leave. Well, as you can imagine, if there's no gravity, the bubbles don't come up," he said. "So here you are with his stomach full of carbonated beverage, with the gasses kind of comfortably staying there."

Mission Specialist Karl G. Henize.

The STS-51F crew held the results of the carbonated beverage container evaluation private until their first post-flight press conference on Aug. 14, 1985, a week after they had landed back on Earth. The evaluation concluded that both cans functioned well, dispensing the beverages without issue, despite the sodas being at room temperature.

Coca-Cola claimed a symbolic victory in this "space cola war" by being the first soft drink tasted in space, and both companies celebrated their achievement by partnering with educational organizations. Pepsi and Coca-Cola each produced replicas of their space cans, with Pepsi supporting the Young Astronauts organization and Coca-Cola collaborating with U.S. Space Camp.

The Smithsonian National Air and Space Museum in Washington, D.C., displays both the Coca-Cola and Pepsi cans, commemorating this unique venture into making carbonated beverages accessible in space. Pepsi's space can did not fly again, though the company did launch an oversize inflatable can (of the style used on Earth) to film a commercial aboard the Russian space station Mir in 1996.

Coca-Cola continued trying to develop a drink for the astronauts. In 1991, it flew its STS-51F-style can to Mir to similar results. The company then changed its approach, launching two versions of a dispensing machine ("Fluids Generic Bioprocessing Apparatus"), which could be used to fill either a pressurized cup or bottle with a choice of different Coca-Cola carbonated beverages, on STS-63 in 1995 and STS-77 the following year.

Since then, both soft drinks have remained Earthbound other than a fictional Coke commercial from 2014 which was not actually filmed in space. Perhaps the introduction of Space Doritos and the attendant actually-filmed-in-space commercial, later in this chapter, will motivate them to try again.

Lucite with STS-36 Flown Thermal Insulation Tile, 1990

On 28 February 1990, the orbiter Atlantis and her STS-36 crew – Commander John "J.O." Creighton, Pilot John Casper, and Mission Specialists Mike Mullane, Dave Hilmers, and Pierre Thuot – rocketed into orbit on the 34th mission of the Space Shuttle program, for four days of activities on behalf of the Department of Defense. During that short period of time, the astronauts deployed a classified payload, known at the time as Air Force Program (AFP)-731, but more commonly known under the program name "Misty," whose exact details even today continue to mystify. Atlantis performed a "dogleg" maneuver during ascent to reach the highest inclination (62 degrees) ever achieved by a U.S. human space mission.

The Misty low observables spacecraft program was initially justified on the basis that it would help the Reagan Administration catch the USSR cheating on arms control. The Misty satellite is believed to have been derived from the "Keyhole" KH-11 (the latter being very similar to the Hubble Space Telescope), but modified to make it invisible to radar, and harder to detect visually. The U.S. believed at the time, correctly or not, that the Soviets hadn't recognized this as a photoreconnaissance satellite – until an ex-CIA employee named William Kampiles sold them the operators manual. Misty allowed the United States to peek into some buildings at the anti-ballistic missile testing range at Sary Shagan that had been invisible when the earlier Keyhole satellites went overhead.

The general enthusiasm for nuclear war fighting programs of the early 1980s might have been of equal or greater importance than the desire to enforce arms control. Such programs as the B-2 stealth bomber, Continuity of Government, and the formation of the DDX/K Group strategic counter-C3 at NSA all occurred at around that time, and were all characterized by the same ultra-blackness as the ZIRCONIC programs – which included the Misty spacecraft. It may also have been argued that Misty would give the U.S. a survivable Trans-SIOP reconnaissance capability. I don't know what that is.

This Lucite contains a 1" x 1" piece of flown HRSI thermal protective tile from Space Shuttle Atlantis. The tile piece was removed after the STS-36 classified DoD mission and encased in Lucite by United Space Alliance (USA), presented to VIPs as a token of appreciation.

There are no known pictures of a Misty satellite.

A KH-12 Keyhole reconnaissance satellite.
© *Charles P. Vick*

Lucite with ESA Solar Cells Flown on the Hubble Space Telescope, 1991 – 1993

When Galileo Galilei first turned a spyglass to the heavens in 1610, he had trouble making out the rings of Saturn that are visible in inexpensive telescopes today. Advances in optics eventually improved scientists' views of the planets, stars and distant galaxies, but Earth's atmosphere still blocked or distorted much of the light for observers on the ground. Larger telescopes were, and still are, placed atop mountains, where the thinner atmosphere at higher elevations allows clearer pictures.

In 1946, soon after World War II, astronomer Lyman Spitzer proposed launching a space telescope, which could overcome the limitations of ground-based observatories. It took a couple more decades before the idea garnered enough support for the U.S. National Academy of Sciences to organize a committee of scientists to evaluate the potential of a "Large Space Telescope". With Spitzer at the helm, the committee published a document in 1969 that outlined the scientific uses of a Large Space Telescope and advocated for its construction, according to a Hubble history written by Gabriel Olkoski for NASA.

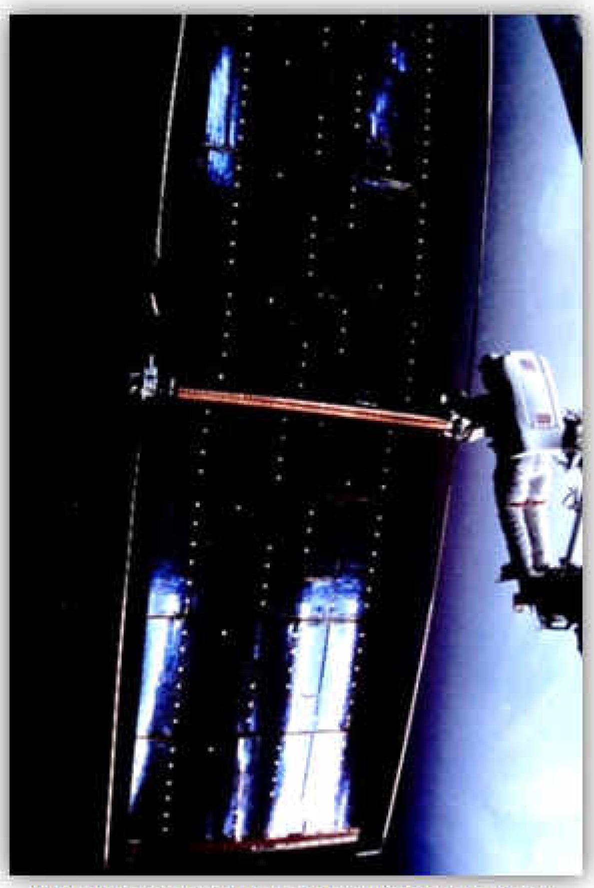
The National Academy of Sciences took the pitch to NASA – the only agency capable of making the Large Space Telescope a reality. NASA was already considering a space telescope of some type, but the agency was undecided about how big to make it and where to start. In 1971, George Low, the agency's acting administrator at the time, greenlit the Large Space Telescope Science Steering Group, and NASA soon began lobbying Congress for funding for the endeavor.

The expensive project was a tough sell, and funding was initially denied by the House Appropriations Subcommittee in 1975. NASA then upped its lobbying efforts and got buy-in from European Space Agency, which shared the costs. Congress eventually granted funding for NASA's portion of the Large Space Telescope in 1977. Development began almost immediately.

NASA planned to launch the telescope in 1983, but various production delays pushed the launch date back to 1986. In the meantime, the Large Space Telescope was renamed Hubble in honor of Edwin Hubble, an American astronomer who, among other things, determined that the universe extended beyond the borders of the Milky Way. Hubble's planned liftoff was delayed again after the space shuttle Challenger exploded a minute after takeoff on

January 28, 1986, killing all seven astronauts on board. It was more than 2.5 years before shuttle flights resumed and NASA could begin planning Hubble's launch again.

Hubble finally launched aboard the space shuttle Discovery mission STS-31 on April 24, 1990, and a day later was deployed into low Earth orbit, about 340 miles (545 kilometers) above our planet. Getting Hubble developed and launched cost $1.5 billion, but there would be ongoing costs as well – both expected and unexpected.



Most of the replaced solar panel material was jettisoned.

Initial instruments on Hubble included the Wide Field Planetary Camera, the Goddard High Resolution Spectrograph (GHRS), the Faint Object Camera (FOC), the Faint Object Spectrograph (FOS) and the High Speed Photometer. Hubble experienced equipment issues right off the bat. For example, the telescope's first images came back so blurry that they were close to useless scientifically. It turned out that Hubble's 7.9-foot-wide (2.4 meters) main mirror had a defect – a spherical aberration caused by a manufacturing error. The flaw was minute, at just 1/50th the thickness of a sheet of paper, but that was big enough to cause major imaging problems.

Hubble became a laughingstock, the butt of jokes that spread through popular culture. For instance, the 1991 film "Naked Gun 2 1/2: The Smell of Fear" features a photo of Hubble. It appears on the wall of an establishment called Loser's Bar, along with pictures of the Hindenburg, the 1906 San Francisco earthquake, the Ford Edsel and other famous disasters.

But all was not lost, for Hubble was designed to be serviced by astronauts. On Dec. 2, 1993, the space shuttle Endeavour ferried a crew of seven to fix Hubble during five days of spacewalks. Two new cameras, including the Wide-Field Planetary Camera 2 (WFPC-2), which later took many of Hubble's most famous photos, were installed during the fix. In December 1993, the first new images from Hubble reached Earth, and they were breathtaking.

The Pillars of Creation.

Spacewalking astronauts repaired, maintained and upgraded Hubble on four additional servicing missions, which took place in February 1997, December 1999, March 2002 and May 2009. The 1997 mission replaced some failed or degraded hardware and installed two new instruments, the Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer. The new instruments, which replaced the GHRS and FOS, extended Hubble's vision into the near-infrared wavelength range, NASA officials wrote in a mission explainer.

The next astronaut visit was originally intended to be a relatively routine maintenance trip that lifted off in June 2000. But the fourth of Hubble's orientation-maintaining gyroscopes failed in November 1999, sending the observatory into a protective "safe mode". (Hubble has six gyros but needs at least three functioning to collect science data.) In response, NASA revised its servicing mission plans, splitting the next one into two parts, the first launching in December 1999.


A cool bipolar nebula.

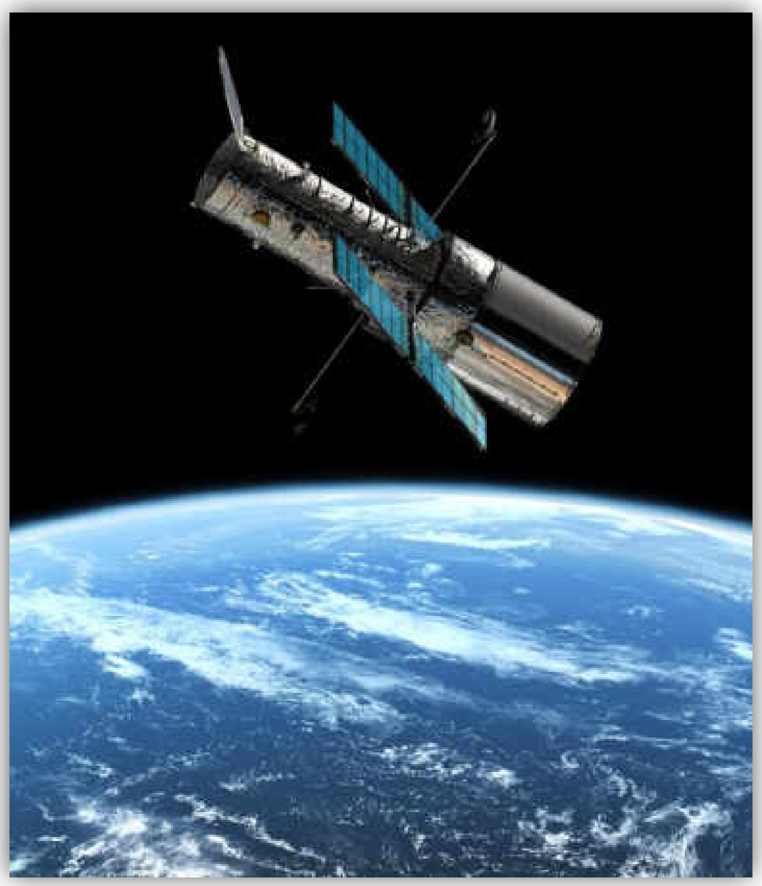
On that 10-day mission, astronauts replaced all of Hubble's gyros, as well as one of its three fine guidance sensors, and performed other maintenance work as well.

The next crewed Hubble visit, known as Servicing Mission 3B (following from 1999's Servicing Mission 3A), occurred in December 2002. During that 11-day trip, "astronauts replaced Hubble's solar panels and installed the Advanced Camera for Surveys (ACS), which took the place of Hubble's Faint Object Camera, the telescope's last original instrument", NASA officials wrote in the mission explainer. They also brought solar panel material back to Earth for inspection, some of which is contained in this artifact.

Like Hubble's launch, the fifth and final servicing mission was delayed by tragedy – the February 2003 breakup of Columbia during its reentry to Earth's atmosphere, which killed all seven astronauts on board. That accident ended up pushing the mission back from its initial 2005 target date to May 2009. During the flight, astronauts put in new batteries and gyroscopes and installed new instruments, the Cosmic Origins Spectrograph and the Wide Field Camera 3. Among other tasks, the spacewalkers also revived the ACS and STIS which had both failed. "With these efforts, Hubble was brought to the apex of its scientific capabilities", NASA officials wrote. Ever since, Hubble has continued to provide unprecedented information about our universe and inspire curious minds around the world. STS-61 was the first Hubble servicing mission, and the fifth flight of the Space Shuttle Endeavour.


Arp 273.

This Lucite contains a piece of Dutch-made solar array retrieved from Hubble and returned to Earth.



Cassette Tape Flown on STS-76, 6 Months Aboard Mir, and on STS-79 with Shannon Lucid, 1996

On March 22, 1996, 53-year-old Shannon Lucid, a member of NASA's original class of women astronauts and a veteran of four previous space missions, lifted off from Kennedy Space Center aboard the space shuttle Atlantis, which transported her to the ten-year-old Russian space station Mir. There, she joined Russian astronauts Yuri Onufrienko and Yuri Usachev for what was to be a five-month research mission, but which turned into a record-breaking 188-day stay in space, the longest ever by an American. Lucid would circle the Earth more than 3,000 times, covering 75 million miles, before returning home on September 26, 1996. A down-to-earth mother of three, Lucid likened day-to-day life on Mir to "living in a camper in the back of your pickup with your kids… when it's raining and no one can get out".

The daughter of a Baptist minister and a missionary nurse, J. Oscar Wells and Myrtle Wells, Lucid was born in war-torn China in 1943. When she was just six months old, she and her parents were interned in a Japanese prison camp for a year.

Oscar and Myrtle kept their daughter alive by feeding her their daily ration of rice, but almost starved to death themselves. The family was eventually turned over to U.S. officials in exchange for Japanese POWs, and remained in the United States until the end of the war, when they returned to China. When the Communists took over in 1949, they again returned to the United States, settling permanently in Bethany, OK, where Oscar embarked on a career as a tent evangelist.

As a youngster, Lucid was fascinated with American frontier history and its pioneering spirit. A biography of rocket pioneer Robert Goddard inspired her to be a space explorer. "People thought I was crazy, because that was long before America had a space program," she said. After graduating as salutatorian of her high school, Lucid earned a B.S. in chemistry from the University of Oklahoma. She also earned her pilot's license and purchased an old Piper Clipper, in which she occasionally flew her father to revival meetings. "The Baptists wouldn't let women preach," she said, "so I had to become an astronaut to get closer to God than my father."

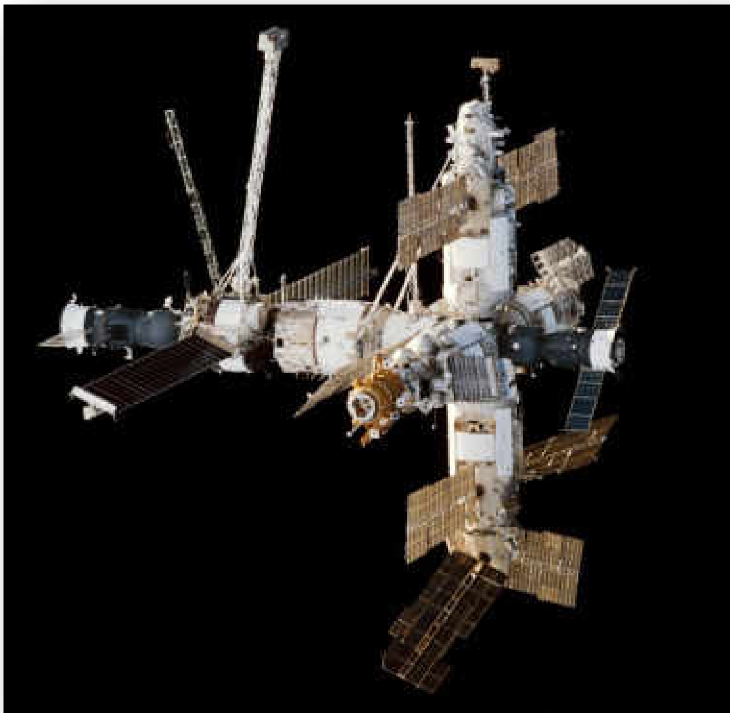
Signed Newsweek cover,
also in my collection.

Space Station Mir itself was a survivor too, enduring 15 years in orbit, three times its planned lifetime. It outlasted the Soviet Union that launched it into space. It hosted scores of crewmembers and international visitors. It raised the first crop of wheat to be grown from seed to seed in outer space. It was the scene of joyous reunions, feats of courage, moments of panic, and months of grim determination. It suffered dangerous fires, a nearly catastrophic collision, and darkened periods of out-of-control tumbling.

Mir soared as a symbol of Russia's past space glories and her potential future as a leader in space, but – like most legends – was controversial and paradoxical. At different times and by different people, Mir was called both "venerable" and "derelict". It was also "robust", "accident-prone", and "a marvel", as well as "a lemon".

The cosmonauts and astronauts fortunate enough to travel to Mir were always impressed by its appearance. Regardless, Mir remained difficult to describe. Someone once called Mir a 100-ton Tinker Toy. Adding modules over the years, and then sometimes rearranging them, the Russians had built the strangest, biggest structure ever seen in outer space. Traveling at an average speed of 17,885 mph, the space station orbited about 250 miles above the Earth. Mir was both great and graceful – and incongruous and awkward – all at the same time.

In outward appearance, some modules were relatively new additions and looked it – sporting shiny gold foil, bleached-white solar blankets, and unmarred thruster pods. Others showed their age. Solar blankets were yellowed and looked as drab as a Moscow winter, and were pockmarked with raggedy holes, the result of losing battles with micrometeorite and debris strikes over the years.



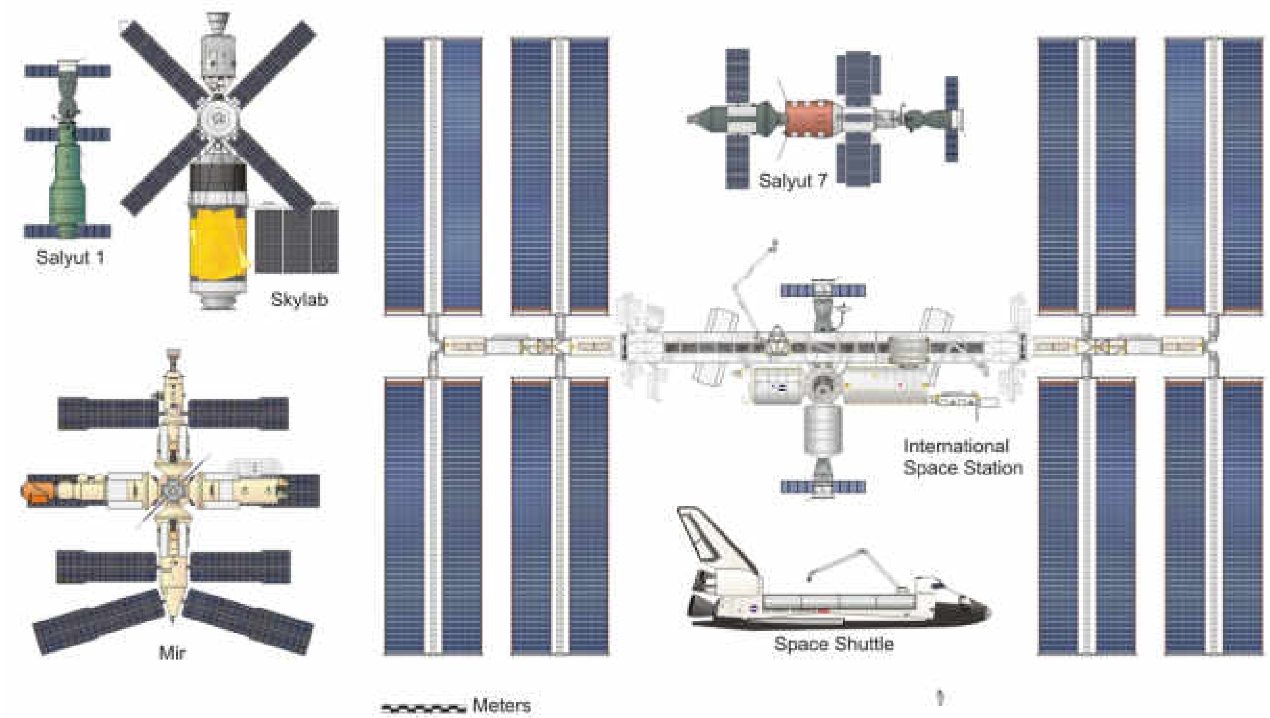
On the inside, Mir often surprised people, too, even when they thought they were ready. By the time Shannon Lucid arrived on Mir the station had become cluttered with used up and broken equipment and floating bags of trash. No adequate remedy was ever developed to deal with the stowage situation. Mir looked like a metal rabbit warren, or, as Mike Foale put it, “a bit like a frat house, but more organized and better looked after”.

Still, Mir was home and shelter to its crews, and how it looked to them depended on their perspectives and situations. The ivory-like controls of the Base Block reminded David Wolf of classic science-fiction stories, such as The Time Machine, by H.G. Wells.

After a fly-around in the cramped Soyuz capsule, Jerry Linenger wrote: “Looking into the station I could see a lone ray of light shining through the port widow and outlining the dining table. We had left some food out for dinner. It was the only time during my stay in space that Mir looked warm, inviting, and spacious. It reminded me of opening the door to a summer cottage that been boarded up for the winter, looking inside, and seeing familiar surroundings.”

Shannon’s tape could be somewhere on the right!

The Russians’ investment had begun when a Soviet Proton launcher boosted Mir’s Base Block into orbit on February 20, 1986. This module resembled the existing Salyut-7 space station, but Mir’s design called for expansion through the addition of future modules. Mir’s first crew arrived in mid-March 1986. In 1987, the Soviets added Mir’s first expansion module, Kvant-1, creating the world’s first modular space station. Mir continued to expand during the next years with the additions of modules for research and residence.



International Space Station included for scale. ISS construction did not begin until 1998, so it did not exist yet at the time of Lucid's stay aboard Mir.
© *Richard Kruse*

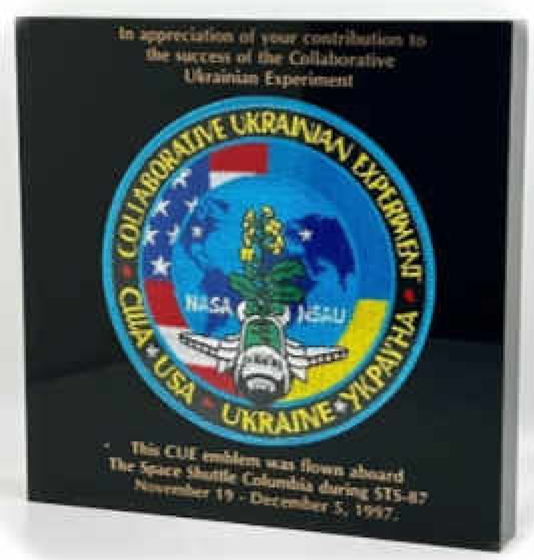
After the Russian space station moved into its second decade, the Mir became notorious as an accident-prone spacecraft, even as it remained in continuous service. Failures of the Elektron electrolysis oxygen-generating units and problems with attitude and environmental controls often seemed to alternate with computer malfunctions and power outages. On June 29, 1995, U.S. Space Shuttles began docking with the Russian space station. The next year, on April 23, 1996, the final module, the Priroda, was added to the Mir. A 15-minute fire in an oxygen generating device imperiled the station in February 1997, and in June 1997 a collision with a Progress supply vehicle breached the integrity of the Spektr's hull, rendering that module uninhabitable.

Looking a little battered towards the end.

Alas, the sturdy Mir was literally built on a sinking foundation. Without repeated boostings, all things in low Earth orbit must eventually come down. With the new International Space Station requiring much of the Russian space program's attention and financing, the Mir was doomed to be deorbited. A strong effort rallied in Russia to keep Mir aloft including an attempt to privatize and rehabilitate the station, an artifact from which appears a few pages later in this chapter.

However, on December 30, 2000, Russian Prime Minister Mikhail Kasyanov would sign a resolution calling for Mir to be sunk into the ocean, early in 2001. After more than 86,000 total orbits, Mir re-entered Earth's atmosphere on Friday, March 23, 2001, at 9 a.m. Moscow time. The 134-ton space structure broke up over the southern Pacific Ocean. Some of its larger pieces blazed harmlessly into the sea, about 1,800 miles east of New Zealand. Observers in Fiji reported spectacular gold-and-white streaming lights. An amazing saga and a highly successful program finally had come to a watery end.

Lucite with STS-87 Flown Collaborative Ukrainian Experiment Patch, 1997



In 1994, U.S. President Clinton and President Kuchma of Ukraine signed an agreement to support joint activities in space. NASA and the National Space Agency of Ukraine (NSAU) subsequently planned to collaborate on a Space Shuttle mission.


Leonid Kadenyuk.

STS-87, Nov 19, 1997 – Dec 5, 1997, was the 24th flight of the Space Shuttle Columbia and the 88th flight of the Space Shuttle Program. The orbiter crew included Commander Kevin R. Kregel, Pilot Steven W. Linsey, Mission Specialists Winston E. Scott, Kalpana Chawla, and Takao Doi, and the first Ukrainian astronaut, Payload Specialist Leonid K. Kadenyuk.

Life sciences payloads on this mission included the Collaborative Ukrainian Experiment (CUE), a collection of ten space biology plant experiments on topics ranging from the effects of micrograving on amino acid structuring to the susceptibility of plants to fungal pathogens in space. The primary objective of these experiments was to discover what developmental events during plant reproduction fail to function normally in microgravity. A secondary objective was to compare pollination and fertilization processes in microgravity with ground controls. Over 600,000 students in both the United States and the Ukraine performed experiments similar to those performed in space by the Ukrainian Cosmonaut.

Columbia touched down at KSC on December 5, 1997. Less than six years later, in February 2003, she disintegrated upon reentry, killing the seven-member crew of STS-107 and destroying most of the scientific payloads aboard. This crew included Kalpana Chawla, fellow crew member on STS-87 – and the first Indian woman to go into space. The loss of Columbia and its crew led to a refocusing of NASA's human exploration programs and led to the eventual retirement of the Space Shuttle program.

One of Ukraine's other claims to space fame was the world's largest plane, known as the Antonov An-225 Mriya, which was destroyed at Hostomel Airport near Kyiv, Ukraine in late February 2022. The An-225 was unique due to its massive size and was originally designed to transport the Soviet space shuttle Buran. It was repurposed for commercial use after the Soviet Union's collapse, capable of carrying oversized cargo incomparable to any other aircraft. The aircraft was in a hangar when the area came under attack, leading to catastrophic damage to the plane. The An-225 held several records, including those for carrying the heaviest cargo load and the longest cargo item ever transported by air.


Mriya carrying Buran.


Kalpana Chawla.

Lucite with Multilayer Insulation Flown on the Hubble Space Telescope 1991 – 1999

Scheduled for June 2000, the third mission to the Hubble Space Telescope (STS-103) was originally planned to carry out preventive repairs. However, urgency to address the failure of Hubble's third gyroscope led NASA managers to split SM3 into two parts (SM3A and SM3B), scheduling an early servicing mission (SM3A) for December 1999.

The unexpected failure of the fourth of Hubble's six gyroscopes on 13 November 1999, with SM3A already planned, caused NASA to place Hubble into safe mode. Unable to conduct science without at least three working gyros, Hubble went into a sort of protective hibernation until 19 December 1999, when a crew of astronauts aboard the Discovery Space Shuttle flew to its rescue and replaced all the gyroscopes.

Tim Lorenzano worked in Facilities Management at Goddard.

I visited Discovery at the NASM's Udvar-Hazy Center.

Since the second Servicing Mission in February 1997, three of the gyroscopes had failed and caused some concern among NASA officials. Additionally, NASA deemed necessary the replacement of one of Hubble's three Fine Guidance Sensors (FGS). Both devices are part of Hubble's advanced pointing control system, and as such, they keep the telescope steady during observations. During the 8-day flight, astronauts conducted several other crucial servicing and upgrading tasks, which involved the installation of several other instruments.

I bought this Lucite containing Multilayer Insulation (MLI) material flown on Hubble for more than 8 years from Tim & Lu Lorenzano. Tim worked at Goddard, and they later generously sent me the little shuttle award, a bunch of photos and mission patches, a big framed award presentation with amazing photos, and other cool stuff.

Some of the gifts Tim & Lu Lorenzano sent me.

Lucite with Flown Soyuz TM-30 (Mir EO-28) Heat Plug, 2000

Soyuz TM-30 (Russian: Союз TM-30, Union TM-30), also known as Mir EO-28, was a Soyuz mission between April 4 and June 16, 2000, and was the 39th and final human spaceflight to the Mir space station. The crew of the mission was sent by MirCorp, a privately funded company, to reactivate and repair the station. The crew also resupplied the station and boosted the station to an orbit with a low point (perigee) of 360 and a high point (apogee) of 378 kilometers (223 and 235 miles, respectively); the boost in the station's orbit was done by utilizing the engines of the Progress M1-1 and M1-2 spacecraft. At that time a transit between Mir and the International Space Station was already impossible – such a transfer was deemed undesired by NASA – and the orbital plane of ISS had been chosen some time before to be around 120 degrees away from that of Mir.

The mission was the first privately funded mission to a space station, and was part of an effort by MirCorp to refurbish and privatize the aging Mir space station, which was nearing the end of its operational life. Further commercially funded missions beyond Soyuz TM-30 were originally planned to continue the restoration efforts of the then 14-year-old space station, but insufficient funding and investment ultimately led to the de-orbit and fiery death of the station in early 2001, shown below.

Although the mission was scheduled to last only two months, commander Sergei Zalyotin said before the flight that if additional funds became available the mission could be extended. The other possible scenario, which occurred in reality, was again to leave the station uninhabited, as had been done before the mission. Actor Vladimir Steklov trained and was initially assigned for a 2000 flight on Soyuz TM-30 to film scenes for the movie "Thiefs and Prostitutes. Spaceflight is the Prize on Mir." [*sic*] The plans were scrapped weeks before launch due to lack of funding, and space scenes were filmed in studio instead.

The text on this artifact reads: "ELEMENT OF SPACE SHIP SOYUZ TM-30 MIR EO-28"

It is a large flown threaded heatshield plug removed post-flight from the Soyuz TM-30 spacecraft, which flew the final flight to the Russian MIR Space Station. The surface shows charring from the intense heat of re-entry. Marked on back side with Soyuz spacecraft No. 204 for TM-30 mission.

Reverse.

Huge Flown Koutonori / HII-B Fairing Segment, 2009

Japan's Mitsubishi HII-B rocket and automated Kounotori H-II Transfer Vehicle (HTV) have played a significant role in supporting and developing the International Space Station, which we will see in the next article, by delivering supplies, equipment, and experiments. This includes both pressurized cargo for the crew and unpressurized cargo for external experiments and station hardware, essential for maintaining the ISS's operations, supporting its crew, and facilitating ongoing scientific research.

Like the ISS itself, the HTV missions, contributed by the Japan Aerospace Exploration Agency (JAXA), demonstrate successful collaboration between countries in space. Beyond delivering supplies and experiments, HTV missions have carried important components for the maintenance and upgrade of the ISS's systems and infrastructure, including batteries for the station's power system, spare parts, and new equipment to enhance the station's capabilities and extend its operational life.

The HTV, also called Kounotori (こうのとり or "white stork"), is an expendable, automated cargo spacecraft used to resupply the Kibō Japanese Experiment Module (JEM) and the International Space Station (ISS). JAXA has been working on the design since the early 1990s. The first mission, HTV-1, was originally intended to be launched in 2001. It finally launched eight years later at 17:01 UTC on 10 September 2009 on an H-IIB launch vehicle.

The name Kounotori was chosen because "a white stork carries an image of conveying an important thing (a baby, happiness, and other joyful things), therefore, it precisely expresses the HTV's mission to transport essential materials to the ISS". After the retirement of the Space Shuttle the HTV is the only vehicle that can transfernew 105 cm wide International Standard Payload Racks (ISPRs).

After unloading its cargo, the HTV vehicle is loaded with waste materials from the ISS, which are then safely burned up in the Earth's atmosphere upon re-entry. This disposal capability is crucial for managing the accumulation of waste on the station and ensuring a clean and safe living environment for the crew.

This Lucite box contains a huge 20x14x4cm chunk of HII-B payload fairing. It was flown on the third mission, Kounotori 3 / HTV-3, which launched on July 21, 2012. It's large enough to see the curvature, which would make the fairing about as big around as my office.

Lucite with STS-130 / ISS 20A Flown Hardware, 2010

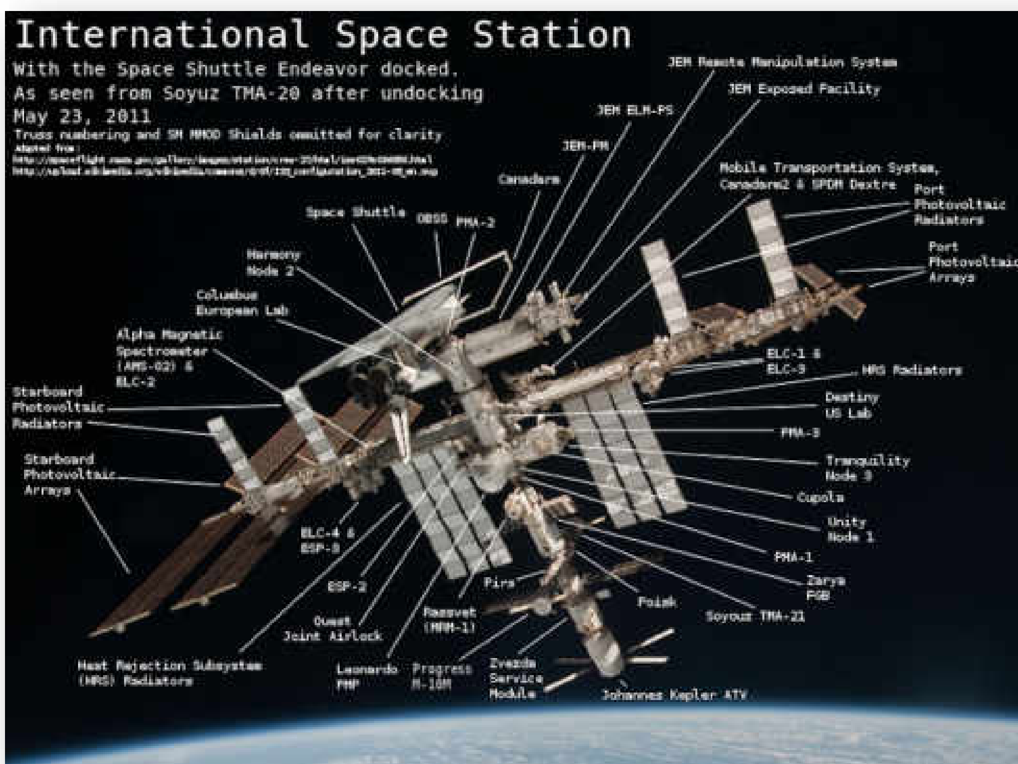
Born of hard-won experience on both sides of the old Iron Curtain, the International Space Station is a 450-tonne research outpost circling Earth every ninety minutes at roughly the same altitude once patrolled by Russia's Mir. Mir, occupied from 1986 to 2001, proved that modular spacecraft could be assembled in orbit and sustained for more than a decade; its Soyuz lifeboats, Progress tankers, and expandable solar wings became working templates for the ISS. Shuttle–Mir dockings in the 1990s let NASA rehearse long-duration missions, cross-train crews, and refine the rendezvous software later used to guide U.S. modules into their places on the ISS truss. When Washington and Moscow agreed in 1993 to build a single station, Mir's pressurized docking node, photovoltaic arrays, and relentless supply chain of Progress freighters were folded into the baseline design.

Closeup.

Even today the ISS's Russian segment retains Mir's layout of living quarters forward and propulsion aft, while the U.S. segment reflects Mir's lesson that redundancy – two life-support loops, two power buses, two escape vehicles – keeps a crew safe through solar storms, debris alerts, and the inevitable snags of orbital construction.

Space Shuttle Endeavour's STS-130 flight in February 2010 was the last major assembly run for the U.S. segment, delivering the Tranquility node and the European-built Cupola. Cupola rode to orbit bolted to Tranquility's forward hatch, its seven fused-silica windows hidden behind an aluminum launch cover.

After docking, pilot Terry Virts used the shuttle's Canadarm to berth Tranquility on Unity's port side; then he and Kathryn Hire executed a delicate arm-to-arm hand-off, freeing Cupola from its launch mount and planting it on Tranquility's Earth-facing port. The relocation looked straightforward on paper but triggered a chain of practical problems that left mission controllers cataloguing a loose screw and – most unusually – one partly rebuilt Extravehicular Mobility Unit.



Hours before the first spacewalk, a power-harness continuity test in Bob Behnken's suit failed. The crew had three EMUs on board: two earmarked for flight and one spare. To keep the EVA timeline intact they scavenged the good harness from the spare, then resized that spare torso and limb set for Nick Patrick, who stood nearly a head taller than Behnken. In the Quest airlock the astronauts popped torso-disconnect rings, swapped hard-upper-torso shells, and rejiggered sizing inserts – a modularity feature that lets technicians tailor an EMU by up to eight centimeters. The ad-hoc tailoring worked; Patrick slipped into the refurbished suit and joined Behnken outside less than a day behind schedule. Ten years later Behnken would again don an EMU, floating outside the station during SpaceX Crew Demo-2 – the flight that opened commercial crew transport to the ISS and beyond.

During three EVAs the pair removed launch-lock saddles, drove sixteen quarter-turn bolts to free Cupola, hooked up ammonia cooling lines and installed a pan-tilt-zoom camera beside the new windowed outpost. One launch-lock screw made an unexpected hop when the torque gun slipped; it bounced off a handrail and drifted down the starboard truss, a three-gram fleck of stainless steel destined to burn up within days. Cupola's relocation almost stalled when two berthing bolts balked, but ground engineers walked Virts and Hire through a back-off-and-re-drive routine that seated them firmly.

In the grasp of the station's Canadarm2, the Tranquility module is transferred from its stowage position in space shuttle Endeavour's payload bay to position it on the port side of the Unity node of the International Space Station. Tranquility was locked in place with 16 remotely-controlled bolts.

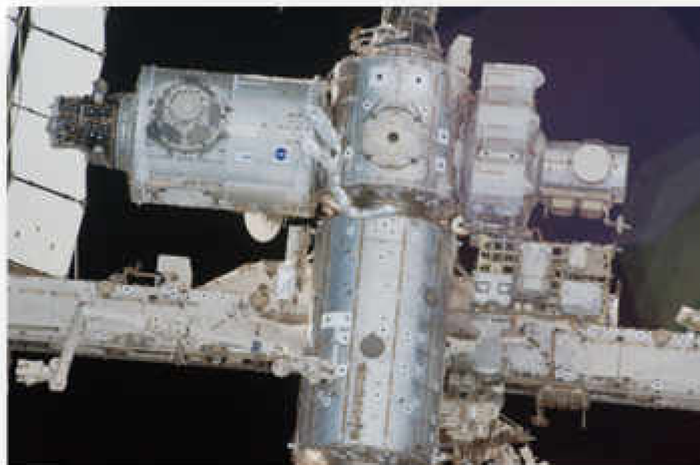
Relocation of the cupola to Tranquility's Earth-facing port.

Patrick released the launch cover, Virts swung open Cupola's hatch, and the first view through its circular center pane revealed the ochre ridges of the Sahara sliding eastward five miles below – a payoff for a week spent coaxing balky fittings, worn harnesses, and temperamental bolts. Endeavour undocked on 19 February, leaving Tranquility humming on its ammonia loops and Cupola's shutters cycling each orbit to guard against micrometeoroids.

During the mission's third spacewalk, Nicholas Patrick, Left, and Robert Behnken remove thermal blankets from the cupola.

Today Cupola is the station's most photographed workspace; its robotics console has guided hundreds of Canadarm2 operations, and its windows host a continuous parade of Earth-observation cameras. Somewhere in a NASA warehouse an EMU torso bears the penciled note "STS-130 resize complete." They are reminders that grand orbital projects succeed because crews improvise fixes, tailor spacesuits on the fly, and keep pushing ahead. Bob Behnken would keep pushing, returning to the station a decade later not by shuttle, but atop a Falcon 9.

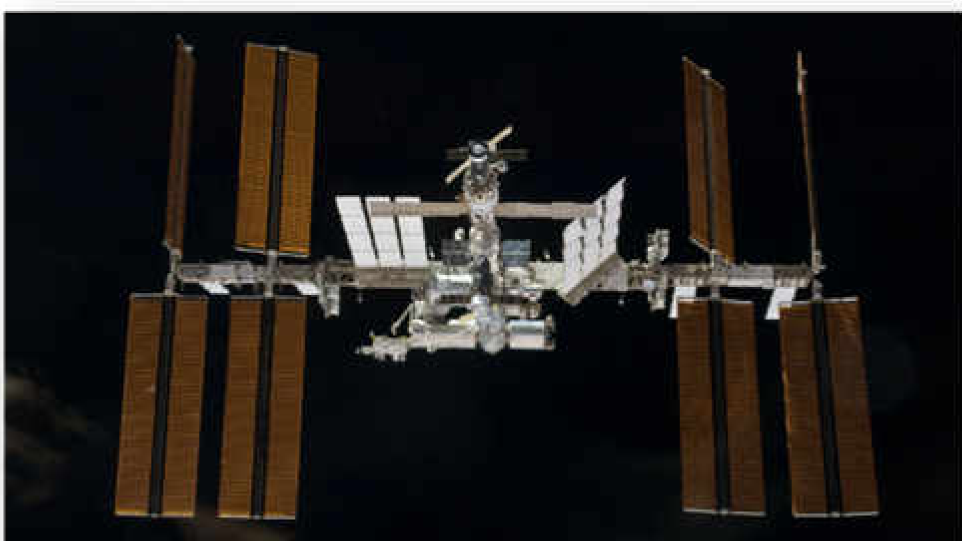
I am not sure what exactly the piece of fabric and the screw in this artifact are. It's fun to think they're remnants from all the MacGyvering, but I am no expert in spacesuit fabrics. I tried reaching out to Michael Suffredini, whose signature adorns this object, to determine their nature, but Mr. Suffredini moved on from ISS Program Manager to become a co-founder and CEO of Axiom Space, who aim to build the first commercial space station. As such I am sure he's a busy guy, and he did not respond.



This image photographed by an STS-130 crew member on space shuttle Endeavour after undocking shows the newly-installed Tranquility node and Cupola at top left.

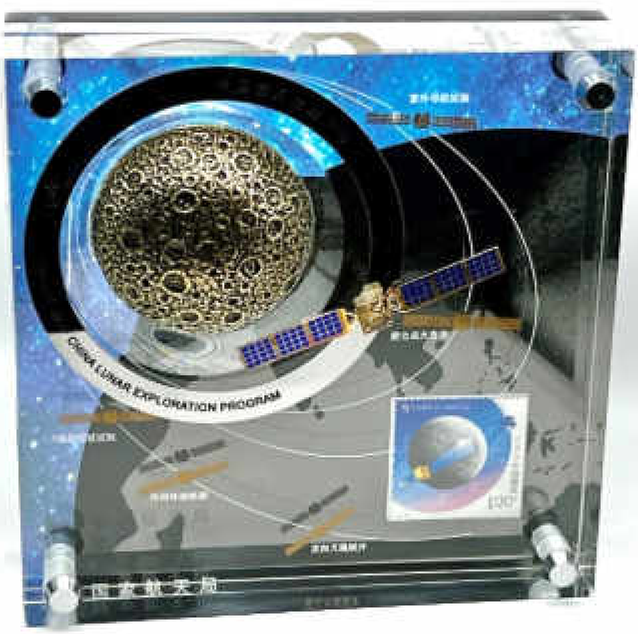
Terry Virts, left, and Jeffery Williams in the cupola after opening the micrometeoroid shields for the first time.

Colonel Chris Hadfield, total badass and first Canadian to walk in space or command the ISS, performing a truly epic cover of David Bowie's "Space Oddity" in the cupola in 2013.



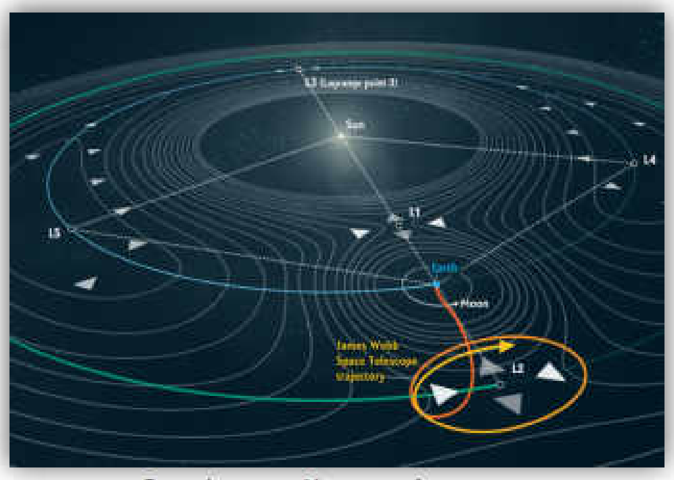
The ISS, with the new Tranquility module and the cupola, seen from Endeavour after undocking.

Lucite Commemorating Chinese Chang'e 2 Lunar Probe Satellite, 2010



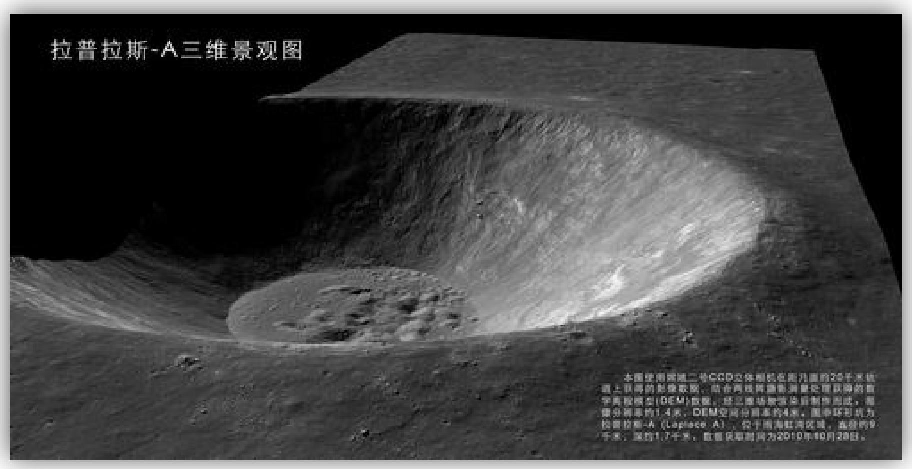
Chang'e 2 (/tʃæŋ'ʌ/; simplified Chinese: 嫦娥二号; traditional Chinese: 嫦娥二號; pinyin: Cháng'é èr hào) is a Chinese unmanned lunar probe that was launched on October 1, 2010. It was a follow-up to the Chang'e 1 lunar probe, which was launched in 2007. Chang'e 2 was part of the first phase of the Chinese Lunar Exploration Program, and conducted research from a 100-km-high lunar orbit in preparation for the December 2013 soft landing by the Chang'e 3 lander and rover. Chang'e 2 was similar in design to Chang'e 1, although it featured some technical improvements, including a more advanced onboard camera. Like its predecessor, the probe was named after Chang'e, an ancient Chinese moon goddess.

After completing its primary objective, the probe left lunar orbit for the Earth–Sun L2 Lagrange point (where the JWST is now hanging out), to test the Chinese tracking and control network, making the China National Space Administration the third agency after NASA and ESA to have visited this point. It entered orbit around L2 on August 25, 2011, and began transmitting data from its new position in September 2011. In April 2012, Chang'e 2 departed L2 to begin an extended mission to the asteroid 4179 Toutatis, which it flew by in December 2012. This success made China's CNSA the fourth space agency to explore asteroids, after NASA, ESA and JAXA.



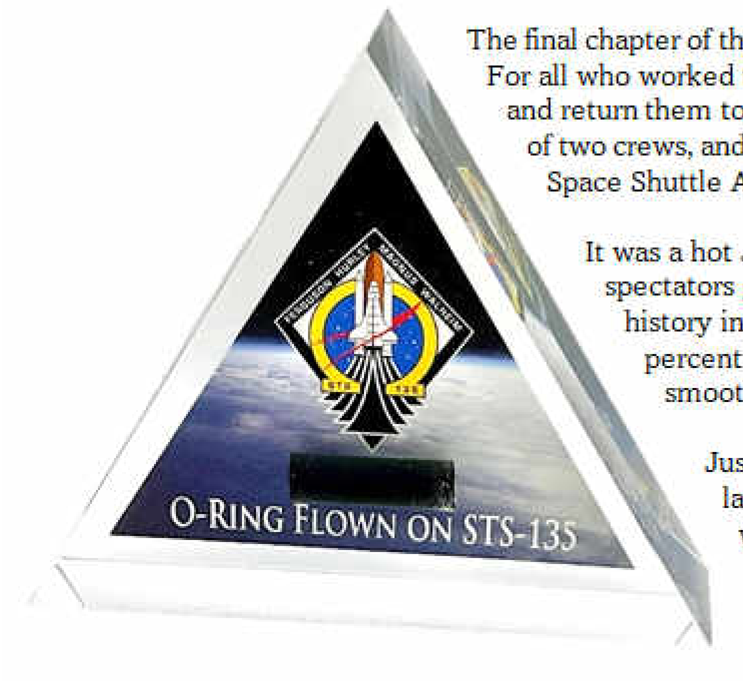
© *Matthew Twombly / Scientific American*

As of 2014, Chang'e 2 has travelled over 100 million km, conducting a long-term mission to verify China's deep-space tracking and control systems. Contact with the spacecraft was lost in 2014 as its signal strength weakened due to distance. The probe is expected to return to Earth's vicinity sometime around 2027.



From the estate of Charles Bolden, former NASA administrator.

Lucite with STS-135 (Last Space Shuttle Flight) Flown O-Ring, 2011



The final chapter of the Space Shuttle's 30-year history was an emotional moment. For all who worked to send these first-of-a-kind engineering marvels to space and return them to Earth, all who flew aboard them, all who mourned the loss of two crews, and for all who simply watched with awe and pride as they flew, Space Shuttle Atlantis' final STS-135 mission was the tearful end of an era.

It was a hot July day on Florida's Space Coast as nearly a million spectators gathered along the beaches, rivers and causeways to watch history in the making. The weather forecast was a daunting 70 percent "no-go" to start the day, yet the countdown proceeded smoothly.

Just as expectations peaked and launch looked imminent, a last-minute glitch held the clock at T-31 seconds. The issue was quickly resolved by the team inside the Launch Control Center at NASA's Kennedy Space Center in Florida, and the clock began counting down the final seconds.

Down to the wire, with less than a minute left in the day's launch window, the three main engines roared to life and the twin solid rocket boosters thundered. Atlantis rose from the launch pad on a plume of fire and parted the high clouds on its way to the International Space Station and to its place in history. The 11:29 a.m. EDT liftoff on July 8, 2011, marked the last time a space shuttle would soar toward the heavens.

The crew of four veteran astronauts aboard Atlantis – Commander Chris Ferguson, Pilot Doug Hurley, and Mission Specialists Sandy Magnus and Rex Walheim – set off on the STS-135 mission to deliver a stockpile of supplies and parts to the space station.

One of the main tasks before meeting up with the station was getting a close look at Atlantis' heat shield to verify that it hadn't sustained any damage during the climb to orbit. Once Atlantis caught up to the space station, Ferguson executed a backflip about 600 feet below to enable station crew members to photograph the shuttle's heat shield. Mission Control in Houston gave them a "thumbs up" on the results a few days later.

With that complete, Atlantis began its final approach to the station from about eight miles and successfully docked two days after launch. The station crew greeted Atlantis with the ceremonial ringing of the station's bell, welcoming a visiting space shuttle for the final time.

While the bulk of the work on many shuttle missions has revolved around spacewalks, this mission's main focus was inside. Over the course of the more than eight days Atlantis spent docked to the station, both crews spent much of their time unloading more than 9,400 pounds of supplies and equipment from the Raffaello multipurpose logistics module, plus the additional 2,200 pounds stowed on the shuttle's middeck. For the return trip to Earth, Raffaello was filled with 5,700 pounds of equipment and discards no longer needed on the station. The crew was given some extra time to complete the extensive transfer when the mission was extended by one day.

Atlantis en route to becoming a museum artifact.

One week into Atlantis' mission, President Barack Obama radioed the combined shuttle and station crews to help mark the final shuttle flight. The President told them, "We're all watching as the 10 of you work together as a team," adding, "Your example means so much not just to your fellow Americans, but also your fellow citizens on Earth. The space program has always embodied our sense of adventure and explorations and courage."

Ferguson presented the station's crew a U.S. flag flown on the first space shuttle mission, STS-1. The flag will remain displayed onboard the station until the next crew launched from the U.S. retrieves it for return to Earth so that it can be carried by the first crew launched from the U.S. on a journey of exploration beyond Earth orbit.

With the last of the mission's work at the station complete, shuttle and station crews parted company for the last time. Weather on landing day proved more predictable than it was for launch, and Mission Control in Houston gave the STS-135 astronauts the "go" for a deorbit burn that would bring them home on their 200th orbit of Earth. At 5:57 a.m. on July 21, space shuttle Atlantis dropped out of the predawn darkness and landed at Kennedy's Shuttle Landing Facility Runway 15. Caught in the last seconds by the brilliant xenon lights, a space shuttle rolled to a stop for the final time.

I visited Atlantis at KSC.

"Although we got to take the ride," said Commander Chris Ferguson on behalf of his crew as they stood on the runway, "we sure hope that everybody who has ever worked on, or touched, or looked at, or envied or admired a space shuttle was able to take just a little part of the journey with us."

With that, the flying days of the most amazing and complicated machine ever built came to an end. Until SpaceX launched a crew to the ISS in 2020, American astronauts were reduced to hitching rides on Russian Soyuz craft.

Coin with SpaceX COTS Demo Flight 2 (Dragon C2+) Flown Copper, 2012

After the retirement of the Space Shuttle, SpaceX swiftly stepped into a crucial role, attempting to ensure continued access to the International Space Station (ISS) for both cargo and crew. Under NASA's Commercial Orbital Transportation Services (COTS) program, SpaceX's Dragon spacecraft became the first commercially-operated vehicle to deliver cargo to the ISS and safely return cargo to Earth. This capability was pivotal in maintaining the station's supplies and supporting ongoing experiments.

One of the early demonstrations of SpaceX's capabilities was the COTS Demo Flight 2 (COTS 2), which was a significant precursor to regular cargo delivery missions. This flight tested the Dragon spacecraft's ability to berth with the ISS, a critical step that paved the way for subsequent resupply missions under the Commercial Resupply Services contracts

COTS 2, also known as Dragon C2+, was the second test-flight for SpaceX's uncrewed Cargo Dragon spacecraft. It launched in May 2012 on the third flight of the company's two-stage Falcon 9 launch vehicle. The flight was performed under a funded agreement from NASA as the second Dragon demonstration mission in the Commercial Orbital Transportation Services (COTS) program.

The Dragon C2+ spacecraft was the first American vehicle to visit the ISS since the end of the Space Shuttle program. It was also the first commercial spacecraft to rendezvous and berth with another spacecraft.

Dragon C2+ successfully launched from Cape Canaveral on 22 May 2012. The mission's first three days included a fly-by of the ISS, rendezvous maneuver practice, and communications with the station. On 25 May Dragon rendezvoused again with the ISS, and then was successfully captured using the Canadarm2. It was berthed to the station later that day, using the robotic arm. Dragon stayed for almost six days during which the astronauts unloaded cargo, and then reloaded Dragon with Earth-bound cargo. On 31 May, Dragon unberthed from the ISS, its capsule landed in the Pacific Ocean off the California coast and was recovered. All the objectives of the mission were successfully completed, and the Falcon 9-Dragon system became certified to start regular cargo delivery missions to the ISS under the Commercial Resupply Services program.

Overall, SpaceX's emergence and evolution in the post-Space Shuttle era have been transformative, reshaping the landscape of space exploration and transportation. By ensuring reliable, cost-effective access to space, SpaceX has maintained and expanded human presence in space, enabled a new era of commercial space activities, and brought us significantly closer to a return to the Moon, and one day perhaps an expedition to Mars.

This coin contains copper material from the Dragon capsule, carried on the flight to the ISS and returned to earth.

Orion Exploration Flight Test 1 / USS San Diego LPD-22 Underway Recovery Test Medallion, 2014

Orion is America's new spacecraft that will take astronauts to destinations not yet explored by humans, including an asteroid and Mars. It will have an emergency abort capability, sustain the crew during space travel and provide safe re-entry from deep space. During Exploration Flight Test-1, an uncrewed spacecraft traveled 15 times farther than the International Space Station before returning to Earth at speeds as fast as 20,000 mph and temperatures above 4,000 degrees Fahrenheit to evaluate the spacecraft's heat shield and other systems.

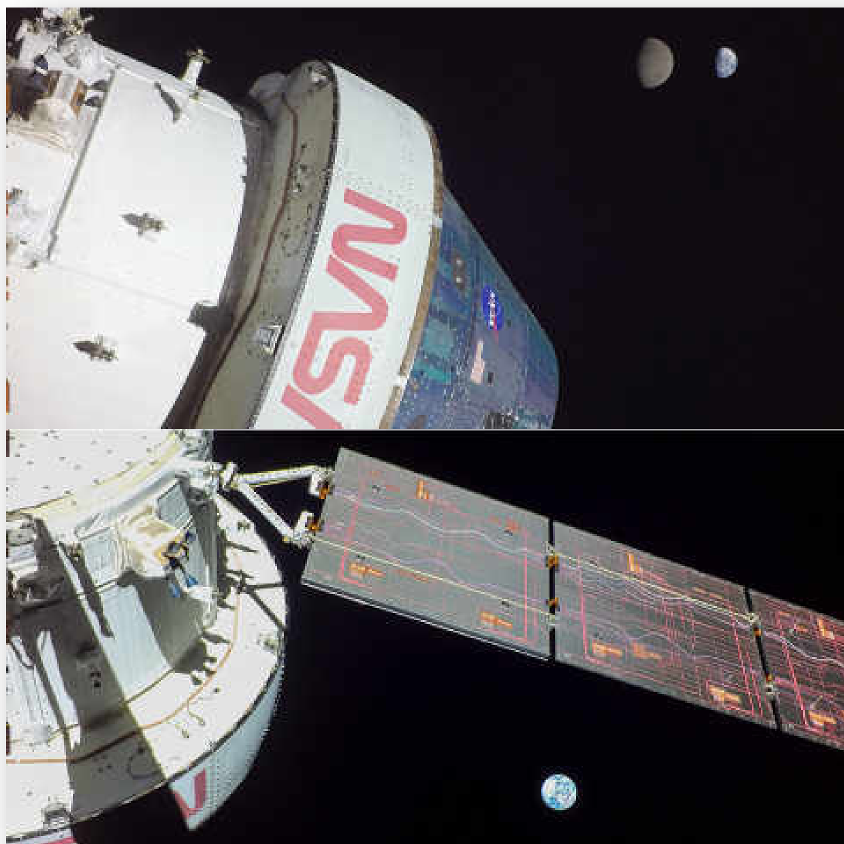
Tragicomically mirroring the journey of one of the first space-flown artifacts in my collection, and illustrating once again how incredibly difficult spaceflight is, this medallion memorializes some challenging initial testing of post splashdown recovery procedures for the Orion capsule. The first full joint testing between NASA and the U.S. Navy off the coast of California in February 2014 was suspended after the team experienced issues with handling lines securing a test version of Orion inside the well deck of the USS San Diego. The testing was planned to allow teams to demonstrate and evaluate the processes, procedures, hardware and personnel that will be needed for recovery operations.

Headed the way of Liberty Bell 7.

The lines were unable to support the tension caused by crew module motion that was driven by wave turbulence in the well deck of the ship. The team called off the week's remaining testing to allow engineers to evaluate next steps. The challenges that arose demonstrate why it is important to subject Orion to tests in the actual environments that the spacecraft will encounter.

The testing has provided important data that is being used to improve recovery procedures and hardware ahead of Orion's first flight test this fall. Several of the test objectives were accomplished before the remaining tests were called off, including successful recoveries of the forward bay cover, parachute and demonstrations of the coordination required between the team onboard the ship and mission control in Houston.

In the EFT-1 Orion capsule also flew approximately 1,200 seeds from five tree species – loblolly pine, American sycamore, sweetgum, Douglas fir, and giant sequoia. The seeds left Earth on Nov. 16, 2022, orbited the moon, and traveled as far as 270,000 miles from our planet before splashing down on December 11, 2022. Scientists selected which species would travel into space based on a few factors, including which seeds flew on Apollo 14.

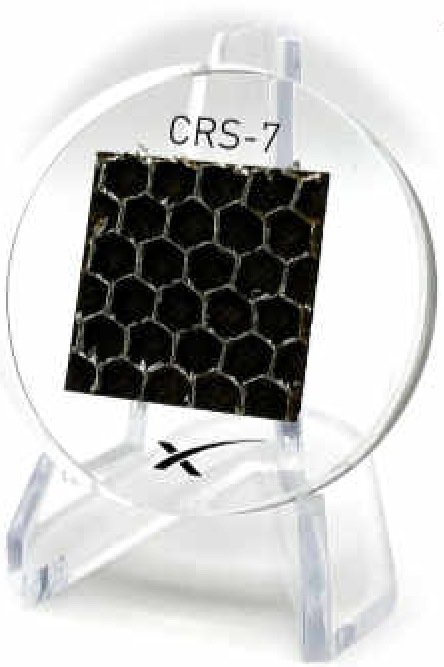


The Orion spacecraft on its first unmanned lunar mission.

If you have read this entire chapter, you may recall that the Artemis Moon Trees project harks back to 1971 when Stuart Roosa, the command module pilot for the Apollo 14 mission, orbited the moon with tree seeds tucked into his personal kit. Roosa, a former Forest Service smokejumper, carried these seeds at the request of the Forest Service Chief. Forest Service employees then grew these seeds into seedlings and distributed them across the country. Many so-called "Moon Trees" survive today. This next generation of Moon Trees builds upon this legacy.

Orion stands to play an important part in American space exploration's future. The tests preceding its lunar orbit missions, especially the EFT-1, were pivotal in validating the spacecraft's design, particularly its heat shield and other critical systems, under the harsh conditions of space travel and reentry. Although as of this writing Orion has since successfully journeyed to lunar orbit, it has not yet embarked on a crewed flight.

Lucite with Piece of Burnt Solar Panel from SpaceX Dragon CRS-7, 2015

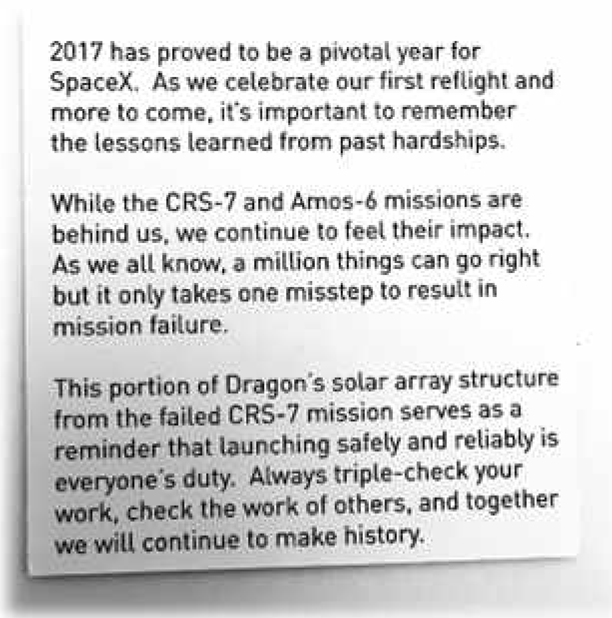


As SpaceX continued to work towards restoring U.S. human launch capabilities, a chilling event served as yet another reminder of the dangers of spaceflight. Unlike SpaceX experimental flights, which explode with great regularity, the "unplanned rapid disassembly" of this spacecraft was a terrifying surprise. CRS-7, also known as SpX-7, was a private American Commercial Resupply Service mission to the International Space Station, contracted to NASA, which launched and failed on June 28, 2015. It disintegrated 139 seconds into the flight after launch from Cape Canaveral, just before the first stage was to separate from the second stage. It was the ninth flight for SpaceX's uncrewed Dragon cargo spacecraft and the seventh SpaceX operational mission contracted to NASA under a Commercial Resupply Services contract. The vehicle launched on a Falcon 9 v1.1 launch vehicle. It was the nineteenth overall flight for the Falcon 9 and the fourteenth flight for the substantially upgraded Falcon 9 v1.1. Dragon would not fly again until 2017.

This Lucite contains a charred piece of solar panel from the CRS-7 craft.

CRS-6, which did not explode.

CRS-7, which did.



2017 has proved to be a pivotal year for SpaceX. As we celebrate our first reflight and more to come, it's important to remember the lessons learned from past hardships.

While the CRS-7 and Amos-6 missions are behind us, we continue to feel their impact. As we all know, a million things can go right but it only takes one misstep to result in mission failure.

This portion of Dragon's solar array structure from the failed CRS-7 mission serves as a reminder that launching safely and reliably is everyone's duty. Always triple-check your work, check the work of others, and together we will continue to make history.

Note accompanying the artifact.

Medallion with Flown X-37B Material, 2017

At 7:47am ET On May 7, 2017, an unmanned experimental U.S. Air Force space plane called the X-37B Orbital Test Vehicle (OTV) landed after a record-breaking 718 days in orbit on a secretive mission. X-37B OTV-4 was launched to low Earth orbit aboard an Atlas V rocket from Cape Canaveral on May 20, 2015, and touched down at NASA's Kennedy Space Centre Shuttle Landing Facility almost two years later, treating Floridians to a sonic boom before landing on a runway that hadn't been used for an orbital mission since the end of the Space Shuttle program.

The solar-powered, uncrewed, vertical-takeoff, horizontal-landing, vehicle, which looks like a miniature, windowless space shuttle, was the fourth X-37B flight since the Air Force inherited the craft's design specs from NASA and DARPA (Defense Advanced Research Projects Agency) in 2006. Beginning in 2010, the Air Force has launched a series of classified orbital missions with the X-37B, each running longer than the last, with OTV-4, also referred to USA-261 or AFSPC-5, representing the second flight of the second Boeing aircraft of its kind.

While the vehicle has an official orbit window of 270 days, the Air Force has been pushing the envelope with its clandestine space drone. The OTV-4 mission, launched on 20 May 2015, eclipsed the 674-day record set by X-37B OTV-3 in 2014.

According to the Air Force, the X-37B's primary objectives are to research reusable spacecraft technologies for America's future in space, and to conduct experiments that can be returned to, and examined, on Earth. Beyond that, officials are tight lipped about the specifics of most of its orbital experiments, leading to speculation that the military might be testing an EM Drive in space – a hypothetical fuel-less propulsion system that's been studied by NASA, and which China claims it's already testing.

Other speculation has suggested the Air Force might be using the X-37B for weapons research or orbital surveillance operations – although as far back 2010 the Air Force denied that the program involved any "offensive capabilities". "The program supports technology risk reduction, experimentation and operational concept development," a spokesperson said at the time. Prior to the launch of OTV-4 in 2015, the Air Force did disclose that one of the experiments aboard involved researching Hall-effect thrust propulsion, while another was a materials science project for NASA called METIS. Beyond that, it's not quite clear what this top-secret orbital vehicle was doing for almost two years above our heads. "What's interesting to me is it's being done in such an opaque manner," space policy analyst Joan Johnson-Freese from the U.S. Naval War College told CBS News in 2015. "If the Chinese were doing this, oh my god, there would be congressional hearings on a daily basis and programs being ginned up to respond to it," says Johnson-Freese. "It has capabilities that other countries aren't sure about, and so they're going to be very nervous about them. If it's a highly maneuverable space vehicle, that has some pretty significant implications."

Later missions continued to push the boundaries of reusable spacecraft technology with some unprecedented maneuvers. The seventh mission of the X-37B, designated USSF-52, stood out for a few novel experiments confirming the versatility and maneuverability of the craft. After being launched into a highly elliptical orbit – a first for the spacecraft – the mission tested an advanced maneuver known as aerobraking. This technique allows spacecraft to use atmospheric drag to change their orbit with minimal fuel consumption. The Space Force has highlighted this maneuver as critical for developing more efficient methods of space travel and satellite deployment.

Aerobraking involves dipping into the Earth's atmosphere at lower altitudes, which increases drag and gradually reduces the spacecraft's orbit. This allows a craft like the X-37B to slow down or change its orbital path without burning large amounts of fuel, making it a cost-effective and energy-efficient technique. For the U.S. Space Force, this capability represents a leap in orbital control, offering a way to manage satellite orbits more precisely and sustainably.

Additionally, NASA is involved in several experiments aboard the spacecraft. One focuses on the long-term exposure of seeds to space radiation, continuing the tradition of the Apollo Moon Trees, while another continues the study of materials exposed to the harsh conditions of space. The results from these experiments are expected to inform future spacecraft design, as well as broader space exploration efforts.

Assorted Debris from SpaceX Starship SN11, 2021

While Orion and the Artemis program represent the United States government's attempts to return to the moon, SpaceX has its eyes set on Mars. To reach the red planet, SpaceX has been developing a craft called "Starship". A stainless-steel vehicle, known as SN11 ("Serial No. 11"), launched on a test flight on March 30, 2021, from SpaceX's South Texas facilities near the Gulf Coast village of Boca Chica.

SN11 soared to a maximum altitude of 6.2 miles as planned, and the 165-foot-tall craft checked a number of boxes on the way down as well. But SN11 didn't stick its landing, instead exploding in a massive fireball – because of a plumbing problem, SpaceX founder and CEO Elon Musk announced on April 5, 2021.

"Ascent phase, transition to horizontal & control during free fall were good. A (relatively) small CH4 leak led to fire on engine 2 & fried part of avionics, causing hard start attempting landing burn in CH4 turbopump. This is getting fixed 6 ways to Sunday," Musk said.

© SpaceX webcast

CH4 is methane, the propellant for SpaceX's powerful, next-generation Raptor engine. And a "hard start" refers to ignition when there's too much fuel in the combustion chamber and the pressure is therefore too high – not a good thing for any engine.

SpaceX is developing Starship to take people and cargo to the moon, Mars and other distant destinations. The transportation system consists of two elements, both of which will be fully reusable: the Starship spacecraft and a giant first-stage booster called Super Heavy, later in this chapter.

Both Starship and Super Heavy will be powered by Raptors – six for the final Starship and about 30 for the huge booster, Musk has said. SN11 sported three Raptors, as did each of its three predecessors, SN8, SN9 and SN10, which launched on 6-mile-high test flights in December, February and early March, respectively. All four flights were broadly similar, with the prototypes performing well until the very end. SN10 even landed in one piece, in fact, but exploded about eight minutes later.

© SpaceX

Other pieces of SN11 debris, also in my collection.

Fog concealed SN11's launch. The sound of the rocket taking off and later exploding were all the hopeful spectators on Isla Blanca were able to witness.

However, aside from the sounds, one more thing made it to Isla Blanca following the event: debris from the rocket. Spectator Jessa Koppenhofer witnessed something fall from the sky a short time later. After recovering the object from the surrounding Isla Blanca jetties, she described it as smelling like fuel and still being warm when she touched it. "I went out there and we looked, and it's soft, it's fabric of some… I don't even know, and it smelled like fume [to] some extent and it was still warm as well."

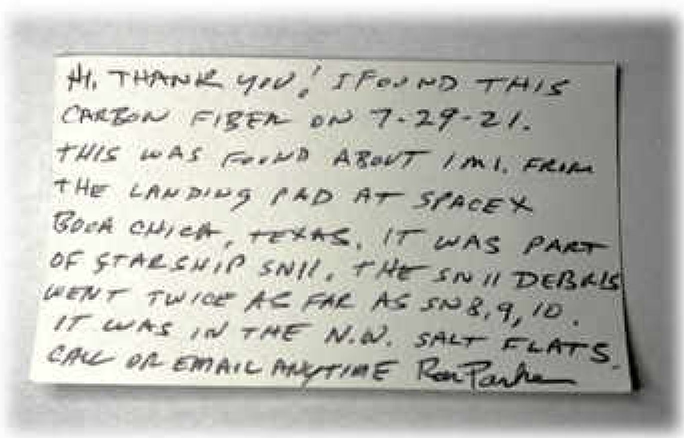
A few hours after the launch, SpaceX put out a hotline and email address for the public to report such findings and further advised that they should not handle them. While debris falling roughly five and a half miles away from the launch site signaled this explosion was different from the previous SN8, SN9 and SN10 explosions, concern from the public rose once the fog dissipated and images of rocket pieces littered across protected habitats began to circulate on social media.

Though cleanup efforts began almost immediately after the Starship explosion, large pieces of debris remained scattered across the mudflats across the street from the launch site weeks after the explosion. U.S. Fish and Wildlife Service (USFWS), which leases and manages the land, was not immediately able to retrieve the debris.

"At this time we are stalled as conditions are not ideal for recovery of the large pieces of debris. We are continuing to evaluate our options and are working closely with SpaceX to make the best decisions for the habitat," said USFWS. A statement from the Texas Parks and Wildlife Department noted, "SpaceX worked closely with USFWS in retrieval of explosion debris to minimize impacts to wildlife and sensitive habitats." Furthermore, the retrieval has also impacted the area as they work towards dislodging large pieces of the rocket.

"The falling debris lodged into different types of habitats and soils. Access in the way of constant ingress/egress to retrieve debris materials has created disturbance and unintentional paths across the landscape," according to USFWS.

For many, it wasn't just the visible debris that caused concern. Contamination from fluids used by the Starship may also be harmful. Environmental organizations such as the Sierra Club, the Friends of Wildlife Corridor, and concerned citizens in the environmental research field have expressed their displeasure at SpaceX's Boca Chica activities.



HI, THANK YOU! I FOUND THIS CARBON FIBER ON 7-29-21.
THIS WAS FOUND ABOUT 1 MI. FROM THE LANDING PAD AT SPACEX BOCA CHICA, TEXAS. IT WAS PART OF STARSHIP SN11. THE SN11 DEBRIS WENT TWICE AS FAR AS SN8,9,10. IT WAS IN THE N.W. SALT FLATS.
CALL OR EMAIL ANYTIME

Future research may show that contamination from rocket fluids harmed wildlife in the surrounding area. “Contaminants such as those of hydrocarbons are able to kill aquatic life, both vertebrate and invertebrate, at very low concentrations, especially when it’s in a semi-enclosed area as the Lagunas are,” explained Chris Sandoval, a science teacher in Brownsville with degrees in Wildlife and Fisheries and Ecotoxicology.

Sandoval said that the presence of SpaceX at Boca Chica is in direct contrast to the mission of its surrounding protected land and explained that USFWS has actively worked to increase the population of the Aplomado falcons that nest in the areas surrounding SpaceX. Further expansion of the facility would limit the availability of nesting areas for the species.

“There’s really been a large increase in death to wildlife that the refuge around it has specifically been trying to increase,” said Sandoval. “The Aplomado falcon, the ocelot, and a couple of other species including the Boca Chica flea beetle, which is only found, as far as we know, in Boca Chica Beach sand dunes, are all at risk from these explosions and from the existence of the spaceport.”

We don’t often talk about the environmental impact of spaceflight, but the uneasy relationship between SpaceX and its neighbors highlights the need for a whole new set of standards and technologies to limit the negative impact of this burgeoning new industry.

In addition to the carbon fiber on display, my pieces of Starship 11 include a stainless-steel clip from a heat tile, a piece of heat tile, a piece of aluminum from an electrical component, a piece of rubber insulation, a piece of Teflon, and some wiring.

As of this writing, SpaceX is preparing for the first orbital flight of a Starship, and is considering moving its launch operations from Starbase Boca Chica to Launch Complex 39A at Cape Canaveral.

KVEO.

Fragment of Blue Origin NS-18 New Shepard Flown Drawing by Norrie Kilchenmann, 2021

On October 13, 2021, Star Trek actor William Shatner went boldly where some hundreds of men and women have gone before and returned safely with three other crew members aboard a Blue Origin – Jeff Bezos' space company – capsule, launched from West Texas by a comically phallic rocket. Shatner, 90, became the oldest person ever to reach space. The New Shepard rocket that carried the crew lifted off into a mostly sunny sky at 09:50 from the company's Launch Site One about 160 miles east of El Paso. The capsule touched down 11 minutes later after reaching space and descending back to the Texas desert.

"That was unlike anything you described, unlike anything I've experienced," Shatner was heard saying on a live broadcast during descent. He appeared overcome with emotion as he thanked Blue Origin founder Jeff Bezos, who pinned astronaut wings on the four crew members. Shatner said viewing Earth's atmosphere made him feel it was fragile, a "sliver" of precious air.

"Everyone needs to see [...] the blue down there, and the black up there. It was so moving to me," Shatner said. "What you have given me is the most profound experience," he told Bezos. "I'm so emotional about what just happened."

Shatner, who portrayed Captain James. T. Kirk in the 1960s television series, said in a Blue Origin video that he's aware of the impact his spaceflight will have.

"It looks like there's a great deal of curiosity about this fictional character, Captain Kirk, going into space. So, let's go along with it and enjoy the ride!" Shatner said.

Boldy going where other wieners have gone before.
© Blue Origin

© Paramount

Shatner was an invited guest of Blue Origin. He traveled with two businessmen who are paying customers and a company executive, Audrey Powers, the vice president of mission and flight operations. The passengers were Chris Boshuizen, a former NASA engineer and co-founder of San Francisco-based satellite company Planet

Labs, and Glen de Vries, a French software firm executive and co-founder of New York clinical trials technology firm Medidata.

© Blue Origin

The mission was titled NS-18 for the 18th flight of a New Shepard rocket. It was only the second crewed mission for Blue Origin, after Bezos flew July 20 with three crew members. Blue Origin delayed the launch due to winds at the launch site Tuesday. Flight director Nick Patrick said in a video release that the crew spent the day training.

The capsule passed the Karman line, about 62 miles high – an international definition of the edge of space. The crew spent about three minutes in weightlessness before strapping in for the descent, ultimately under parachutes. Training covered what would happen if safety systems activated, primarily a backup parachute, and how to move safely while weightless.

Patrick said watching Shatner actually go to space in real life and not just on a fictional TV show would be a treat.

“He’s somebody who’s been responsible, I think, for inspiring millions of us to be interested in space exploration and spaceflight. And somebody who certainly inspired me to get into this business,” he said.

Tragically, Glen de Vries was killed in a small plane crash in New Jersey only weeks later. He was 49 years old.

In addition to the humans aboard, NS-18 carried postcards from students around the world as part of Blue Origin’s “Club for the Future” initiative. Their “Postcards to Space” initiative encourages kids to send in postcards with their dreams of the future and vision for life in space answering the question:
“WHY DO YOU THINK EARTH NEEDS SPACE?”

© Norrie Kilchenmann

Norrie Kilchenmann (5 at the time) drew this postcard in Torrance CA, and then sent it to Blue Origin headquarters. Blue Origin flew it onboard NS-18 and sent it back to the artist after the suborbital space flight via regular mail on October 21, 2021. During the transit back to her, the card was ripped at the bottom right.

After a family discussion, they decided to cut it up (since it was already ripped) and gift some pieces to other collectors (sharing the love). Dad Roger offered them to other geeks in a space collectors’ group, and that is how I came to own this fun little piece of space art history.

SpaceX Crew-2 Couch Material, 2021

On May 30, 2020, SpaceX's Crew Dragon Demo-2 mission launched from Kennedy Space Center's Pad 39A, carrying NASA astronauts Bob Behnken and Doug Hurley to the International Space Station. This was the first crewed launch from U.S. soil since the retirement of the Space Shuttle, ending nearly a decade of reliance on Russian Soyuz spacecraft for American access to space. The spacecraft, named Endeavour by its crew in homage to the Shuttle of the same name, was the first commercially built and operated vehicle to carry astronauts to orbit – a major validation of SpaceX's crew transportation system under NASA's Commercial Crew Program.

The connections to past eras of spaceflight was not just symbolic. Doug Hurley had been the pilot on the final Space Shuttle mission, STS-135, and the flight reused historic Launch Pad 39A, which had once hosted Apollo 11 and many Shuttle missions. Behnken and Hurley's 64-day jaunt included extensive testing of Crew Dragon's systems while docked to the ISS, certifying it for operational use. Their safe return to Earth with a parachute-assisted splashdown in the Gulf of Mexico was the first water landing of American astronauts since Apollo-Soyuz in 1975.

Demo-2's success was crucial for the ISS. With Soyuz tickets costing NASA upwards of $80 million per seat, developing an independent U.S. launch capability was not just about national pride. Crew Dragon's certification enabled regular crew rotations from U.S. soil again, supporting a steady American presence aboard the station and allowing international collaboration to expand. It also added redundancy: if one vehicle – Soyuz, Crew Dragon, or Boeing's Starliner (still delayed at the time) – became unavailable, others could cover the gap.

The broader framework for this achievement was NASA's Commercial Crew Program (CCP), launched during the Obama administration to foster private-sector innovation in space transportation. Instead of the traditional model of NASA designing, owning, and operating spacecraft, the agency contracted companies like SpaceX and Boeing to deliver

Go for launch.

services, spurring competition and reducing costs . This commercial model was controversial at first, facing political resistance and funding shortfalls, but ultimately it transformed how America approached crewed spaceflight. Notably, the CCP traces back to an earlier, less publicized initiative called the Commercial Orbital Transportation Services (COTS) program, which had helped fund the development of SpaceX's original Dragon cargo vehicle after traditional aerospace contractors showed little interest.

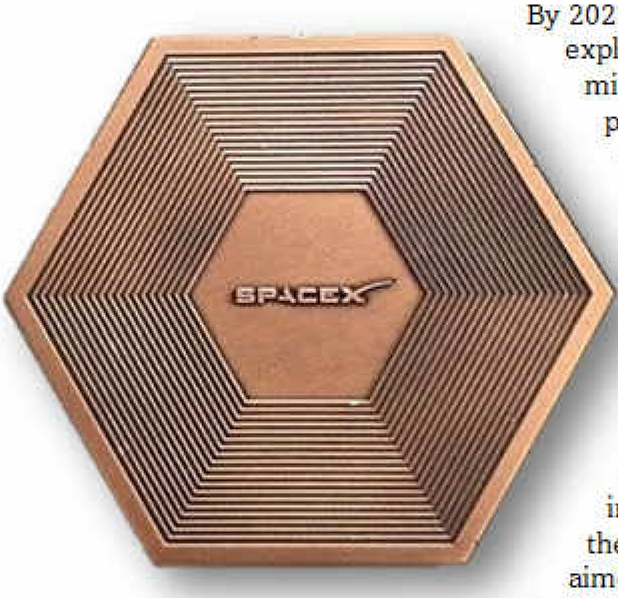
One of the innovations on Demo-2 was the crew's use of modern, touchscreen-driven cockpit controls rather than traditional switches and dials, a departure that initially worried some veteran astronauts used to physical feedback in high-stress environments. SpaceX's minimalist approach, influenced by automotive and software design, represented a generational shift in spacecraft interiors. The mission also introduced a new style of space suit, custom-fitted to each astronaut and manufactured by SpaceX itself, which became a cultural icon due to its sleek, almost sci-fi appearance – a sharp contrast to the bulky "pumpkin suits" of the Shuttle era.

Demo-2 was more than a test flight, it signified the return of American human spaceflight capability, the maturation of commercial partnerships in orbit, and a renewed flexibility for the ISS program. It set the stage not only for operational Crew Dragon missions but also for future efforts like lunar missions under the Artemis program, where commercial vehicles will again play a crucial role. As NASA looks outward to the Moon and Mars, the success of Demo-2 helped forge a new era of exploration where public ambition goes hand in hand with private enterprise.

This SpaceX employee memento contains flown couch material from the Demo-2 spacecraft.

The Expedition 63 crew expanded to five members with the arrival of the SpaceX Crew Dragon. (From left) Anatoly Ivanishin, Ivan Vagner, Chris Cassidy, Bob Behnken and Doug Hurley.

SpaceX Achievements Medallion, 2022



By 2022, SpaceX had firmly established itself as a leading force in space exploration and commercial spaceflight, achieving several significant milestones. It had become the most prolific commercial launch provider in the world, regularly conducting missions for a diverse range of customers, including NASA, other international space agencies, commercial satellite operators, and private individuals. The Falcon 9 rocket, known for its reliability and reusable first stage, was the workhorse of its fleet.

In that year, SpaceX maintained a high launch cadence, breaking records for the number of orbital launches conducted in a single year by any single company or country. This included the continued deployment of the Starlink satellite constellation, which aimed to provide high-speed internet access globally, including remote and underserved regions.

SpaceX also conducted multiple crewed missions to the International Space Station (ISS) under NASA's Commercial Crew Program, safely transporting astronauts. These missions supported ISS operations and underscored SpaceX's role in human spaceflight. Additionally, the company hosted the first fully private crewed mission to orbit, Axiom Space's Ax-1 mission.

Significantly involved in NASA's Artemis program, aimed at returning humans to the Moon, SpaceX's Starship was selected to be the lunar lander for these missions. The company made significant progress in testing and developing this next-generation spacecraft, aimed at missions beyond low Earth orbit, including to the Moon and Mars. Starship represents SpaceX's ambition for interplanetary travel, and several high-altitude test flights were conducted throughout the year.

A "train" of Starlink satellites against the night sky.
Update: this image is fake!!!

SpaceX also used its Starlink system to provide internet services to areas affected by natural disasters and conflicts such as the war that broke out that year in Ukraine, showcasing the system's rapid deployability and utility in emergency situations.

Also in my collection, a similar medallion from 2023.

By 2022, SpaceX's achievements reflected significant progress toward its long-term goals of making space more accessible and pursuing human life beyond Earth. This employee-issued medallion celebrates the many milestones achieved that year. As spaceflight becomes more and more routine, mementos are no longer necessarily made to commemorate each flight.

SpaceX Presentation With IFT-1 Launch Pad Rebar, 2023

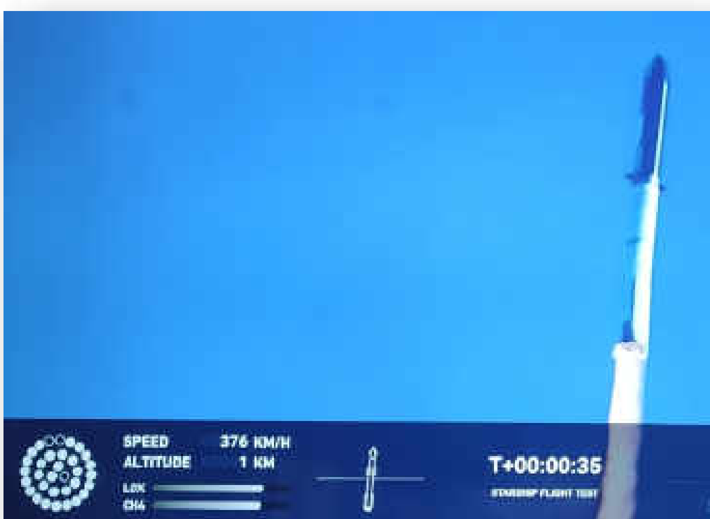
Integrated Flight Test 1 (IFT-1) was the first of the SpaceX Starship mated with the "Super Heavy" launch vehicle. The test was performed on April 20, 2023, and the prototype vehicle was destroyed less than four minutes after lifting off from SpaceX Starbase in Boca Chica, Texas. The vehicle became the most powerful rocket ever flown, breaking the half-century-old record held by the Soviet N1 rocket.

SpaceX's Starship program follows an iterative and incremental development approach, like those pioneered at Bell Labs and mentioned elsewhere in this book, involving frequent, and often destructive, test flights of prototype vehicles.

Before the launch, SpaceX officials said they would measure the mission's success "by how much we can learn" and that various planned mission events "are not required for a successful test". The flight was regarded as having furthered Starship's development.

It was planned for the Starship spacecraft to complete nearly one orbit around the Earth before reentering the atmosphere, performing a controlled landing and splashing down in the Pacific Ocean near Hawaii. The Super Heavy booster was to have performed a similar landing in the Gulf of Mexico, about 20 mi (30 km) off the Texas coast about 8 minutes after liftoff.

The most powerful rocket ever launched.
© *SpaceX*



The diagram at bottom left shows 3/33 engines malfunctioning.
© *SpaceX webcast*

The rocket blasted off at 08:33 from SpaceX's private launch site, Boca Chica, Texas. The liftoff damaged the launch pad and its surrounding infrastructure, which SpaceX said was unexpected. Once again, debris spread into Boca Chica State Park. Three engines did not start or aborted before liftoff, and several others failed during the flight. The vehicle passed max q and entered supersonic flight, but, due to a lack of thrust or thrust vector control, no attempt was made at stage separation.

Starship tumbled, and the autonomous flight termination system (AFTS) was activated but did not destroy the vehicle immediately, as was intended. The vehicle disintegrated 40 seconds

Immediately following the launch.
© *SpaceX*

later, nearly 4 minutes into the flight. When the dust cleared at Starbase after the liftoff, a scene of wreckage emerged: Starship's 33 first-stage Raptor engines blew out a crater beneath the orbital launch mount, pummeling nearby infrastructure with flying chunks of cement and other debris. Starbase's orbital launch mount did not have a flame trench, a structure designed to deflect plume exhaust away from the pad during liftoff.

Flame trenches are common features of pads that host launches of powerful rockets. For example, NASA built a new one at Kennedy Space Center's Pad 39B, so the site could support liftoffs of the agency's massive Space Launch System (SLS) megarocket which hurled the Orion capsule around the moon.

Patrick Fallon / AFP via Getty Images

After the test, the Federal Aviation Administration (FAA) grounded the launch program pending results of a standard "mishap investigation" overseen by the agency and performed by SpaceX. The FAA said that a return to flight would depend on the agency's determination that future launches would not affect public safety. In August 2023, SpaceX submitted to the FAA the 63 "corrective actions" that it would need to take before another Starship launch would be allowed. Dust scattered by the launch initially caused some health concerns, but was later found by a laboratory to be ordinary beach sand, not posing a health hazard.

SpaceX began work on the launch mount to repair the damage it sustained during the test and to prevent future issues. The foundation of the launch tower was reinforced and a water powered flame deflector was built under the launch mount. Following SpaceX's final report, the FAA closed the investigation on September 8, 2023 and the Starship program resumed.

The source of my rebar.
© *SpaceX*

This employee-issued block of acrylic contains a piece of rebar from the damaged launch structure.

SpaceX Polaris Dawn Flown and Space Exposed Doritos Tin, Featured in Ad Filmed in Space, 2024

Near the beginning of this chapter in 1962, when Scott Carpenter became the sixth human to orbit the Earth, the floating crumbs from his experimental "food cubes" posed a serious safety hazard. The cubes' anti-crumbling coating had been destroyed when they were inadvertently smashed prior to launch. His candy bar melted too, and Carpenter declared his unappetizing early astronaut food generally not worth the trouble. Many of us remember another culinary letdown: the chalky, freeze-dried "astronaut ice cream" bars hawked in museum gift shops. Decades later, designing food that's flavorful, nutritious, easy to consume, and safe for microgravity environments remains one of the most peculiar challenges in spaceflight.

We all know and love Doritos, but on Earth, they leave your fingers covered in radioactive-orange dust – part of their charm, perhaps, but an absolute menace in microgravity, where floating debris can damage instruments, clog filters, and even choke or blind astronauts. Foods like crunchy corn chips have therefore been banned from space. But now, Frito-Lay (PepsiCo) food scientists have cracked the code for zero-gravity snacking.

Asteroid, Polaris Dawn Zero-G Indicator, also in my collection

Enter Cool Ranch Zero Gravity Doritos: the same flavor, but with an oil-based coating in place of the traditional powdered topping. The chips themselves are "Minis", bite-sized versions that reduce the risk of breakage and crumbs escaping. This new format allows for the chips to be consumed in space without compromising spacecraft and crew safety.

Polaris Dawn Mission Challenge Coin, also in my collection

NASA and other space agencies have long engineered clever food adaptations for orbit. Before switching to flour tortillas, NASA's early spacefarers had to nibble bread from bite-sized cubes. Salt and pepper are dispensed in liquid form on the ISS to keep them from becoming airborne particles. But never before has a mass-market snack chip made the leap. That changed with the Polaris Dawn mission, which launched aboard a SpaceX Falcon 9 on September 10, 2024, and successfully returned to Earth five days later.

© PRNewsfoto/Frito-Lay North America

The four-person crew aboard the Dragon spacecraft – Jared Isaacman (nominated as next NASA administrator), Scott “Kidd” Poteet, Sarah Gillis, and Anna Menon – achieved multiple milestones: flying higher than any mission since Apollo 17, performing the first-ever commercial “spacewalk”, the first violin performance in zero gravity, broadcast via Starlink, and yes, becoming the first humans to eat Doritos in space.

Cool Ranch Zero Gravity Doritos were packaged in three tins specially certified for flight – and one of those tins has now found its way into my collection. I received it this spring, by way of a donation to St. Jude’s Children’s Research Hospital, which partnered with the Polaris Program.

While Boeing continues to troubleshoot its Starliner capsule and SpaceX pushes the limits of Starship with more explosive test flights, the workhorse Dragon spacecraft quietly logs mission after mission – serving both government and commercial needs, and expanding the definition of what’s possible in private spaceflight. Including better snacks. Now, to bring back space Coke.

My tin in orbit.

Zero Gravity Cool Ranch Minis (L) vs Regular Cool Ranch Minis ®, both in my collection until I ate them. My tin arrived empty, I bought a limited-edition tube of the chips on eBay, but they were a little stale when they arrived so it wasn’t a fair comparison.

Photos on this page © PRNewsfoto/Frito-Lay North America

Blue Origin New Glenn, First Integrated Stage Mate Bolt, 2024

New Glenn is Blue Origin's heavy-lift orbital launch vehicle, named in honor of astronaut John Glenn. Standing approximately 98 meters tall, it is among the tallest rockets in operation, although less powerful than Starship. The rocket features a reusable first stage powered by seven BE-4 engines, each generating 550,000 pounds of thrust, and a second stage equipped with two BE-3U engines optimized for vacuum conditions.

Designed to deliver payloads to various orbits, New Glenn can carry up to 45 metric tons to low Earth orbit (LEO) and over 13 metric tons to geostationary transfer orbit (GTO). Its 7-meter-diameter payload fairing offers twice the volume of standard 5-meter-class commercial launch systems, accommodating larger and more complex payloads.

New Glenn's first stage is designed for a minimum of 25 flights, aiming to reduce launch costs through reusability. This capability positions New Glenn as a competitive option for a range of missions, including commercial satellite deployments, national security launches, and future crewed missions.

Blue Origin achieved a significant milestone in the development of this rocket by successfully mating the first and second stages for the first time on November 12, 2024. This critical integration took place at Launch Complex 36 (LC-36) at Cape Canaveral Space Force Station in Florida.

The mating process involved joining the 57.5-meter-long first stage, powered by seven BE-4 engines, with the second stage, which utilizes two BE-3U engines optimized for vacuum operation. This step was essential for validating structural interfaces and preparing for the rocket's inaugural launch.

Following this integration, Blue Origin conducted a series of tests, including a full wet dress rehearsal and a 24-second static fire test in December 2024, to ensure the vehicle's readiness for flight. These preparations culminated in the successful maiden flight of New Glenn on January 16, 2025, marking a significant advancement in Blue Origin's launch capabilities.

Coin commemorating the stage integration, also in my collection.

United Launch Alliance Commemorative CFT-1 Keychain with Boeing Starliner Flown Material, 2025

Boeing's Crew Flight Test-1 (CFT-1), launched on June 5, 2024, was supposed to mark a long-awaited step forward in NASA's Commercial Crew Program – a public-private initiative launched after the retirement of the Space Shuttle to restore American crewed access to low Earth orbit. The program aimed to foster competition and innovation by funding both Boeing and SpaceX to develop independent human-rated spacecraft. SpaceX succeeded early with its Crew Dragon, flying astronauts as soon as 2020. Boeing's Starliner, in contrast, faced years of delays, test failures, and mounting skepticism from both the public and lawmakers.

CFT-1 was the first crewed flight of Boeing's Starliner capsule, a spacecraft developed under NASA's program to ensure that astronauts could be launched from U.S. soil without reliance on foreign vehicles. The mission flew two veteran NASA astronauts – Barry "Butch" Wilmore and Sunita "Suni" Williams – from Cape Canaveral Space Force Station to the International Space Station (ISS). It was meant to last just eight days, ending with a landing in the American Southwest. Instead, it became one of the most protracted and technically troubled crewed spaceflights of the post-Shuttle era.

The mission's troubles began long before liftoff. CFT-1 was originally scheduled for 2017 but was delayed repeatedly due to development issues. The first uncrewed flight test, Boe-OFT in 2019, failed to reach the ISS due to software errors. A follow-up attempt, Boe-OFT-2, was delayed by valve problems and finally launched in 2022. Even then, Starliner had yet to fly a single astronaut.

Final preparations for the crewed flight began in earnest in 2024, with the Starliner capsule – named Calypso – mounted atop a United Launch Alliance (ULA) Atlas V rocket on April 16. But more delays followed. A faulty oxygen valve on the rocket scrubbed the May 7 attempt. A June 1 launch try was canceled due to a ground computer failure. Meanwhile, helium leaks in the Starliner service module appeared – and persisted.

Calypso docked to the ISS, where she would remain for many moons.
© *AP*

Despite those known issues, the launch finally proceeded on June 5 at 10:52 a.m. Eastern Time, and the Atlas V performed flawlessly. ULA's custom "N22" configuration – designed specifically for human spaceflight – successfully delivered Starliner and its crew into orbit.

Once in space, however, the spacecraft encountered multiple failures. As Starliner approached the ISS, five of its 28 reaction control thrusters underperformed or failed. Four were eventually restored after repeated resets and in-orbit testing. The helium leaks worsened, with five separate leaks confirmed during the mission. Although docking with the ISS was successful, NASA soon ruled out using Starliner for the return trip. The propulsion anomalies and persistent leaks posed too much risk.

What had been planned as an eight-day demonstration turned into a long-term residency. Wilmore and Williams remained aboard the ISS for nine months while engineers investigated and tested Starliner's systems from afar. The extended stay sparked concern not only about Starliner's reliability but also about NASA's decision to green-light the crewed flight despite known issues. Critics in Congress questioned whether Boeing had received leniency compared to other contractors and whether dual-provider redundancy remained viable in an era where SpaceX had become the de facto provider of crewed access.


Suni Williams and Butch Wilmore during a press conference from the International Space Station on Friday, September 13, 2024.

Whether the astronauts were "strabded", or "abandoned" even became an issue of partisan debate.
© *Fox News*

The mission quickly became a focal point of election year political controversy, with debates centering on whether their prolonged mission was due to technical challenges or political decisions. Former President Donald Trump and SpaceX CEO Elon Musk publicly criticized the Biden administration, alleging that the astronauts were "abandoned" in space for political reasons. Musk claimed he had offered to expedite their return, but the administration declined. These assertions were amplified on social media and in political circles, framing the situation as a failure of leadership. NASA and the astronauts refuted these claims. Wilmore stated, "From my standpoint, politics has not played into this at all", emphasizing that their training prepared them for extended missions and unforeseen circumstances.

On September 7, 2024, Starliner returned to Earth uncrewed. It landed safely at White Sands Missile Range in New Mexico despite a navigation fault and the failure of one reentry thruster. The astronauts, meanwhile, were officially reassigned to return aboard SpaceX's Crew Dragon as part of the Crew-9 mission in March 2025. It was the first time in NASA history that astronauts launched aboard one vehicle and returned aboard a different commercial spacecraft.

From left, Nasa astronaut Butch Wilmore, Russia's Alexander Gorbunov, and Nasa astronauts Nick Hague and Suni Williams sit inside a SpaceX capsule onboard the SpaceX recovery ship Megan after splashdown in Florida.

This image taken from video released by SpaceX shows dolphins swimming near a SpaceX capsule, Tuesday, March 18, 2025, after landing off the coast of Florida with astronauts Suni Williams, Butch Wilmore and Nick Hague, and Russian cosmonaut Alexander Gorbunov. *(SpaceX via AP)*

Unlike that of Boeing, ULA's role in the mission was unblemished. The Atlas V rocket, flying its final crewed mission before retirement, performed precisely as intended. While Boeing faced intense scrutiny for its spacecraft's performance, ULA's steady and proven launch operations delivered as expected and safely delivered "Calypso" to orbit. The fallout for Boeing however was severe and had lasting consequences across technical, financial, and reputational fronts. I doubt that they made commemorative keychains.

The mission exposed persistent reliability issues in Starliner that cast doubt on the spacecraft's readiness for routine crewed service. Financially, Boeing faces escalating costs without revenue from operational flights, and its significantly higher per-seat price compared to SpaceX's Crew Dragon raises concerns about viability. The high-profile nature of the delays and the politically charged debate around the astronauts' return damaged Boeing's credibility, both with the public and within government circles. It is unclear when – or if – Starliner will carry humans again. What's certain is that trust in the vehicle, once assumed, must now be earned the hard way. Spaceflight reputations, once lost, are hard-won back.

This keychain celebrates the return of CFT-1 to Earth, the medallion to the left commemorates its successful orbit insertion. From ULA's perspective, the launch of the final human spaceflight atop a venerable Atlas rocket was a resounding success.

Because when we get home from a trip, who is most stoked to see us?

Various Other Space Lucites

NASA Tracking & Data Relay System TDRS-1 Satellite.

Space launch evolution of the Titan II ICBM.

Film strip (flown?) with photos of an early Space Shuttle cockpit.

Titan IV Centaur, the first cryogenic upper stage.

Multi-layer insulation from SpaceX CRS-3

The moonwalkers signed space travel accident insurance policies with Travelers.

STS-6 Flown Checklist.

Not on the lunar rover though, on a cart.

Flown Space Shuttle Main Engine (SSME) turbine blade.

Avoid the solid stuff.

An Ariane 5 launched the James Webb Space Telescope.

There was no need for the LEM to be aerodynamic.

Flown Space Shuttle brake disc segment.

Bella Machina.

Power
&
Violence

Two Lucites with Pieces of Henry VIII's Flagship "Mary Rose", 1511 – 1545

In the early 16th century, the Age of Exploration was unfolding, and the oceans, once barriers, became highways of conquest and commerce. Against this backdrop, nations were beginning to realize the importance of controlling the waves, spurring innovation in naval warfare and ushering in the transition from oar-powered galleys to sail-driven vessels equipped with heavy artillery. For centuries, naval battles had relied on ramming and boarding tactics, with oarsmen, be they Vikings, Spaniards, Ottomans, Greeks, or Phoenicians, propelling ships into close combat.

The advent of gunpowder and cannon changed everything. New warships, their broadsides bristling with guns, could engage enemies from a distance, delivering devastating volleys of fire. This shift in naval strategy demanded larger, sturdier ships capable of carrying heavy armament and withstanding the recoil of powerful cannons, and led to the emergence of purpose-built warships like the Mary Rose

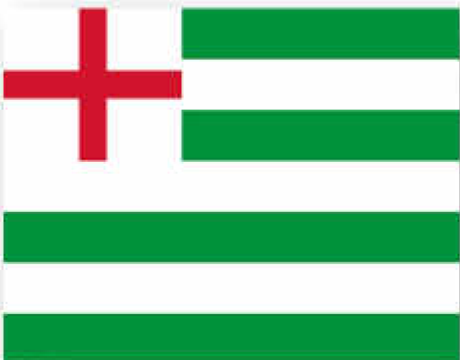
Henry VIII, the Tudor king of England, was acutely aware of the changing tides, and during his reign from 1509 to 1547 became the "Father of the English navy". He inherited seven small ships from his father and would add two dozen more by 1514. In addition to those built in England, he bought up Italian and Hanseatic ships. In March 1513, he proudly watched his fleet sail down the Thames under command of Sir Edmund Howard. It was the most powerful naval force to date in English history: 24 ships led by the 1600-ton "Henry Imperial"; the fleet carried 5000 combat marines and 3000 sailors. It forced the outnumbered French fleet back to its ports, took control of the English Channel, and blockaded Brest. Henry was the first king to organize the navy as a permanent force, with a permanent administrative and logistical structure, funded by tax revenue and supervised by the new Navy Board. His personal attention was concentrated on land, where he founded the royal dockyards, planted trees for shipbuilding, enacted laws for inland navigation, guarded the coastline with fortifications, set up a school for navigation and designated the roles of officers and sailors. He closely supervised the construction of all his warships and their guns, knowing their designs, speed, tonnage, armaments, and battle tactics.

One of the first dedicated warships he built was the Mary Rose, one of the most imposing of the time. The Mary Rose was not just a ship; she was a symbol of England's burgeoning naval ambitions, a showcase of the technological advancements of the era, and a harbinger of the mighty fleets that would come to dominate the seas in centuries to follow.

The Mary Rose's final battle in the Solent

The idea of a dedicated warship was still relatively novel in the early 1500s. Before this period, most naval engagements were fought using ships that were originally designed for trade or transport, hastily armed with cannons and soldiers. But as the importance of naval power grew, so did the need for ships specifically designed for warfare. This shift was reflected in the construction of the Mary Rose.

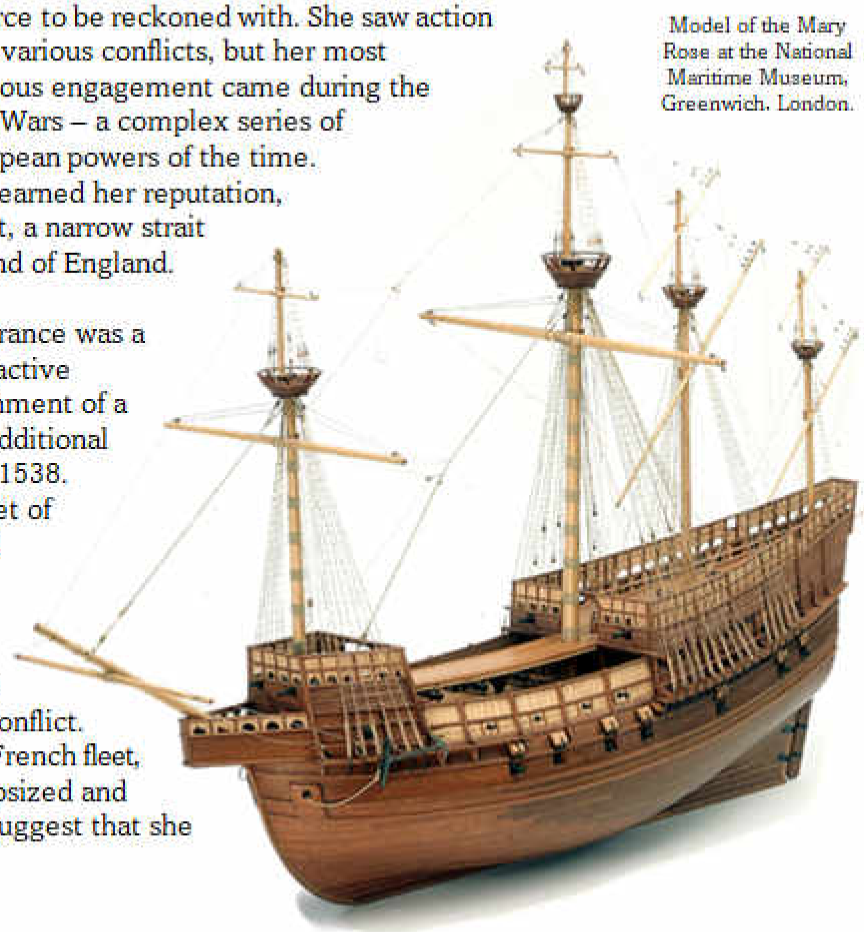
Laid down in 1510 and launched in 1511, the Mary Rose was built under the watchful eye of Henry VIII himself. At nearly 600 tons, she was a massive ship for her time, capable of carrying a crew of over 400 men. Her design was revolutionary, embodying the transition from the medieval cog and carrack to the purpose-built warship. The Mary Rose was equipped with heavy artillery on her gun decks, making her one of the first ships in history to feature broadside firing – a hallmark of naval design that would dominate warship construction for the next three centuries.



Ensign of the Tudor Navy.

The Mary Rose was intended to be the pride of Henry's fleet, a vessel that could enforce England's will on the seas. Her name, like many of Henry's creations, carried deep symbolism. "Mary" was likely in homage to the Virgin Mary, while "Rose" represented the Tudor emblem. Thus, the ship bore the dual legacy of faith and dynasty, embodying the ideals of a Christian warrior king and the unshakeable sovereignty of the Tudor line.

From her earliest days, the Mary Rose was a force to be reckoned with. She saw action in various conflicts, but her most famous engagement came during the Italian Wars – a complex series of conflicts that involved most of the major European powers of the time. It was during this period that the Mary Rose earned her reputation, fighting against the French fleet in the Solent, a narrow strait separating the Isle of Wight from the mainland of England.



Model of the Mary Rose at the National Maritime Museum, Greenwich, London.

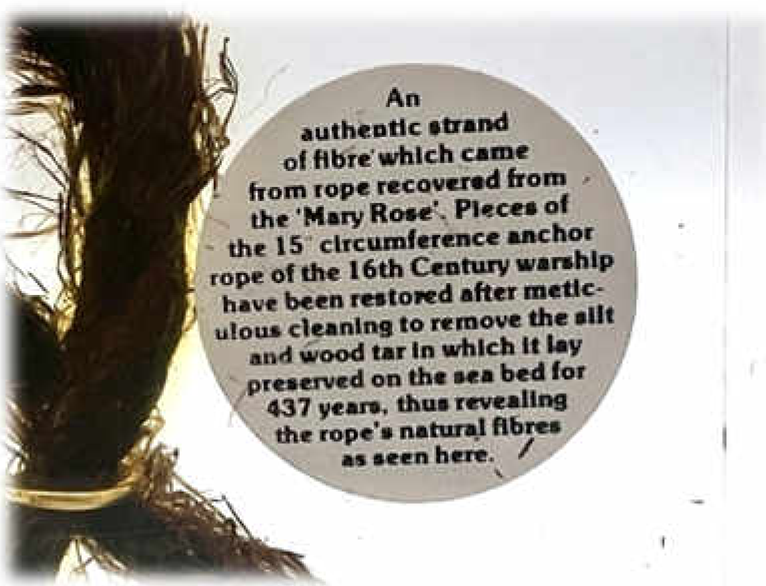
In the end, the chief result of the war with France was a decision to keep the King's fleet of 30 ships active during peacetime. This entailed the establishment of a number of shore facilities, and the hiring of additional administrators; a royal shipwright appears in 1538. By 1540 the navy consisted of 45 ships, a fleet of 20 ships was sent to Scotland in 1544 to land troops to burn Edinburgh, and in 1545 Lord Lisle had a force of 80 ships fighting a French force of 130 attempting to invade England in conjunction with the Battle of the Solent. This was to be the Mary Rose's last conflict. On July 19, 1545, during a skirmish with the French fleet, the Mary Rose suddenly and inexplicably capsized and sank in the Solent. Contemporary accounts suggest that she heeled over sharply, taking on water through her open gun ports. Within minutes, the pride of Henry VIII's fleet was lost, taking with her nearly all of her crew. In that same year a memorandum established a "king's majesty's council of his marine", the first formal organization comprising seven officers, each in charge of a specific area, presided over by "Lieutenant of the Admiralty" or Vice-Admiral Thomas Clere. When war was not at hand the Navy was mostly occupied with chasing pirates.

The Mary Rose Museum.

The sinking of the Mary Rose was a blow to Henry's naval ambitions, but it also marked a pivotal moment in naval history. The loss of such a significant warship underscored the inherent dangers of naval warfare and the challenges of managing such powerful and complex vessels. In many ways, the tragedy of the Mary Rose highlighted the growing pains of a navy transitioning from medieval traditions to modern warfare.

For centuries, the Mary Rose lay forgotten beneath the waters of the Solent, her timbers buried in the silt. It wasn't until 1982 that she was raised from her watery grave, offering a unique glimpse into the world of 16th-century naval warfare. The preservation of the Mary Rose and the thousands of artifacts recovered from her wreck have provided historians and archaeologists with invaluable insights into the life and times of Tudor sailors, as well as the technological advancements of the period.

The Mary Rose today.



This second Lucite contains a strand of rope.

These Lucites came from the Mary Rose Museum in Portsmouth.

Lucite with Colt Derringer

A derringer is a small handgun that is neither a revolver nor a semi/fully automatic pistol. It is not to be confused with mini-revolvers or pocket pistols. The modern derringer is often multi-barreled, and is generally the smallest usable handgun of any given caliber and barrel length due to the lack of a moving action, which takes up more space behind the barrel. It is frequently used by women because it is easily concealable in a purse or a stocking.

The original Philadelphia Deringer was a muzzle-loading cap lock single-shot pistol introduced in 1825 by Henry Deringer. In total, approximately 15,000 Deringer pistols were manufactured. All were single barrel pistols with back-action percussion locks, typically .41 caliber with rifled bores, and walnut stocks. Barrel length varied from 1.5 to 6 in, and the hardware was commonly a copper-nickel alloy known as “German silver”.

The term “derringer” (/ˈdɛrɪndʒər/) became a genericized misspelling during the reporting of the Lincoln assassination, which was committed with a concealed Philadelphia Deringer. Many copies of the original Philadelphia Deringer pistol were made by other gunmakers worldwide, and the name remained often misspelled; this misspelling soon became an alternative generic term for any pocket pistol, along with the generic phrase “palm pistol”, which Deringer’s competitors invented and used in their advertising. With the advent of metallic cartridges, pistols produced in the modern form are still commonly called “derringers”.

The actual gun used to assassinate Lincoln.

The most famous case involving a derringer is the assassination of President Abraham Lincoln. On April 14, 1865, John Wilkes Booth used a Philadelphia Deringer pistol to shoot Lincoln at Ford’s Theatre in Washington, D.C.

Lucite with Piece of the Oval Office Floor Supporting Six Presidents, 1934 - 1964

A present from President Ronald Reagan to friends and supporters, a small piece of the cork flooring from the Oval Office embedded in Lucite. Inscription in gold leaf printing reads "This fragment of cork was part of the floor installed in the White House Oval Office in 1934. The floor supported six Presidents of the United States before it was removed in 1969. Ronald Reagan". This artifact came in a metal rim jewel case with embossed gold Presidential Seal, sitting in blue velvet.

Together with the phone exchange Lucite a few pages later, these two artifacts have heard the private words of every president from Roosevelt to Reagan.

Roosevelt & the floor.

Nixon's Oval Office.

Auschwitz III / Monowitz IG Farben Employee Mug, 1945

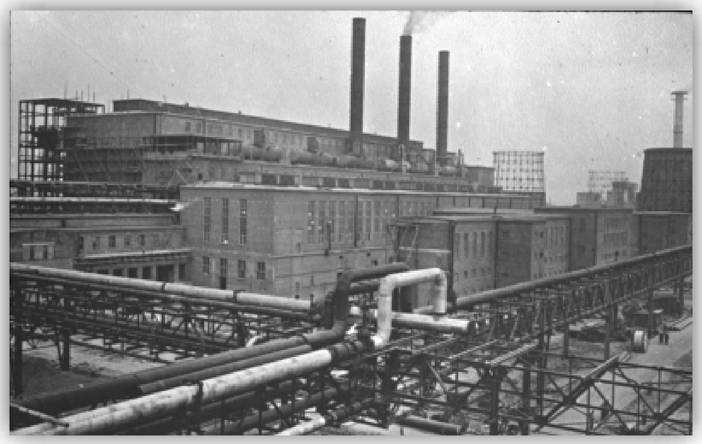
The camp in Monowice was one of the first and the largest of the industrial sub-camps of Auschwitz. Its founding was connected to the German chemical concern IG Farben, notorious for manufacturing the Zyklon B gas used in the Nazis' gas chambers, planning to build a plant for synthetic rubber and liquid fuels beyond the range of Allied bombers.

Among the several sites proposed in late 1940, the final choice fell on the flat land between the eastern part of Oświęcim and the villages of Dwory and Monowice in Silesia. The belief that it would be possible for the firm to employ prisoners from the nearby Auschwitz concentration camp may have been decisive in the choice of the project.

IG Farben bought the land in early 1941 for a knock-down price after it had been seized from its Polish owners without compensation; their houses were vacated and demolished. At the same time, the German authorities expelled the Jews from Oświęcim, confiscated their homes, and sold them to IG Farben as housing for company employees.

IG Farben officials reached an agreement with the camp commandant on hiring prisoners at a preferential rate of 3 to 4 marks per day. In a letter to his colleagues about the negotiations, IG Farben director Otto Ambros wrote that "our new friendship with the SS is very fruitful."

Trucks ferried the first prisoner detail to work on plant construction in the spring of 1941. The labor was hard: leveling ground, digging drainage ditches, laying cables, and building roads. By early November the camp population was 2,000, rising to over 11,000, mostly Jews, in July 1944.



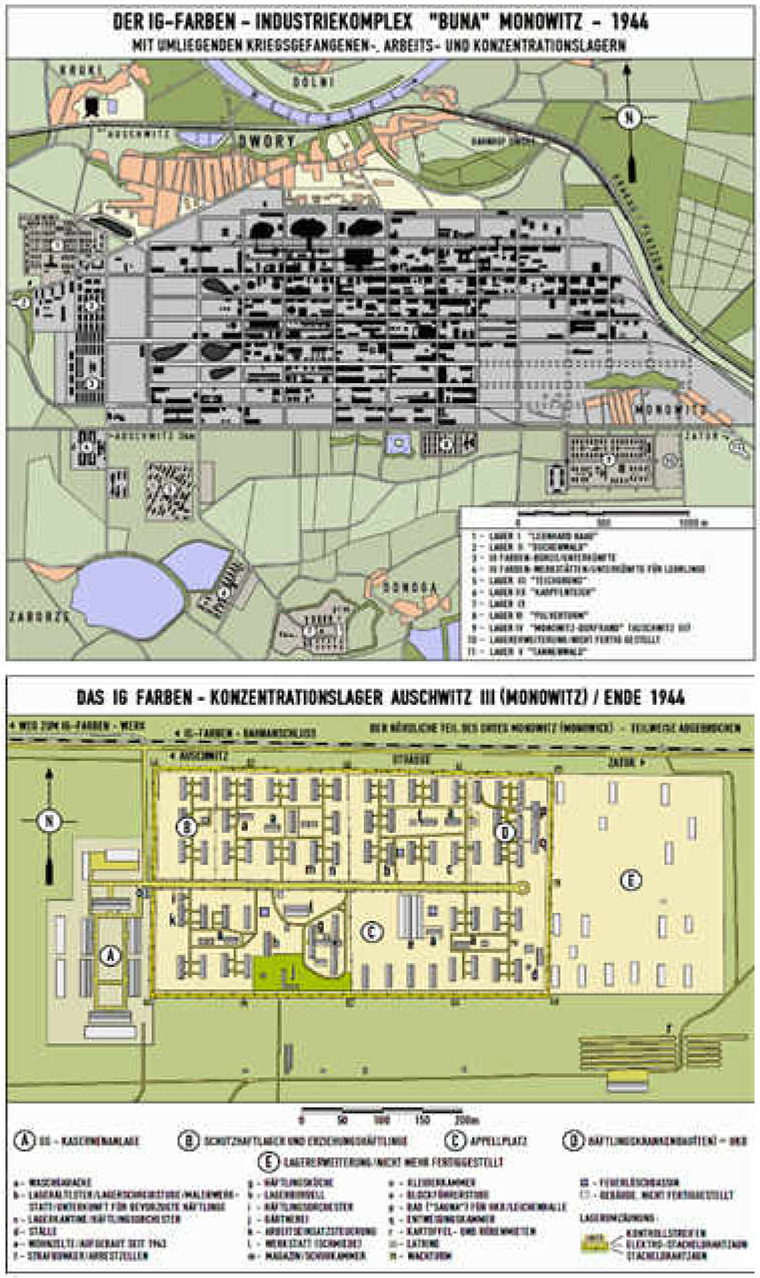
Bundesarchiv, Bild 146-2007-0056 / CC BY-SA 3.0

This growth occurred despite significant mortality in the camp and numerous "selections." Factory management insisted on removing sick and exhausted prisoners; the company, they argued, had not invested large amounts of money in building barracks to house prisoners incapable of labor.

Bundesarchiv, Bild 146-2007-0068 / CC BY-SA 3.0

After repeated memos and complaints about productivity, SS-Obersturmbannführer Gerhard Maurer traveled to Oświęcim on February 10, 1943. He promised the prompt supply of another 1,000 prisoners, and the systematic "exchanging" of those no longer capable of hard labor at the factory. They were taken to the hospital in the main camp, where most of them were killed by lethal injection of phenol to the heart, or to Birkenau, where most were murdered immediately in the gas chambers. A total of about 10,000 prisoners lost their lives as a result.

Foremen were in charge of the various labor details, and constantly demanded that the capos and SS men enforce higher productivity by beating prisoners. Management approved such methods. Maximilian Faust, the engineer in charge of construction, repeatedly stated in his reports to corporate headquarters in Frankfurt that the only way to keep productivity satisfactory was through the use of violence and corporal punishment. While declaring his own opposition to “flogging and mistreating prisoners to death,” Faust nevertheless added that “achieving the appropriate productivity is out of the question without the stick.”



HEROMAX / CC BY-SA 3.0

The fact that the prisoners, despite the beatings, worked more slowly than German workers was a source of irritation and dissatisfaction to factory management. Soon, a group of specially chosen German common criminal capos was sent to Monowice. When this too failed to yield results, IG Farben officials proposed the introduction of a “rudimentary piecework system” and a motivational scheme including the right to wear watches, longer hair, the payment of scrip that could be used in the camp canteen to buy cigarettes and other low-value trifles, and free visits to the camp bordello.

However, these steps had hardly any real effect on productivity. Only in December 1944, at the conference in Katowice, was attention paid to the true causes of low prisoner labor productivity: the motivational system was characterized as ineffective and the capos as “good,” but it was admitted that the prisoners worked slowly simply because they were hungry.

In January 1945, the majority of the prisoners were evacuated on foot to Gliwice, and then carried by train to the Buchenwald and Mauthausen camps. Prisoners at the camp in Monowice included the Nobel Peace-Prize winner Elie Wiesel and the prominent Italian writer Primo Levi.

This IG Farben coffee mug with a company logo was found in a house near the camp. It came via an eBay seller in Poland from a collector who exhibits in the Birkenau Museum.


Today.


Koos Winkelman / CC BY-SA 4.0

Ajax F-21 KGB Spy Camera, 1952 – 1995

The KMZ F-21 Ajax is a subminiature spy camera produced and built by the Krasnogorski Mekhanicheskii Zavod (KMZ), the Mechanical Factory of Krasnogorsk, between 1951 and 1995. The F-21 was designed and manufactured specifically for the KGB and was highly favored by Soviet intelligence for its diminutive size, only 77 x 54 mm, and ease of use. During a mission, the Ajax could be surreptitiously operated with a remote shutter cable and concealed within a number of specially made disguises including coat buttons, belt buckles, purses, and even full-sized camera cases.

Designed with discretion and ease of use in mind, the F-21 Ajax has a minimal number of controls. With the exception of the aperture which can be adjusted by rotating the ring at the base of the lens, all of the spy camera's buttons and dials are located on the top plate. Starting from the user's left-hand side, is the shutter button with threading for the shutter release cable, shutter speed selector, winding knob for the spring motor, and the frame counter reset knob surrounded by the semicircular frame counter.

Because spies probably shouldn't be seen manually advancing the film on their secret belt buckle cameras in the middle of a mission, the F-21 is motor-driven. By fully winding the spring motor before concealing the camera, the frame will automatically advance with each shutter depression.

To ensure acceptable image quality, this spy camera is equipped with a very sharp, fixed-focus 28mm f/2.8 lens that can be used at four available speeds: 1/100, 1/30, 1/10, and bulb. To match its tiny size, the Ajax uses a miniscule cartridge loaded with 21mm film which must be cut to size from standard 35mm film.

Compared to later 35 mm cameras, such as the Kiev-35A and most domestic camera of the analogue era, the F-21 can be regarded as a half-frame camera. The design was clearly inspired by the wartime Robot Star cameras that also featured a windup mechanism. The F-21 was succeeded in 1985 by the F-27 Neozit 2 and in 1989 by the Zakhod. The Ajax-21 has the distinction of being one of the longest produced single model cameras in the world, with a production run from 1952 to about 1995.

The F-21 Ajax is still illegal to own in some places due to its role as an espionage tool. In 2013, Ukrainian camera collector Alexandr Komarov was arrested for owning two of these and faced up to seven years in prison.

Who knows where this camera has been, and what it has seen and documented?

Lucite with Fragment of the Berlin Wall, 1961 – 1989

On August 13, 1961, the Communist government of the German Democratic Republic (GDR, or East Germany) began to build a barbed wire and concrete "Antifascistischer Schutzwall," or "antifascist bulwark," between East and West Berlin. The official purpose of this Berlin Wall was to keep so-called Western "fascists" from entering East Germany and undermining the socialist state, but it primarily served the objective of stemming mass defections from East to West. The Berlin Wall stood until November 9, 1989, when the head of the East German Communist Party announced that citizens of the GDR could cross the border whenever they pleased. That night, ecstatic crowds swarmed the wall. Some crossed freely into West Berlin, while others brought hammers and picks and began to chip away at the wall itself. To this day, the Berlin Wall remains one of the most powerful and enduring symbols of the Cold War.

As World War II came to an end in 1945, a pair of Allied peace conferences at Yalta and Potsdam determined the fate of Germany's territories. They split the defeated nation into four "allied occupation zones": The eastern part of the country went to the Soviet Union, while the western part went to the United States, Great Britain and (eventually) France. Even though Berlin was located entirely within the Soviet part of the country (it sat about 100 miles from the border between the eastern and western occupation zones), the Yalta and Potsdam agreements split the city into similar sectors. The Soviets took the eastern half, while the other Allies took the western. This four-way occupation of Berlin began in June 1945.

Keystone/Stringer via Getty Images

The existence of West Berlin, a conspicuously capitalist city deep within communist East Germany, "stuck like a bone in the Soviet throat," as Soviet leader Nikita Khrushchev put it. The Russians began maneuvering to drive the United States, Britain and France out of the city for good. In 1948, a Soviet blockade of West Berlin aimed to starve the western Allies out of the city. Instead of retreating, however, the United States and its allies supplied their sectors of the city from the air. This effort, known as the Berlin Airlift, lasted for more than a year and delivered more than 2.3 million tons of food, fuel and other goods to West Berlin. The Soviets called off the blockade in 1949.

ullstein bild / GRANGER

After a decade of relative calm, tensions flared in 1958. For the next three years, the Soviets – emboldened by the successful launch of the Sputnik satellite the year before during the "Space Race" and embarrassed by the seemingly endless flow of refugees from east to west –blustered and made threats, while the Allies resisted. Summits, conferences and other negotiations came and went without resolution. Meanwhile, the flood of refugees continued. In June 1961, some 19,000 people left the GDR through Berlin. The following month, 30,000 fled. In the first 11 days of August, 16,000 East Germans crossed the border into West Berlin, and on August 12 some 2,400 followed – the largest number of defectors ever to leave East Germany in one day.

That night, Premier Khrushchev gave the East German government permission to stop the flow of emigrants by closing its border for good. In just two weeks, the East German army, police force and volunteer construction workers had completed a makeshift barbed wire and concrete block wall – the Berlin Wall – that divided one side of the city from the other.

Before the wall was built, Berliners on both sides of the city could move around fairly freely. They crossed the East-West border to work, to shop, to go to the theater and the movies. Trains and subway lines carried passengers back and forth. After the wall was built, it became impossible to get from East to West Berlin except through one of three checkpoints: at Helmstedt ("Checkpoint Alpha" in American military parlance), at Dreilinden ("Checkpoint Bravo") and in the center of Berlin at Friedrichstrasse ("Checkpoint Charlie"). (Eventually, the GDR built 12 checkpoints along the wall.) At each of the checkpoints, East German soldiers screened diplomats and other officials before they were allowed to enter or leave. Except under special circumstances, travelers from East and West Berlin were rarely allowed across the border.

The construction of the Berlin Wall did stop the flood of refugees from East to West, and it did defuse the crisis over Berlin. (Though he was not happy about it, President John F. Kennedy conceded that "a wall is a hell of a lot better than a war.") Almost two years after the Berlin Wall was erected, John F. Kennedy delivered one of the most famous addresses of his presidency to a crowd of more than 120,000 gathered outside West Berlin's city hall, just steps from the Brandenburg Gate. Kennedy's speech has been largely remembered for one particular phrase. "Ich bin ein Berliner."


picture alliance via Getty Images

Roland Arhelger / CC BY-SA 4.0

In all, at least 171 people were killed trying to get over, under or around the Berlin Wall. Escape from East Germany was not impossible, however. From 1961 until the wall came down in 1989, more than 5,000 East Germans (including some 600 border guards) managed to cross the border by jumping out of windows adjacent to the wall, climbing over the barbed wire, flying in hot air balloons, crawling through the sewers and driving through unfortified parts of the wall at high speeds.

On November 9, 1989, as the Cold War began to thaw across Eastern Europe, the spokesman for East Berlin's Communist Party announced a change in his city's relations with the West. Starting at midnight that day, he said, citizens of the GDR were free to cross the country's borders. East and West Berliners flocked to the wall, drinking beer and champagne and chanting "Tor auf!" ("Open the gate!"). At midnight, they flooded through the checkpoints.

More than 2 million people from East Berlin visited West Berlin that weekend to participate in a celebration that was, one journalist wrote, "the greatest street party in the history of the world." People used hammers and picks to knock away chunks of the wall–they became known as "mauerspechte," or "wall woodpeckers" – while cranes and bulldozers pulled down section after section. Soon the wall was gone and Berlin was united for the first time since 1945. "Only today," one Berliner spray-painted on a piece of the wall, "is the war really over."

The reunification of East and West Germany was made official on October 3, 1990, almost one year after the fall of the Berlin Wall.

Mr. Gorbachev (who died the day before this writing), tear down this wall!
Stringer Germany/REUTERS

Lucite with White House Phone Relay Used by Five Presidents, 1966 - 1986

This line relay was part of the Centrex Telephone System installed by the Chesapeake and Potomac Telephone Company (C&P Telephone) in the White House in August 1966. The system provided telephone communications in excess of 250 million calls while supporting five United States Presidents. The system was replaced by a digital Centrex (vs PBX) system in May 1986. C&P Telephone was a Bell Operating Company; there are a few entries elsewhere in this book touching on Bell and its influence on technology – including the invention of the transistor and digital signal processing (DSP) chips which replaced relays such as this.

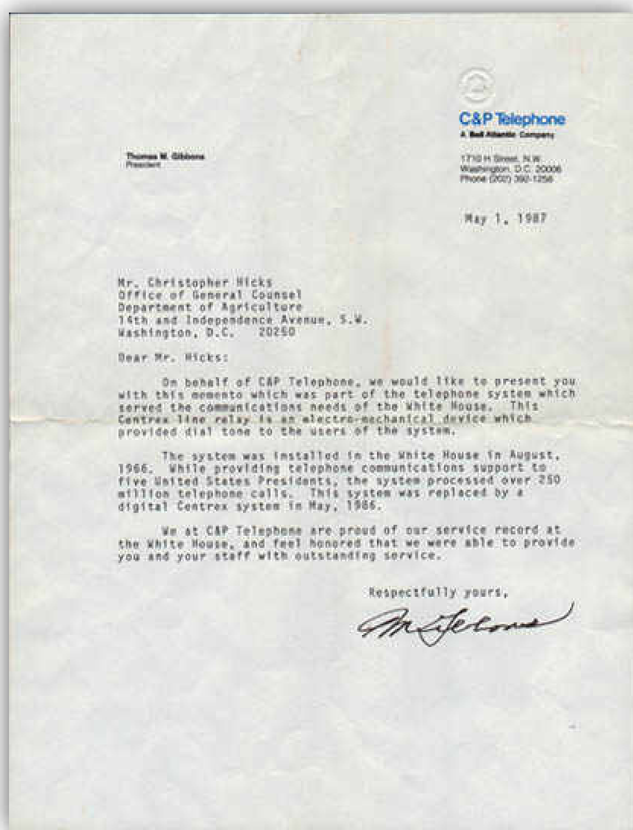
Together with the Oval Office cork floor Lucite a few pages back, these two artifacts have heard the private words of every president from Roosevelt to Reagan.

Did this object carry the voice of Richard Nixon as he spoke with Buzz Aldrin and Neil Armstrong from the Oval Office while they were on the surface of the moon?

On behalf of C&P Telephone, we would like to present you with this memento which was part of the telephone system which served the communications needs of the White House. This Centrex line relay is an electro-mechanical device which provided dial tone to the users of the system.

The system was Installed in the White House in August, 1966. While providing telephone communications support to five United States Presidents, the system processed over 250 million telephone calls. This systeas replaced by a digital Centrex system in May, 1986.

We at CAP Telephone are proud of our service record at the White House, and feel honored that we were able to provide you and your staff with outstanding service.



C&P Telephone
A Bell Atlantic Company
1710 H Street, N.W.
Washington, D.C. 20006
Phone (202) 392-1256

Thomas M. Gibbons
President

May 1, 1987

Mr. Christopher Hicks
Office of General Counsel
Department of Agriculture
14th and Independence Avenue, S.W.
Washington, D.C. 20250

Dear Mr. Hicks:

On behalf of C&P Telephone, we would like to present you with this memento which was part of the telephone system which served the communications needs of the White House. This Centrex line relay is an electro-mechanical device which provided dial tone to the users of the system.

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We at C&P Telephone are proud of our service record at the White House, and feel honored that we were able to provide you and your staff with outstanding service.

Respectfully yours,

This letter, which accompanied an identical artifact, is not in my collection.

Lyndon B. Johnson (1963-1969) | **Richard M. Nixon** (1969-1974) | **Gerald R. Ford** (1974-1977) | **Jimmy Carter** (1977-1981) | **Ronald Reagan** (1981-1989)

General Viktor Alidin's Lucite, Commemorating the 50th Anniversary of the KGB, 1967

Viktor Ivanovich Alidin was born on October 16, 1911, in the small, unassuming town of Kimry, nestled in the Tver Region of Russia. The son of a working-class family, Alidin was determined to rise above his humble circumstances. When he graduated in 1927, the Soviet Union was in the throes of transformation, and young Viktor found himself caught up in the currents of change. He briefly worked as an apprentice cutter in a local shoe workshop, but his drive and work ethic quickly propelled him forward, and by 1930, he was on his way to a different kind of service.

In that year Alidin was sent on a Komsomol voucher to work in the criminal investigation department of the local police. It was an unusual move for a young man with no formal training in law enforcement, but this was the sort of opportunity that Soviet society offered to those willing to take it. Within three years, he headed criminal investigations in Kimry.

In 1933, Alidin was called up for military service, a turning point that would take him away from provincial life and thrust him into the heart of Soviet power. He was assigned to the dreaded OGPU, the precursor to the NKVD and, in turn, the KGB, and served on an armored train.

He soon rose to be secretary of the Komsomol bureau of the 56th Railway Regiment, a role that combined his organizational skills with his growing mastery of the Soviet system.

Demobilized in 1937, Alidin returned to civilian life, but not for long. The Soviet Union was again entering a period of upheaval, and the Communist Party needed capable men to help steer the ship of state. Alidin, with his blend of military and administrative experience, was a natural choice. He was soon appointed to various positions within the party apparatus in Ukraine, where he distinguished himself as capable and loyal.

When the "Great Patriotic War" erupted for Russia in 1941, Alidin found himself once again at the forefront of events. He distinguished himself by playing a crucial role in organizing the people's militia and partisan detachments in Ukraine. His conduct during the war years was notable; at one point in October 1941 he was completely surrounded by enemy forces, but managed a daring breakthrough to his own lines.

Alidin continued to grow in stature. In 1944, Sergei Savchenko, People's Commissar of the State Security, drew attention to the strong wave of antisemitism taking place at that time. His report cited examples of antisemitic utterances and wrongdoings against the Jews, including refusing to hire them, by Ukrainian administrators. Savchenko concluded the report with the recommendation to arrest the instigators of antisemitic rumors. Instead, several apparatchiks, headed by the ever more powerful Viktor Alidin, condemned him and

suggested that on the contrary, perhaps Savchenko should crack down harder on increased Zionism. Despite "seeing the light" and quickly organizing repressions against Jews in western Ukraine, it was too late for Savchenko's career.

The war years had solidified Alidin's reputation as a man of action, and afterwards he continued his ascent through the ranks of the Soviet government. In 1951, he was appointed to the Ministry of State Security (MGB) and quickly rose to the position of head of the 7th Directorate. In that role he became a key figure within the KGB, overseeing external surveillance operations, colloquially known as the "stompers".

He was appreciative of Stalin's direct role in the security apparatus, once explaining that "Stalin worked with young operatives at the Ministry of State Security like a professor works with postgraduates, infusing them with hope. He invited them to visit him at his summerhouse, personally revised documents, and told them how to draw up bills of indictment. He personally devised which questions investigators should pose. He personally decided who should be arrested and when, and which prison to keep them in. It can be said that Stalin performed the duties of the head of the Investigations Department for Especially Important Matters of the Ministry of State Security on a social basis."

Alidin's career was not without its trials. In the mid-1950s, after Stalin's death, he was demoted to head a less significant department within the Ministry of Internal Affairs, a move that might have signaled the end of his career. But Alidin was a sophisticated player, and soon returned to his former position, now within the KGB, where he promptly resumed his trajectory and was promoted to colonel and later major general.

This photo transparency in glass is also in my collection.

Alidin was tangentially connected to the theft of samples of formulas to solid rocket fuels for American nuclear capable Inter-Continental Ballistic Missiles (ICBMs), in an anecdote that illustrates his ruthlessness. In the 1960s, Oleg Kalugin, former head of counterintelligence for the KGB (and later a defector to the US), had recruited Anatoly Kotlobai, a Thiokol employee code named "Cook" who was passing along classified information about rocket fuel.

Around this time, Kalugin also caught Viktor Alidin's son-in-law embezzling payments intended for KGB operatives. Kalugin recommended tough action, but Solomatin, his rezident, limited the response to a reprimand to avoid the trouble with Alidin that would have followed any stronger action. According to Kalugin: "Victor Alidin was an abominable KGB officer, with a solid reputation for brutality and widely reviled. Yet, he was extremely close to Premier Brezhnev".

This did not deter Alidin from a vigorous response, and he used the Thiokol affair as an excuse to persecute Kalugin, who later said that "Alidin & Company engaged in the worst possible behavior as investigators. Using their well-exercised nefarious stratagems, they were able to make right look wrong and good look bad. After being surreptitiously interviewed formally by Alidin and his investigators under the guise that they were fact-finding and needed his help in investigating Cook of Thiokol, it did not take Kalugin long to figure out what they were driving at. Kalugin's description of the moment when he became conscious of his KGB investigators' plans against him was chilling."

It didn't end well for "Cook" either. After he arrived in the Soviet Union and had been debriefed for more than a year, he was assigned to work as a scientist in a major Moscow chemical plant. The scientist, who had long held an idealistic view of life under Communism, was evidently shocked by the degradation and fear that characterized Soviet life. Confident that Soviet authorities would want to hear his criticism of our Communist experiment, the naive Cook began to speak out.

He also espoused a brand of radical pro-Mao Tse-Tung Marxism at a time when Soviet-Chinese relations were hostile. Cook was, of course, surrounded by informers, and soon his KGB dossier began to grow thicker. He became such a nuisance to the factory directors that they forced him out. He then was given a job at the Institute of World Economics where he continued to criticize the system. Eventually the Moscow branch of the KGB decided it could no longer ignore this troublemaker and trumped up some charges.

Alidin's influence within the KGB continued to grow, and by 1967, he had become a member of the KGB Collegium, at the center of the Soviet security apparatus. His long career in the shadowy world of Soviet intelligence reached its zenith in 1971 when he was appointed head of the KGB for Moscow and the Moscow region. This position placed him at the heart of some of the Soviet Union's most sensitive operations in the country, a role he performed with characteristic efficiency. One of his first orders in this new role was to repair the clocks on the old building of the Moscow KGB directorate. They had not worked for many years, and Alidin insisted on their restoration, saying, "Let the passersby know that the Moscow KGB officers work like clockwork."

During this period, Alidin was a key actor in what later became known as the "Efremov Affair". Ivan Antonovich Efremov was a renowned paleontologist and science fiction author, best known for his works that often intertwined scientific ideas with utopian and philosophical themes. However, his writings, which celebrated human progress and criticized authoritarianism in subtle ways, led to suspicions about his loyalties at a time when the Soviet state was deeply concerned about ideological purity. Alidin initiated a politically motivated investigation into Efremov, centered on baseless accusations of espionage on behalf of Great Britain. The charges were grave, and the crime of espionage often carried the death penalty or long-term imprisonment, but no conclusive evidence of espionage ever surfaced, and the case never resulted in a trial or conviction. The charges were eventually quietly dropped, and Efremov continued his work until his death in 1972. The "Efremov Affair"" showed the harsh and unpredictable nature of Soviet governance, where even celebrated intellectuals could find themselves targets of suspicion and repression.

In 1973, Alidin directed the rescue operation during a Yak-40 passenger plane hijacking, and went on to play a key role in establishing specialized anti-terrorism units and protocols. During another hijacking in 1976, these protocols led to a successful redirection of the plane, and cooperation of the flight attendants in identifying suspects. Alidin personally interrogated all the passengers. The investigation ultimately identified Anatoly Popov, wanted for embezzlement, as the hijacker. The KGB then orchestrated an elaborate operation to apprehend him, successfully capturing him at a staged birthday party.

When Moscow was preparing to host the 1980 Summer Olympic Games, the situation was tense after the USSR's recent invasion of Afghanistan, Western countries were calling for a boycott, and terrorist "chatter" was high. Alidin was responsible for securing Moscow from all threats, and initiated a crackdown on suspected terrorists and criminal elements, such as a gang of "Baza Nazis" who would meet foreigners at Sheremetyevo Airport, take them to their hotels posing as KGB officers, and rob them. Along with hundreds of other criminals, they were "neutralized" by the KGB in advance of the Games. The Moscow Olympics proceeded peacefully and without serious incident. At the end of the event, during a press conference, a Swedish journalist asked, "Which team performed the best?" The answer was, "The [KGB] team".

This brutal, terrifying, hardworking instrument of the state's life of service to the Soviet Union was recognized with numerous honors and a total of 56 medals, including three Orders of Lenin. Retired in 1986, Alidin spent his final years away from the corridors of power, witnessing the dissolution of the state he had so faithfully served.

Viktor Ivanovich Alidin died on January 9, 2002 after a surgical procedure, and was laid to rest at the Vagankovo Cemetery in Moscow. His son also became an intelligence officer. General Alidin's uniform, with its 56 ribbons, is preserved in the museum of the FSB in Moscow, while two of his desk ornaments are preserved in my collection.

General Alidin commissioned or was given this Lucite for his desk on the occasion of the KGB's 50th anniversary, and it was purchased from his estate along with the photo in glass.

Lucite with Ronald Reagan Thank You and Initials, 1980s

There really isn't any way to know which task force The Gipper was referring to. Task Force sounds super action packed, but it probably wasn't. Your options are the:

President's Private Sector Survey on Cost Control (also known as the Grace Commission): Formed in 1982, this task force was charged with investigating and identifying inefficiency and waste in the federal government. It was led by businessman J. Peter Grace and sought to find ways for the government to save money and be more fiscally responsible.

National Bipartisan Commission on Central America: Established in 1983, this task force, also known as the Kissinger Commission after its chairman, former Secretary of State Henry Kissinger, was created to assess and make recommendations regarding U.S. policies towards Central America, which was experiencing significant political and civil unrest at the time.

President's Task Force on Victims of Crime: Initiated in 1982, this group was set up to examine the treatment of crime victims in the justice system and to make recommendations for improvements. It led to various legislative initiatives aimed at enhancing the rights and services available to victims of crimes.

President's Commission on Organized Crime: Formed in 1983, this commission was tasked with analyzing the impact of organized crime in America and suggesting ways to counteract its influence.

A statistical analysis of mobsters is about as exciting as Task Force is going to get.

© AG/Keystone USA/Rex Features

Lucite with Flown Army M47 Dragon Rocket Engine, 1969

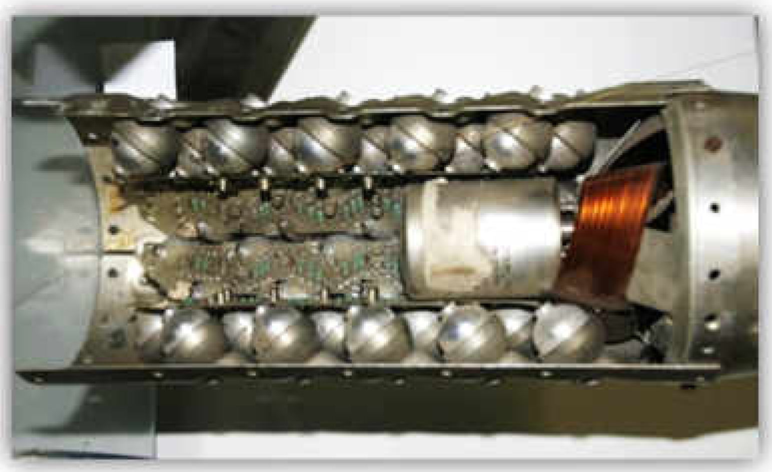
In the 1970s, the United States produced what might be considered one of the worst anti-tank guided missiles (ATGM) of all time. The M47 Dragon was slow, quirky and took forever to reach its target.

What made the M47 Dragon bad? The primary reason is the Dragon's propulsion system. Instead of a simple arrangement of a continuous burn rocket motor and fins, the M67 Dragon featured many rings of tiny rocket engines which "popped" off in short bursts to adjust the missile's flight path. This led to a myriad of downsides. The missile's guidance was erratic, with the missile jumping around in flight as the bursts fired off. The bursts were loud and distinctive, they would warn a target that a Dragon had been fired and was closing on them.

Finally, in certain environmental conditions, the bursts could leave a trail of smoke puffs, which could give away the position of the gunner. The burst-engine method didn't even make the missile fast. In fact, it was slower than most of its counterparts, taking over eleven seconds to reach its effective range of 1 kilometer out.

Guidance itself was accomplished by tracking an infrared flare on the rear of the missile, similar to the TOW. This meant that the Dragon could be defeated by the Soviet and Russian Shtora active protection system.

The Dragon was usable at night, but doing so required an additional night-sight that needed even more equipment. Canisters of freon were used to cool the night sight's sensors, but this was only effective for two hours.

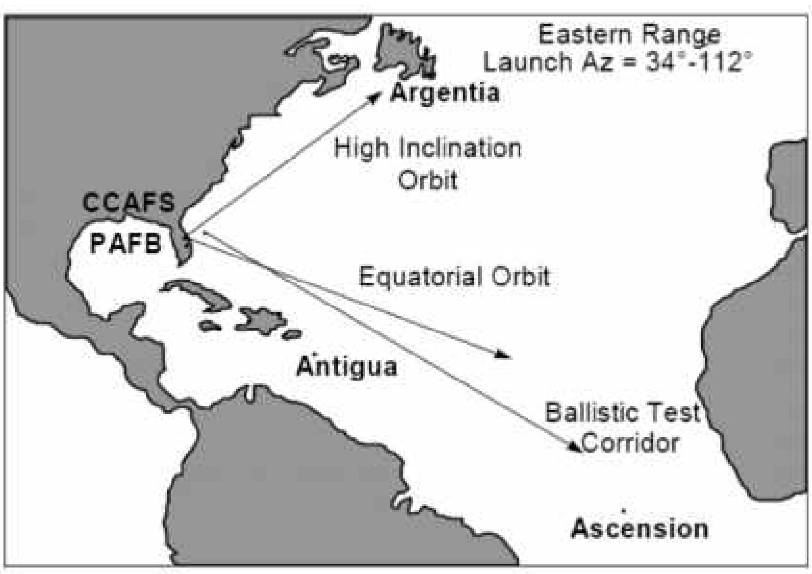


The United States would upgrade the M47 Dragon into the Dragon II and Super Dragon, which boosted the range and penetrating power of the missile. But these upgrades didn't solve the primary flaw of the Dragon, the propulsion system. By the 1980s, the United States was looking into replacing the Dragon. The program was initially called the Advanced Anti-Tank Weapon System – Medium. After a competitive process that ruled out a laser-beam riding missile and a fiber-optic link missile (similar to the Israeli Spike), Texas Instruments won the contract and began developing the Javelin, a far superior weapon.

Aside from being a rocket engine, this artifact has another cool link to space history. Complex 44 (see Lucite text) is part of the AFETR, now known as the Eastern Range (ER). The ER is an American rocket range (Spaceport) that supports missile and rocket launches from the two major launch heads located at Cape Canaveral Space Force Station and the Kennedy Space Center (KSC), Florida. The range has also supported Ariane launches from the Guiana Space Centre (where the JWST was launched) as well as launches from the Wallops Flight Facility and other lead ranges. The range also uses instrumentation operated by NASA at Wallops and KSC.

It extends from the eastern United States mainland through the south Atlantic Ocean area eastward into the Indian Ocean. It includes all stations, sites, ocean areas, and air space necessary to conduct missile and space vehicle test and development. The range can support launches between 37° and 114° azimuth and its headquarters is the 45th Space Wing at Patrick Space Force Base. The history of the Eastern Range began on January 10, 1940, with the activation of the Banana River Naval Air Station which supported antisubmarine sea-patrol planes during World War II. The station was deactivated and put into a caretaker status in 1947.

Launches of captured German V-2 rockets had been ongoing since the end of World War II at White Sands Proving Grounds in New Mexico, but it became clear that a much longer range away from heavily populated areas would be needed. The Joint Research and Development Board established the Committee on the Long Range Proving Ground in October 1946 to study locations for such a range, with three potential sites emerging: along the northern coast of Washington state with a range along the Aleutian Islands; El Centro, California, with a range along the Baja California Peninsula; and Banana River Naval Air Station with a launch site at Cape Canaveral and a range over the Bahamas and into the Atlantic Ocean. El Centro was put forth as the primary choice (due to being close to missile manufacturers) with the Cape as second choice. However, the El Centro site had to be abandoned after a wayward V-2 missile from White Sands crashed into a cemetery in Juarez, Mexico, leading to then Mexican President Miguel Alemán Valdés refusing to allow missiles to overfly Baja.



On May 11, 1949, President Truman redesignated the Banana River Naval Air Station the Joint Long Range Proving Ground Base and Advance Headquarters. In May 1950, range and base dropped the "Joint" in their names due to a DoD decision earlier in the year to put the range exclusively under U. S. Air Force jurisdiction. On July 24, 1950, Bumper #8 became the first missile to launch from Cape Canaveral; 2024 saw 72 launches from the same facility.

This Lucite contains an actual rocket engine flown during development of this crappy missile.

U.S. & North Korea Singapore Summit Challenge Coin, 2018

One of international relations' most cringeworthy modern spectacles – and the bar is high – took place on June 12, 2018 at Singapore's Capella Hotel on Sentosa Island, where a reality-TV landlord-turned-commander-in-chief strutted in to meet a third-generation despot sporting a haircut that looks as if someone slammed a Soviet mess-kit onto his skull and traced the rim with garden shears. The steamy setting dripped with cheesy boutique-resort chic – the perfect décor for Geopolitical smarm.

In the run-up, Trump publicly fanned himself with the "beautiful letters", "love letters" even, that his pen-pal Kim had mailed, each note allegedly brimming with moist devotion. Kim, taking a break from designing apocalyptic weapons, stealing crypto, rehearsing goose-steps, and chortling at famine statistics, arrived beaming: here at last was the free global legitimization package every dictator covets, gift-wrapped in orange bronzer and delivered by Air Force One.

Five hours, eight handshakes, and one bromantic photo op later, they signed a joint statement so foggy it could wander the DMZ at dawn and never find either side. Trump bragged he had solved nuclear Armageddon "in one meeting," while Kim pocketed the priceless image of an American president treating him as an equal.

Substance, of course, didn't survive all the humidity. "Complete denuclearization of the Korean Peninsula" floated like a trash and shit-filled balloon drifting into oblivion the moment cameras stopped clicking. Kim went home to choreograph yet another parade; Trump flew off to tweet in all caps about peace and Nobel nominations. And maybe choreograph a parade. What endured is the image: two martinets grinning like prom dates, each convinced he'd out-hustled the other, neither noticing – or – caring that the rest of us were choking on the farce.

This challenge coin is extremely rare, apparently these were personally handed out by The Donald. It comes in a fine walnut presentation box.

This much more common challenge coin is available to the general public through the White House gift shop.

Swank packaging.

B-21 Raider Challenge Coins, 2024

The B-21 Raider, the U.S. Air Force's next-generation stealth bomber developed by Northrop Grumman, completed its maiden flight on November 10, 2023. The aircraft departed from Air Force Plant 42 in Palmdale, California, around 6:51 a.m. and landed at Edwards Air Force Base, where it entered an intensive testing phase. This successful first flight marked a major milestone in the program and demonstrated that the aircraft was ready to begin flight evaluations after years of design and development.

As the first sixth-generation aircraft to take to the skies, the B-21 is designed with advanced stealth features, digital integration, and an open systems architecture that will allow it to evolve with future threats. It is intended to replace the aging B-1B Lancer and B-2 Spirit, ultimately serving as the backbone of America's bomber fleet. Capable of carrying both conventional and nuclear munitions, the B-21 plays a central role in the modernization of the nuclear triad – America's three-pronged strategy for nuclear deterrence that includes land-based missiles such as the Minuteman II, submarine-launched ballistic missiles like the Trident, and strategic bombers. The Raider strengthens the air-based leg of this triad by combining long-range strike capability with enhanced survivability against modern air defense.

In a sign of the times, Northrop Grumman and the U.S. Air Force signed an industry-first data rights agreement, opening B-21 data access and collaboration across the program, including the launch of a shared environment for a B-21 digital twin. The goal is to help deliver greater affordability and rapid upgradability throughout the program lifecycle through enhanced transparency and collaboration. Northrop Grumman has placed a high priority on driving digital engineering further into the B-21 enterprise. Northrop Grumman and the Air Force also successfully demonstrated the migration of B-21 ground systems data to a cloud computing environment. This demonstration included the development, deployment and test of a suite of B-21 data, including the B-21 digital twin, that will support B-21 operations and sustainment.

“The B-21 Raider is a true digital native, and this data rights agreement coupled with the cloud based digital twin allow us to drive down risk in the EMD phase, will enable rapid capability upgrades and lowers sustainment cost over the life of the program,” said Doug Young, sector vice president and general manager, Northrop Grumman Aeronautics Systems.

Following its first flight, the aircraft began a period of rigorous testing at Edwards Air Force Base under the guidance of the Air Force Test Center and the 412th Test Wing’s B-21 Combined Test Force. As of spring 2024, the program remains on schedule, with continued flight evaluations and production efforts underway. In September 2024, the Air Force released the first official video of the B-21 in flight, offering a rare public view of the bomber taking off and landing – a glimpse of the strategic aircraft that will quietly shape the future of U.S. airpower and nuclear deterrence for decades to come.

B-21 (AF 0001) in flight in 2024.
What a gorgeous beast.

The coins feature a reaper and the word “PRAENUNTIUS” or “harbinger of things to come”. The unit that is tasked with bringing the B-21 to life’s challenge coin presents another motto that actually pairs directly with the other: “HUC VENIT MALUM.” Literally it means “here comes evil,” but by most indications the motto is a reference to a quote from Shakespeare’s Macbeth, written about 60 years after Henry VIII’s Mary Rose capsized: “something wicked this way comes.”

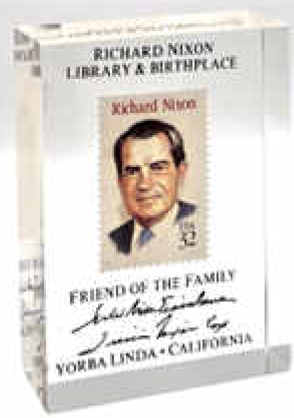
Various Political Lucites

Peanut One, Jimmy Carter's plane.

Dubya inauguration Coke.

60th Anniversary of the CIA.

Great War Ends, American Walks Moon.



Red tape was an actual thing.

Hizzoner, da mayor.

Money

Kroisos Silver 1/3 Stater, 560 – 546 B.C.

Let's start at the beginning, with the world's earliest "real" money. More than two and a half thousand years ago, Kroisos (Croesus), the last king of the Ionian kingdom of Lydia in Asia Minor, ushered in a new era in value exchange when he minted the world's first standardized currency of gold and silver. We learn from the ancient historian Herodotus that the Lydians were the first people to strike gold and silver coins, and that they were the first to engage in retail trade. He also states that young Lydian women earned their dowries by working as prostitutes. Regrettably, he does not clarify the connection, if any, between these three customs.

We do know that Lydia was an enormously wealthy and powerful state when Kroisos ascended the throne around 561 BCE. According to Herodotus, Kroisos once donated four-and-a-half tons of pure gold to the Temple of Apollo at Delphi; at current gold prices, this gift was worth over $250 million USD. He was indeed "as rich as Croesus", the Latin form of Kroisos' name.

During the same period when Kroisos claimed the Lydian crown, Cyrus the Great became the king of Persia and ruler of the Achaemenid Empire. While Kroisos initiated a monetary revolution, Cyrus was preoccupied with conquering the world. By 547 BCE, he had annexed all the Ionian city-states into his empire, with the exception of Lydia.

Kroisos sent a message to the oracle of Apollo at Delphi, asking what would happen if he went to war against Cyrus. The oracle told Kroisos that if he attacked Persia he would destroy a great empire. Kroisos launched his war and, as the oracle foretold, he destroyed a great empire: his own.

Rich as Croesus.

Cyrus captured Kroisos and commanded that he be burned alive on a massive pyre. However, Cyrus, merciful for as a supreme ruler, had a change of heart as the flames climbed higher. Despite his intentions though, the fire had become too intense for the Persians to put out. In desperation, Kroisos beseeched Apollo for salvation. In response, possibly grateful for the four-and-a-half tons of pure gold gifted to his temple earlier, Apollo unleashed a torrential downpour, dousing the flames. Kroisos then served as a valued counselor to Cyrus and lived contentedly ever after. Even the gods have their price.

The obverse of my silver 1/3 stater depicts the confronted foreparts of a lion at left, and a bull with a band around its neck at right. The forelegs of each beast are bent at 90-degree angles. The reverse design consists of two incuse square punches of unequal size, with the larger punch opposite the lion.

Reverse.

Lucite with 4 Reales Coin from Treasure Fleet, 1715

On a sun-drenched summer's day in 1715, a grand assembly of eleven galleons and several smaller vessels, heavy with the plundered spoils of the New World, embarks on its long voyage to Spain from Havana, Cuba. The fleet sails under the command of General Juan Esteban de Ubilla. They would not get far.

Each year, two separate fleets leave Spain loaded with European goods that are in great demand in the Spanish-American colonies. Sailing together down the coast of Africa, the fleets stop at the Canary Islands for provisions before the long voyage across the Atlantic. Once they reach the Caribbean, the two fleets separate. The New Spain fleet, or flota, sails to Veracruz in Mexico to take on silver and other goods, such as porcelain shipped from China and brought overland from Acapulco, Mexico, by mule train. The Tierra Firme fleet, or galeones, travel to Cartagena, Columbia, to take on South American products.

Some ships are sent to Portobelo in Panama to pick up Peruvian silver, while others go to the island of Margarita to collect pearls harvested from offshore oyster beds. Other products include indigo and cochineal dyes, exotic woods, ceramics, leather goods, chocolate, vanilla, sassafras, and tobacco.

Closeup.

After rendezvousing at Havana with the Tierra Firme squadron of Antonio de Echeverz, de Ubilla turns the "Plate Fleet" towards the Atlantic Ocean and the comforts of home on June 24. Destined for the coffers of Spain's embattled and increasingly desperate Philip V, the vessels bear a king's ransom in gold and silver, shimmering jewels, and priceless artifacts. The total value of the treasure has been estimated at over $400 million in today's money. But the sea, as ever, is a fickle mistress.

The route of the Plate Fleets.

A hurricane, ferocious and unforgiving, descends upon the fleet as it navigates the treacherous Florida Straits. The ships, caught in the tempest's fury, are scattered and broken. One by one, they succumb to the waves, their precious cargo sinking to the ocean floor. Eleven galleons lost, their treasures entombed beneath the sands. Over 1,000 people are killed.

The survivors are stranded on the Florida coast, where they subsist on food from the stores of Miguel de Lima's cargo ship, Urca de Lima, which was grounded by the storm but left relatively intact, until

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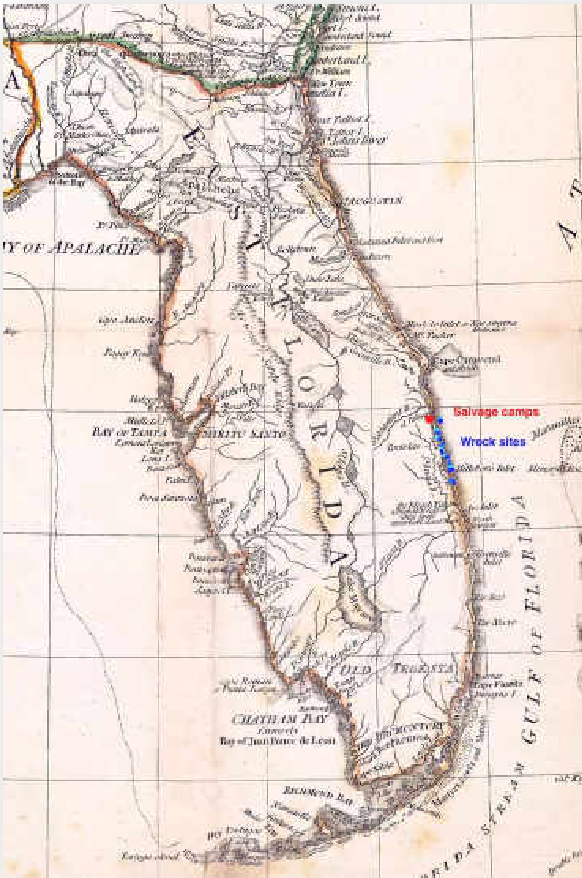


some are rescued by Spanish and English ships, and supplies finally arrive from Havana 31 days after the disaster.
The destruction of the 1715 Treasure Fleet was one of the greatest sea disasters of all time, and had long-lasting consequences for Florida and Spain's other overseas possessions. Once the flow of gold and silver slowed down, Spain's enemies surged ahead in wealth and power. French, Dutch and English mariners became more active, gaining new colonies and a share of New World commerce. Spain entered a century of gradual decline, hastened by another treasure fleet disaster which would occur in 1733.

Attempts to recover the treasure began immediately after the disaster. Spanish salvage crews were able to recover some of it, but most remained on the ocean floor and was quickly engulfed by sand. As the centuries went by, the sunken fleet was largely forgotten. Yet, the lure of lost gold never truly diminishes. In the 20th century, treasure hunters began to search again in earnest. Among them was Kip Wagner, a construction worker turned treasure hunter.

Kip didn't initially set out to uncover a lost Spanish fleet. In the 1950s, he moved his family to Wabasso, Florida, where he began spending his free time combing the beaches for seashells and driftwood.

It was during these leisurely walks that he stumbled upon blackened, misshapen lumps of metal that, upon cleaning, revealed themselves to be Spanish silver coins. Intrigued, Wagner noticed that none of these coins bore a date later than 1715. This piqued his curiosity and set him on a path of historical research. Teaming up with a local physician, Dr. Kip Kelso, who shared his fascination for treasure hunting, the two Kips (what are the odds) immersed themselves in Spanish records, deciphered ancient maps, and meticulously surveyed the Florida coastline searching for clues about shipwrecks in the area.

Their investigations led them to the Treasure Fleet, and Wagner and Kelso became determined to locate its remains. A breakthrough came when they discovered a reference in a 1775 book to a salvage camp established near the Sebastian Inlet after the disaster. Armed with this information, Wagner explored the area and successfully identified the campsite's location. This pivotal discovery narrowed their search area, focusing their efforts on the waters just offshore.

With his salvage crew, Wagner embarked on a series of dives, contending with sharks, strong currents, and murky visibility. Their perseverance yielded extraordinary results. In 1960, they literally struck gold, uncovering a trove of silver coins and artifacts scattered across the seabed. Pieces of eight, gold doubloons, and emerald-encrusted jewelry, long claimed by the sea, were brought back to the surface etched with the passage of time. Thus began a decades-long endeavor to recover the lost treasures of the 1715 fleet.

Wagner's success ignited a treasure-hunting frenzy along Florida's "Treasure Coast". He formed the Real Eight Company, attracting investors and other salvagers such as Mel Fisher, Bruce Ward, and numerous others to join the quest. Over the years, they have recovered millions of dollars worth of coins, jewelry, and other artifacts, and discoveries continue to this day. The story of the fleet and its lost treasure continues to fascinate people around the world, and has been the subject of numerous books, movies, and television shows.

Cufflinks with Dutch East India Company Pennies, 1734

These look great with a suit.

The Dutch East India Company, officially the United East India Company (Dutch: Vereenigde Oostindische Compagnie; VOC), was a multinational corporation founded by a government-directed consolidation of several rival Dutch companies (voorcompagnieën) in the early 17th century, and is believed to be the largest company to ever have existed in recorded history. It was established on March 20, 1602, as a chartered company to trade in pepper and spices with South Asia and Southeast Asia after the Spanish tried to block access to trade routes.

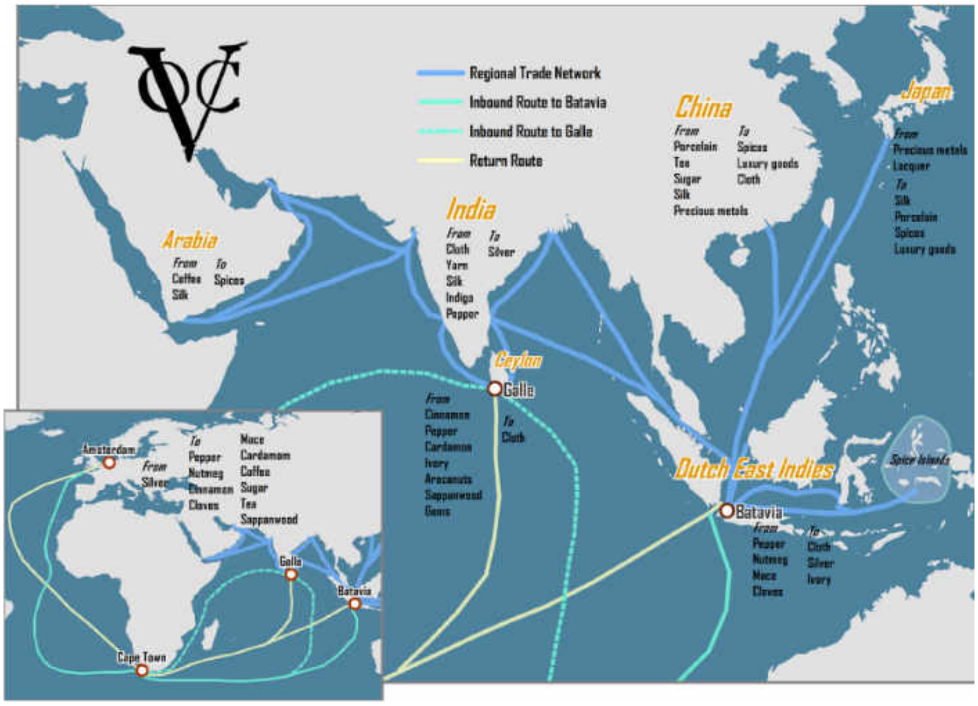
The VOC has been often labelled a trading company or sometimes a shipping company. However, it was in fact an early-modern corporate model of a vertically integrated global supply chain and a proto-conglomerate, diversifying into multiple commercial and industrial activities such as international trade, shipbuilding, and both production and trade of East Indian spices, Indonesian coffee, Formosan sugarcane, and South African wine. The company was a transcontinental employer and a pioneer of outward foreign direct investment.

At the dawn of modern capitalism, wherever Dutch capital went, urban features were developed, economic activities expanded, new industries established, new jobs created, trading companies operated, swamps drained, mines opened, forests exploited, canals constructed, mills turned, and ships were built. In the early modern period, the Dutch were pioneering investors and capitalists who raised the commercial and industrial potential of underdeveloped or undeveloped lands whose resources they exploited, whether for better or worse. For example, the native economies of pre-VOC-era Taiwan and South Africa were largely rural. It was VOC employees who established and developed the first modern urban areas in the history of Taiwan (Tainan) and South Africa (Cape Town and Stellenbosch).

Amsterdam shipyard of the Dutch East India Company.

Dutch Malacca (1750), Malaysia.

The Dutch East India Company (VOC), started off as a spice trader. In the same year, the VOC undertook the world's first IPO, widely issuing bonds and shares to the general populace. "Going public" enabled the company to raise the vast sum of 6.5 million guilders quickly and become the world's first publicly traded company. In many respects, modern-day corporations are all the 'direct descendants' of the VOC model. Its 17th-century institutional innovations and business practices laid the foundations for the rise of giant global corporations in subsequent centuries – as a formidable socio-politico-economic force of the modern-day world – to become the dominant factor in almost all economic systems today. The company, for nearly 200 years of its existence (1602 – 1800), had effectively



transformed itself from a pure for-profit corporation into a state or an empire in its own right. One of the most influential and extensively researched business enterprises in history, the VOC's world has been the subject of a vast amount of literature, both fiction and nonfiction.

Originally a government-backed military-commercial enterprise, the VOC was the wartime brainchild of leading Dutch republican statesman Johan van Oldenbarnevelt and the States-General. From its inception, the company was not only a commercial enterprise but also an instrument of war in the young Dutch Republic's revolutionary global war against the powerful Spanish Empire.

In 1619, the company forcibly established a central position in the Javanese city of Jayakarta, changing the name to Batavia (modern-day Jakarta). Over the next two centuries the company acquired additional ports and safeguarded their interests by taking over surrounding territory. To guarantee its supply, the company established positions in many countries. In its foreign colonies, the VOC possessed quasi-governmental powers, including the ability to wage war, imprison and execute convicts, negotiate treaties, strike its own coins – such as the two in my cufflinks – and establish colonies. With the increasing importance of foreign posts, the company is often considered the world's first true transnational corporation. Along with the Dutch West India Company, the VOC was seen as the international arm of the Dutch Republic and the symbolic power of the Dutch Empire.

To further develop its trade routes, the VOC funded exploratory voyages, such as those led by Willem Janszoon (Duyfken), Henry Hudson (Halve Maen), and Abel Tasman, which revealed previously unknown landmasses to the western world. In the Golden Age of Netherlandish cartography (1570s – 1670s), VOC navigators and cartographers helped shape geographical knowledge of the world as we know it today.

Socio-economic changes in Europe, the shift in power balances, and incompetent financial management resulted in a slow decline of the VOC between 1720 and 1799. After the financially disastrous Fourth Anglo-Dutch War (1780 – 1784), the company was nationalized in 1796, and finally dissolved on 31 December 1799. All assets were taken over by the government, with VOC territories becoming Dutch government colonies.

V.O.C. replica ship the "Duyfken"

Lucite with Piece of Terracotta from the Chicago Stock Exchange, 1894 – 1973

This Lucite contains a buff-colored terra cotta fragment fabricated by the Northwestern Terra Cotta Company, Chicago, IL and salvaged from the non-extant Chicago Stock Exchange building, demolished in 1972.

This magnificent building's exterior was replete with some of Chicago's finest organic ornamental detailing in terra cotta, designed by Louis Henry Sullivan. Between 1881 and 1895, Sullivan and engineer Dankmar Adler designed a series of iconic office towers, including the Chicago Stock Exchange Building (1894 –1972), their largest and perhaps most important commission.

Built on the site of the first brick building in Chicago (1837), the 13-story steel frame building was constructed by the general contracting firm of Falkenau & Company and was completed in 1894 at a total cost of $1,131,555.16.

© Richard Nickel/Ryerson & Burnham Libraries, Art Institute of Chicago

When the stock exchange moved in 1908, the trading room was converted into office space and later a bank. During the course of demolition in 1972, photographer and activist Richard Nickel was working to salvage building ornaments when the unstable structure collapsed, and he was tragically killed. As a tribute to Nickel, sections of the trading room stencils, molded pilaster capitals, and art glass were preserved, and in 1977 the Art Institute created a reconstruction of this room in a new wing of the museum. At the same time, the entry arch of the Stock Exchange was erected on the museum grounds.

This gorgeous building was on the next block over from us, and was replaced by the ugliest and most artistically pointless last gasp of derivative Mies-esque faux-Rohe copycat Modernism.

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Weimar Aluminum 500 Deutschmark Coin, 1923

To help "pay" for the staggering costs of the ongoing First World War, Germany suspended the gold standard when the war broke out. German Emperor Wilhelm II and the Reichstag decided unanimously to fund the war entirely by borrowing.

Off to ze Bäckerei for a loaf of bread.

The government believed that it would be able to pay off the debt by winning the war and imposing reparations on the defeated Allies. Thus, the exchange rate of the mark against the U.S. dollar steadily devalued from 4.2 to 7.9 marks per dollar, a preliminary warning of the extreme postwar inflation to come.

This strategy failed as Germany lost the war, which left the new Weimar Republic saddled with massive debts that it could not afford, totaling 132 billion gold marks ($33 billion). The problem was exacerbated by printing money without any economic resources to back it. The demand in the Treaty of Versailles for reparations further accelerated the mark's decline, with 48 paper marks to the dollar by late 1919.

The first payment was made in June 1921 and marked the beginning of a rapid devaluation of the mark, which fell in value to approximately 330 Marks per dollar. From August 1921, Germany began to buy foreign currency with Marks at any price, but that only increased the speed of the collapse, meaning more and more Marks were required to buy the foreign currency.

Stunning Bauhaus inflation banknotes by Herbert Bayer in the typeface Breite Fette Grotesk, not in my collection.

In June 1922, an international reparations conference produced no workable solution, and inflation erupted into hyperinflation, the Mark falling to 7,400 Marks per U.S. dollar by December 1922. The cost-of-living index was 41 in June 1922 and 685 in December, a nearly 17-fold increase. By fall of 1922, Germany found itself unable to make reparations payments.

The strategy that Germany had been using to pay war reparations was the mass printing of bank notes to buy foreign currency, which was then used to pay reparations, but this strategy greatly exacerbated the inflation. Since the Mark was, by fall of 1922, practically worthless, it was impossible for Germany to buy foreign exchange or gold. After Germany failed to pay France an installment on time, French and Belgian troops occupied the Ruhr valley, Germany's main industrial region, in January 1923. Reparations were to be paid in goods, such as coal, and the occupation was supposed to ensure reparations payments.

The German government's response was to order a policy of passive resistance in the Ruhr, with workers being told to do nothing which helped the invaders in any way. While this policy, in practice, amounted to a general strike to protest the occupation, the striking workers still had to be given financial support. The government paid these workers by printing more and more banknotes, with Germany soon being swamped with paper money, exacerbating the hyperinflation even further. A loaf of bread in Berlin that cost around 160 Marks at the end of 1922 cost 200,000,000,000 Marks by late 1923.

According to one study, many Germans conflate hyperinflation in the Weimar Republic with the Great Depression, seeing the two separate events as one big economic crisis that encompassed both rapidly rising prices and mass unemployment. Since this episode of hyperinflation, German monetary policy has focused heavily on the maintenance of a sound currency.

The beautiful, hyperinflated, worthless Mark banknotes became widely collected abroad. The Los Angeles Times estimated in 1924 that more of the decommissioned notes were spread about the U.S. than existed in Germany.

This aluminum 500 Mark coin weighs only 1.67 grams.

Schwester, vill zees schtacks buy us some candy?

1923 A Germany - Weimar Republic 500 Mark KM# 36 Choice Brilliant Uncirculated BU+

This auction is for a 1923 A Germany - Weimar Republic 500 Mark KM# 36 Choice Brilliant Uncirculated BU Coin. This piece can be found in Krause Numismatic Catalog as KM# 36 This coin is in really super original uncirculated condition with some very light, original toning. Awesome 1910s European style on full display with a great German eagle taking over the entire obverse. We grade this uncirculated coin as choice Brilliant Uncirculated (BU+) condition with no obvious signs of cleaning. Please see the images available for more information about the exact condition of this wonderful, better date, piece of history. This piece would make an amazing gift for a collector or a wonderful addition to any coin collection.

Composition: Aluminum

Weight: 1.6700g

Diameter: 27.1mm

Throwing money to the wind.

Nazi Silver 2 Deutschmark Coin, 1939

After the collapse of the German Mark and Germany's spiral of hyperinflation following World War I, something had to be done to to stem currency instability and to stabilize the economy. The Papiermark was first replaced by a temporary currency called the Rentenmark in 1923, at which time a U.S. dollar was worth 4.2 billion of the nearly worthless Papiermarks, and finally by the official "Reichsmark" in 1924.

The Reichsmark (German: [ˈʁaɪ̯çsˌmaʁk] remained in use until June 20, 1948, in West Germany, where it was replaced with the Deutsche Mark, and until June 23, 1948, in East Germany, where it was replaced by the East German Mark. The Reichsmark was subdivided into 100 Reichspfennigs. The Mark is an ancient Germanic weight measure, traditionally a half pound, later used for several coins; whereas Reich (realm in English), comes from the official name for the German state from 1871 to 1945, Deutsches Reich.

The Reichsmark was introduced as a permanent replacement for the Papiermark, and the temporary Rentenmark was phased out. German inflation had reached its peak in 1923. The exchange rate between the old Papiermark and the Reichsmark was 1 *ℛℳ* = 1012 *ℳ* (one trillion in American English and French, one billion in German and other European languages and British English of the time). To stabilize the economy and to smooth the transition, the Papiermark was not directly replaced by the Reichsmark, but by the Rentenmark, an interim currency backed by the Deutsche Rentenbank, owning industrial and agricultural real estate assets. The Reichsmark was put on the gold standard at the rate previously used by the Goldmark, with the U.S. dollar worth 4.20 *ℛℳ*.

Scrip for prisoners of war, not in my collection. Note the temporary return to Gothic typeface. On January 3, 1941, Nazi official Martin Bormann announced that Hitler no longer wanted to see Gothic typeface used in print, and it was gradually phased out.

With the "unification" of Germany and Austria in 1938, the Reichsmark replaced the Schilling in Austria. During the Second World War, Germany established fixed exchange rates between the Reichsmark and the currencies of the occupied and allied countries, often set so as to give Nazi soldiers and civilian contractors economic benefits. Exchange rates as a weapon of war.

This silver 2 Mark coin weighs 8 grams, almost five times as much as the aluminum 500 Mark coin a few pages earlier. That's 1,198 times as much weight per Mark!

Lucite with $500 "Cash"

Novelty item celebrating the "Bank of Louisville Russell Office Grand Opening May 21, 1991"

It's a monetary example of Schrödinger's cat. You don't know if there's $500 in there until you cut it open somehow, irreparably damaging it. It both simultaneously exists and doesn't exist until it is opened up, observed, and simultaneously destroyed.

The building in which this bank branch is housed is a typical example of nihilistic suburban American architecture. Vast swaths of our country are blighted by winding roads dotted with identical houses, strip malls stuffed with chain restaurants and big-box stores, and thoroughfares designed for cars, with pedestrian walkways as an afterthought.

The anthropologist Marc Augé coined the term "non-places" to describe interchangeable, impersonal spaces lacking in history and culture that people pass through quickly and anonymously. Non-places – such as shopping centers, gas stations, and highways – can be found everywhere, but proliferate particularly in American suburbs.

The writer James Howard Kunstler memorably called this sort of landscape "the geography of nowhere", "deeply demoralizing and psychologically punishing", and "depressing, brutal, ugly, unhealthy, and spiritually degrading", not only because the design of suburbia is unsightly but because it is at odds with human connection and flourishing. He writes in his book that "the immersive ugliness of the built environment in the USA is entropy made visible", and suggests that America has become "a nation of people conditioned to spend their lives in places not worth caring about".

© Google

You're welcome, architecture shaming.

Lucite with Currency from Other Places I Have Lived

This Lucite from the Chicago Mercantile Exchange contains among other currencies Dutch Guilders, German Deutschmarks, and Mexican Pesos. The first two have been replaced by the Euro (symbol: €; code: EUR), now the official currency of 19 of the 27 member states of the European Union.

This group of states is known as the eurozone or euro area and includes about 343 million citizens as of 2019. The euro, which is divided into 100 cents, is the second largest and second-most traded currency in the foreign exchange market after the United States dollar.

The name euro was officially adopted on December 16, 1995, in Madrid. The euro was introduced to world financial markets as an accounting currency on January 1, 1999, replacing the former European Currency Unit (ECU) at a ratio of 1:1 (US$1.1743). Physical euro coins and banknotes entered into circulation on January 1, 2002, making it the day-to-day operating currency of its original members, and by March 2002 it had completely replaced the former currencies.

The Chicago Mercantile Exchange (CME) (often called “the Chicago Merc”, or “the Merc”) is a global derivatives marketplace based in Chicago and located at 20 S. Wacker Drive. The CME was founded in 1898 as the Chicago Butter and Egg Board, an agricultural commodities exchange. Originally, the exchange was a non-profit organization. The Merc merged with the Chicago Board of Trade in July 2007.

Today, CME is the largest options and futures contracts open interest (number of contracts outstanding) exchange of any futures exchange in the world. The Merc trades several types of financial instruments: interest rates, equities, currencies, and commodities.

CME also pioneered the CME SPAN software that is used around the world as the official performance bond (margin) mechanism of 50 registered exchanges, clearing organizations, service bureaus, and regulatory agencies throughout the world.

This beautiful building is only a few blocks from our home in downtown Chicago.

CME Group/Henry Delforn/Allan Schoenberg / CC BY-SA 3.0

Lucite with One Hundred Trillion Zimbabwean Dollars, 2008

One hundred trillion dollars – that's 100,000,000,000,000 – is the largest denomination of currency ever issued, by any government, ever.

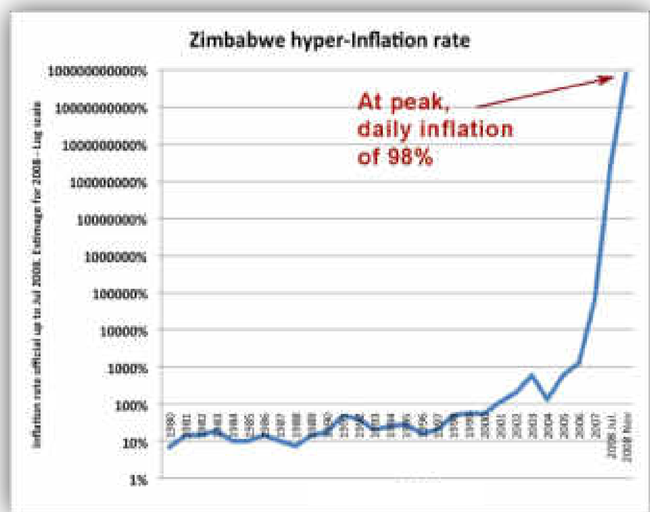
On 18 April 1980, the Republic of Zimbabwe was born from the unrecognized Republic of Rhodesia and the Rhodesian Dollar was replaced by the Zimbabwean Dollar at par; initially more valuable than the United States Dollar at official exchange rates. But this did not reflect reality in terms of purchasing power on the open and black markets. In its early years, Zimbabwe experienced strong growth and development. Wheat production was higher than in the past, the tobacco industry was thriving. Economic indicators were strong.

From 1991 to 1996, ZANU-PF President Robert Mugabe embarked on an Economic Structural Adjustment Programme (ESAP) that effectively destroyed Zimbabwe's economy. In the late 1990s, the government instituted land reforms intended to evict white landowners and place their holdings in the hands of black farmers. However, many of these "farmers" had no experience or training in farming. Many farms simply fell into disrepair or were given to Mugabe loyalists. From 1999 to 2009, the country experienced a sharp drop in food production and in all other sectors. The banking sector also collapsed, with farmers unable to obtain loans for capital development. Food output capacity fell 45%, manufacturing output 29% in 2005, 26% in 2006 and 28% in 2007, and unemployment rose to 80%. Life expectancy dropped. Whites fled the country en masse along with much of the nation's capital. Rampant corruption encouraged the printing of ever more money.

Hyperinflation in Zimbabwe took off in earnest in February 2007. During its height from 2008 to 2009, it was difficult to measure because the government stopped filing official statistics. However, Zimbabwe's peak month of inflation is estimated at 79.6 billion percent month-on-month, 89.7 sextillion percent year-on-year in mid-November 2008. Weimar style wheelbarrows of money came back into fashion!

The entrance of occupied Devonia farm, "repurposed" as a headquarters for local war veterans, renamed "Black power farm" by the squatters.
ODD ANDERSEN via Getty Images

The Reserve Bank of Zimbabwe blamed hyperinflation on economic sanctions imposed by the US, the IMF and the European Union. It responded to the dwindling value of the dollar by repeatedly arranging the printing of further banknotes, often at great expense, from overseas suppliers. On 1 March 2008, it was reported that the Munich company Giesecke & Devrient (G&D) was receiving more than €500,000 (£381,562) for delivering bank notes equivalent to Z$170 trillion a week. By late 2008, inflation had risen so high that automated teller machines for a major bank gave a "data



overflow error" and stopped customers' attempt to withdraw money with so many zeros.

In April 2009, Zimbabwe stopped printing its currency, and attempted to switch to a multi-currency system, causing further chaos and mayhem. In 2015, Zimbabwe announced plans to have completed a switch to the U.S. dollar by the end of that year. That didn't help either, and in 2019 the government announced the reintroduction of the RTGS dollar, now to be known simply as the "Zimbabwe dollar", and that foreign currency was no longer legal tender.

By July 2019 inflation had increased again to 175%, sparking concerns that the country was entering a new period of hyperinflation. In March 2020, with inflation above 500% annually, a new taskforce was created to assess currency issues. By July 2020 annual inflation was at 737%.

Through a combination of fiscal consolidation and widening of the tax base though, perpetual deficits were turned into some surpluses during the periods 2019 and 2020, creating hope for stability. Prices of goods and services stabilized somewhat, with annual inflation dropping from a peak of 761 percent in August 2020 to 50 percent in August 2021. It remains to be seen whether optimism is justified.

Alongside these reforms, Zimbabwe had already been looking to adopt various digital payment systems, which included the Real-Time Gross Settlement, Electronic Funds Transfer, mobile money, and electronic cards, among others. Growth in digital transactions in Zimbabwe has been astronomical. This shift reduced the demand for hard cash and the burden of continuous money printing to meet demand, and has brought other benefits such as increased financial inclusion for marginalized citizens, particularly rural folks, informal businesses, and startups.

This digitization process also contributed to uptake of information and communications technologies in the country, including ramping up demand for internet services. Zimbabwe's government frequently shuts down this internet connectivity though, so the economic benefit is tempered by political repression.

On November 14, 2017, armed military personnel from the Zimbabwe Defence Forces invaded the Zimbabwe Broadcasting Corporation studios in Harare and declared a military coup on live television. Major General Sibusiso Moyo stated that President Mugabe and his family would be safe, and only criminals around him were being targeted. What followed was a well-planned and carefully executed crackdown. The Zimbabwe Republic Police and the Central Intelligence Organisation, both deemed loyal to the president, were neutralized by the army. By November 21, facing all-but certain impeachment from a combined session of the House of Assembly and Senate, Mugabe resigned as president.

Ukraine Special Forces Commemorative 10 Hryven Coin, 2022

Ukraine's ongoing conflict that began in 2014 with Russia's annexation of Crimea and the subsequent war in Eastern Ukraine, followed by the full-scale invasion by Russia in February 2022, has had profound impacts on its economy and its currency, the hryvnia. In the face of war, currencies often undergo rapid devaluation. This has been the case for the hryvnia, which saw significant drops in value during these conflicts.

The reasons behind this include the general uncertainty that war brings, decreased foreign investments, increased military expenditures, and potential disruptions to trade and sanctions. All these factors contribute to a lack of confidence in the currency, leading to its devaluation. Moreover, inflation becomes a significant concern as the costs of goods and services rise. This can be attributed to the disruption of supply chains and the increased cost of importing goods, among other factors. Ukraine has indeed experienced spikes in inflation, further complicating the economic situation for its citizens and the government alike.

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The banking sector and overall financial stability are also put to the test during conflicts. Access to financial services becomes limited, and the government might face challenges in maintaining the operation of its financial systems. For Ukraine, this has meant efforts to stabilize the banking system and ensure that financial transactions can continue with as little disruption as possible. Despite these challenges, Ukraine has made concerted efforts to stabilize its currency and manage the economic fallout from its conflicts.

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This includes interventions by the National Bank of Ukraine and other governmental measures aimed at shoring up the economy, stabilizing the hryvnia, and controlling inflation to the extent possible under such difficult circumstances. The resilience of Ukraine's economy and its currency in the face of ongoing conflict is a testament to the strength and

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determination of its people and government. However, the long-term economic impacts of war, including on the currency, will likely be a significant challenge for Ukraine for years to come.

In 2022, Ukrainian President Volodymyr Zelenskyy signed a bill effectively legalizing the cryptocurrency sector in the country. The decision comes as Ukraine has received cryptocurrency donations worth tens of millions of dollars from individuals and groups hoping to help the country's war effort against Russia.

Bloomberg via Getty Images


Ministry of Defense of Ukraine / CC BY-SA 2.0

Currency isn't just influenced from a value perspective by war and change, it can of course also commemorate historical events or people. This 10 Hryven coin celebrates a part of the Armed Forces of Ukraine, that includes special purpose units and units of informational and psychological special operations.

The slogan of the Special Operations Forces of the Armed Forces of Ukraine was chosen as the combat slogan of Svyatoslav the Brave "I'm coming FOR you!"

Obverse: In the center, on a mirror background, the emblem of the Special Operations Forces of the Ukrainian Armed Forces, to the right of which is the small State Coat of Arms of Ukraine.

The inscription reads: УКРАЇНА – ІДУ НА ВИ – 10 ГРИВЕНЬ (Ukraine – I'm coming for you – 10 Hryven)

Reverse: On the background of the outline of the image of Svyatoslav the Brave with a sword and a shield, a soldier of the Special Operations Forces of the Ukrainian Armed Forces is depicted.


Andriy Ageev / CC BY-SA 2.0


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The inscription reads: СИЛИ СПЕЦІАЛЬНИХ ОПЕРАЦІЙ ЗБРОЙНИХ СИЛ УКРАЇНИ (Special operations forces of the armed forces of Ukraine)

Engravers: Anatolii Demianenko, Volodymyr Demianenko, Designers: Andrii Yermolenko, Olha Kovalenko

Rocks

Flight-Oriented NWA Chondrite Meteorite with Fusion Crust, ~4.5 Billion Years Old

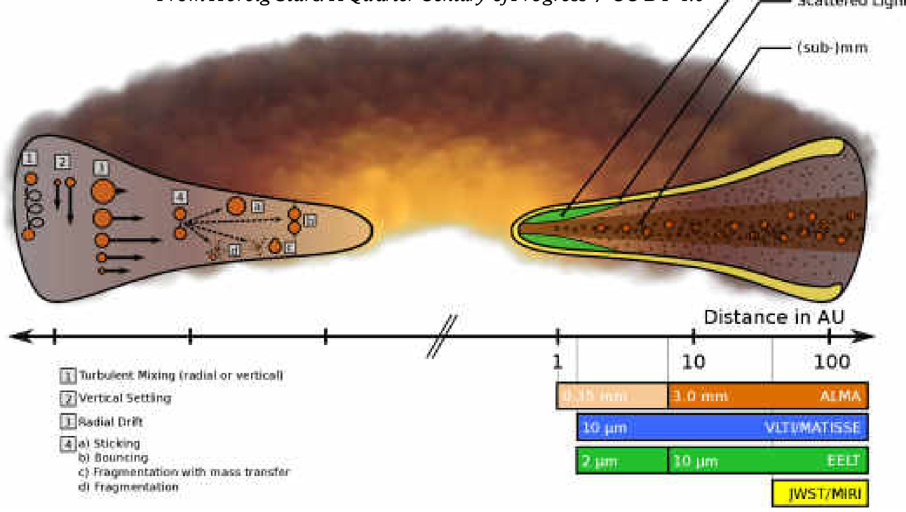
A visitor as old as the Solar System itself, from the asteroid belt between the orbits of Mars and Jupiter. It was formed when the Sun was young and for ten million years was surrounded by a vast, dense swirl of gases and dust known as the protoplanetary disk. As these motes of dust surrounding the sun collided over and over again, they grew into larger and larger aggregates and eventually asteroids and planetesimals. From this disk too our Earth was born, along with all the complex organic molecules necessary for life.

A chondrite is a stony, or non-metallic, meteorite that has not been modified, by either melting or differentiation of the parent body. Some such objects that are captured in our planet's gravity well become the most common type of meteorite by (whether quickly, or after billions of years like our friend) arriving on a trajectory toward the planet's surface. Estimates for their contribution to the total meteorite population vary between 85.7% and 86.2%.

Their study provides important clues for understanding the origin and age of the Solar System, the synthesis of organic compounds, the origin of life, and the presence of water on Earth. One of their characteristics is the presence of chondrules (from the Ancient Greek χόνδρος chondros, grain), which are grains formed as molten or partially molten droplets of minerals, and normally constitute between 20% and 80% of a chondrite by volume.

There are currently over 27,000 chondrites in the world's collections. The largest individual stone ever recovered, weighing 1770 kg, was part of the Jilin meteorite shower of 1976. Chondrite falls range from single stones to extraordinary showers consisting of thousands of individual stones. An instance of the latter occurred in the Holbrook fall of 1912, in which an estimated 14,000 stones grounded in northern Arizona.

When this rock was formed in the primitive Solar System over 4.5 billion years ago, its parent body was a small to medium-sized asteroid that was never part of any body large enough to undergo melting and planetary differentiation. An indication of its age is the fact that the abundance of non-volatile elements in chondrites is like that found in the atmosphere of the Sun and other stars in our galaxy.



Dust evolution in protoplanetary discs.
From Herbig Stars: A Quarter Century of Progress / CC BY 4.0

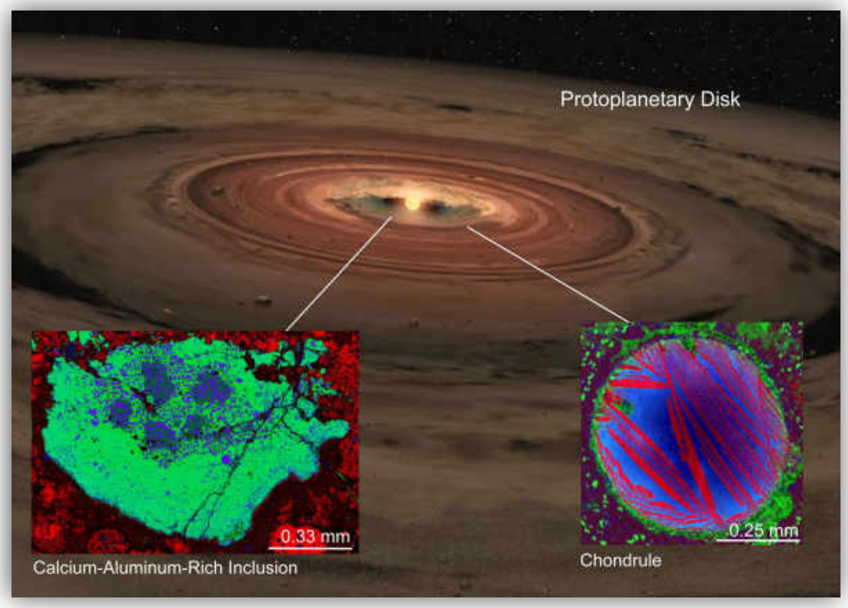
Although chondritic asteroids never became hot enough to melt based upon internal temperatures, many of them reached high enough temperatures that they experienced significant thermal metamorphism in their interiors. The source of the heat was most likely energy coming from the decay of short-lived radioisotopes (half-lives less than a few million years) that were present in the newly formed Solar System. Many chondritic asteroids also contained significant amounts of water, possibly due to the accretion of ice along with rocky material.

NASA artist's rendering of the young Sun at the center of the protoplanetary disc.

As a result, many chondrites contain hydrous minerals, such as clays, that formed when the water interacted with the rock on the asteroid in a process known as aqueous alteration. In addition, all chondritic asteroids were affected by impact and shock processes due to collisions with other asteroids. These events caused a variety of effects, ranging from simple compaction to brecciation, veining, localized melting, and formation of high-pressure minerals. The net result of these secondary thermal, aqueous, and shock processes is that only a few known chondrites preserve in pristine form the original dust, chondrules, and inclusions from which they formed.

Prominent among the components present in chondrites are these enigmatic chondrules, millimeter-sized spherical objects that originated as freely floating, molten or partially molten droplets in space. Most chondrules are rich in the silicate minerals olivine and pyroxene.

Chondrites also contain refractory inclusions, which are among the oldest objects to form in the Solar System, particles rich in metallic Fe-Ni and sulfides, and isolated grains of silicate minerals. The remainder of chondrites consists of fine-grained (micrometer-sized or smaller) dust, which may either be present as the matrix of the rock or may form rims or mantles around individual chondrules and refractory inclusions. Embedded in this dust are pre-solar grains, which predate the formation of our solar system and originated elsewhere in the galaxy. An article published in 2005 proposed that the gravitational instability of the gaseous disk that formed Jupiter generated a shock wave with a velocity of more than 10 km/s, which resulted in the formation of the chondrules.



Meteorites fall equally upon all parts of the earth, but most are found in deserts as the arid environmental conditions limit erosion of the rocks, and for the simple reason that it's easier to see a strange rock on a monotone background. North-west Africa is a prime location, and specimens found there are referred to as "NWA".

Their path to market is an interesting one. They are mostly found by nomadic tribes that cross the Sahara and find them along the way, who then sell or trade them for supplies to local dealers in whatever villages the dealers are located, and then they make their way up the food chain.

Chondrites are far more common than iron meteorites but are much harder to find since they look like ordinary rocks and can't be found by metal detectors either. Almost all the ones being sold are found in the arctic or deserts because they're easy to spot, but also because they usually can't be anything else but a meteorite to be there in the first place. In this case, the nomads know that anything sticking out of a sand dune in the Sahara is a meteorite that will have value to someone when they reach a village.

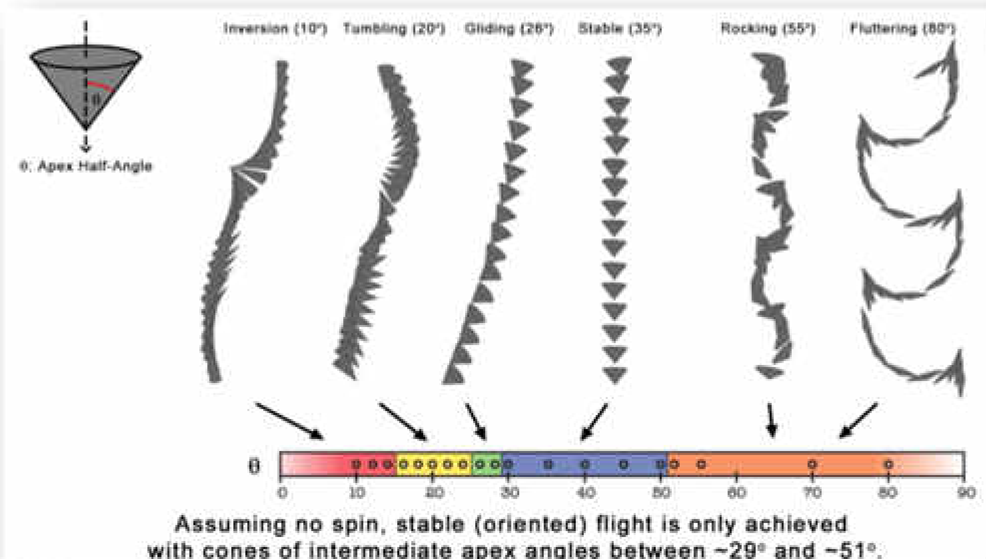
Recorded meteorite strikes in the last 500 years.

Once captured by Earth's gravity, a meteor can enter and pass through the atmosphere in various ways and break apart at various stages during entry. A meteor can tumble and maintain a random shape, or develop what is known as "flight orientation" when it experiences a period of stable flight through Earth's atmosphere and is gradually further ablated into an increasingly more stable and aerodynamic shape (cone or shield).

The resulting meteorite develops a fusion crust, or fusion rind, a thin melted surface layer of thermally transformed components. On stone meteorites it is mainly composed of olivine, glass, wüstite and other iron oxides of the magnetite series, and rarely exceeds a thickness of 1 mm.

Flight oriented meteorites can show evidence of flow lines, roll-over lipping and regmaglypts which are small, shallow indentations or pits on the surface of a meteorite, resembling a thumbprint impression in clay, created by ablation while falling in an atmosphere.

Samples of meteorites can be sent to academic institutions for analysis, where it can be determined with certainty that the rock is indeed a meteorite, and of what kind. The lunar meteorite shown later in this book was analyzed thusly. If you do so, the meteorite will be assigned an identification code and your name will appear in the Meteoritical Bulletin Database. To have your stone classified though, you need to remove a quarter-sized slice. Often this is achieved by making an end cut first, or by cutting the stone in half. This is why my slice of lunar meteorite has its shape.



Types of meteorite flight paths.
Image Modified from the Source: shanghai.nyu.edu

An "unclassified" meteorite has been left intact and has not been verified by an academic institution. An expert can determine with reasonable confidence whether the stone is a meteorite if it is in possession of a fusion crust, regmaglypts, or other features unique to stones from space.

This specimen is an unclassified NWA flight oriented ordinary chondrite meteorite, with fusion crust and some regmaglypts, weighing 1980 grams and measuring roughly 10 by 12 cm.

Lucite with Slice of Admire Pallasite Meteorite

The Admire meteorite was found in 1881 in Kansas by a farmer plowing a field. It's named after the city of Admire in Lyon County (meteorites are named for the places they were found). Kansas – or more generally, the Midwest – seems like a hot spot for meteorite falls. Meteorites, however, fall randomly across the surface of our planet, and they could land anywhere. Why, then, do so many meteorite finds happen in Kansas?

It's a combination of factors; the soil in Kansas contains very few indigenous stones. The Kansas soil is also very fertile, so it's farmed intensely. Meteorites frequently turn up as a result of this farming and, since Kansas soil contains such few stones, these meteorites are less likely to be mistaken for terrestrial rocks.

Scientists believe, after much study, that the Admire pallasite formed at the core-mantle boundary of an ancient asteroid. Pallasites are among the rarest of meteorites; less than 1% of all meteorites are pallasites, and even fewer still contain un-shocked crystals, something which academics were surprised to discover in the Admire pallasite.

Example of a faceted pallasitic peridot, or "space gem", not in my collection.

About 1/100 of these crystals, remarkably, lend themselves to faceting, something that is not possible with shocked crystals. Admire is one of the only meteorites that produces these "space gems." When sliced and polished, Admire meteorite slices present a wealth of richly-colored, angular crystals of different sizes and shapes.

Meteorite Men was a documentary reality television series featuring meteorite hunters Geoff Notkin and Steve Arnold. The pilot episode premiered on May 10, 2009. Professors and scientists at prominent universities including UCLA, ASU, UA, Edmonton, and other institutions, including NASA's Johnson Space Center, were featured. The Meteorite Men found several very large masses at Admire. The most impressive, weighing in at 223 pounds, has been preserved intact and is frequently exhibited at gem shows and museums around the country. Some of the other masses were cut into slices, and prepared examples were taken to the Center for Meteorite Studies at ASU.

Unfortunately, I do not own this.

This Lucite is one of only three made.

© Meteorite Men / Anvil 1893 Entertainment / Science Channel

End Cut Slice of Lunar Feldspathic Breccia Meteorite NWA 13676

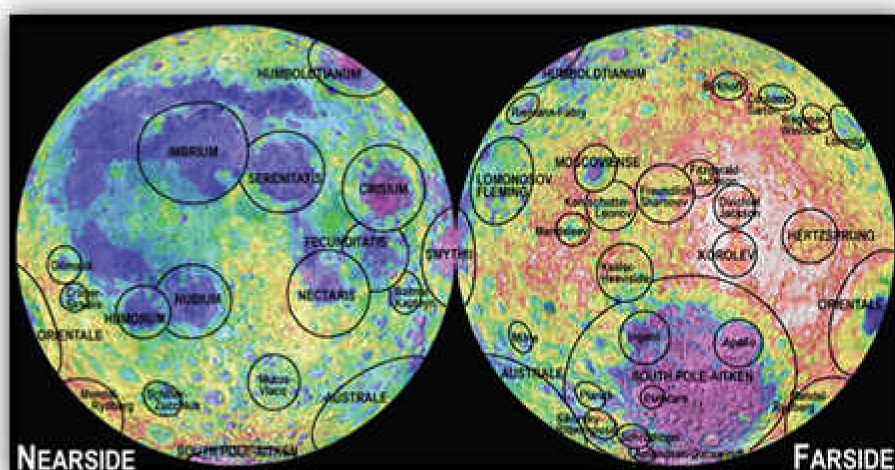
Most recovered meteorites, like Admire and the chondrite a few pages back, are pieces of asteroids. A few rare meteorites come from the Moon (0.7%) and Mars (0.5%). Lunar meteorites, or lunaites, are rocks found on Earth that were previously ejected from the Moon by the impact of an asteroidal meteoroid or possibly a comet.

Because the Moon has no atmosphere to stop them, meteoroids strike its surface every day. Lunar escape velocity is only a few times the muzzle velocity of a common rifle. Any rock on the lunar surface that is accelerated by an impact to escape velocity or greater, will leave the Moon's gravitational influence. Most rocks ejected from the Moon become captured by the gravitational field of either the Earth or the Sun and go into orbit around those bodies. Over a period of just a few to tens of thousands of years, those orbiting our planet eventually fall to Earth.

On a broken or sawn face, all lunar meteorites look like some kinds of Earth rocks. We can often tell that they came from space because many lunar meteorites have fusion crusts from the melting of their exterior that occurs during their passage through Earth's atmosphere. On meteorites found in hot deserts, the fusion crusts sometimes have weathered away. However, all meteorites contain certain isotopes (nuclides) that can only be produced by reactions with penetrating cosmic rays while outside Earth's atmosphere. Presence of cosmogenic nuclides is evidence of cosmic-ray exposure, and the ultimate test of whether a rock is a meteorite.

For several reasons, we know that lunar meteorites derive from many different impacts on the Moon. The textural and compositional variety spans, and in some ways exceeds, that of rocks collected on the six Apollo landing missions, so the meteorites must come from many locations. More importantly, it is possible to determine how long ago a rock left the Moon using cosmic-ray exposure ages.

Because the various radionuclides all have different half-lives it is often possible to tell how long a rock was exposed on or near the surface of the Moon, how long it took to travel to Earth, and how long ago it fell. For example, cosmic-ray exposure data for Kalahari 008/009 suggest that the meteorite left the Moon at most a few hundred years ago. At the other extreme, Dhofar 025 took 13-20 million years to get here from the Moon (Nishiizumi and Caffee, 2001). Because there is a wide range in the Earth-Moon transit times, we know that many impacts on the Moon were required to launch all the different lunar meteorites.



Schematic map of lunar impact basins on the near and far sides of the Moon. © *LPI/Paul Spudis/David Kring*

Meteorites are very rare rocks; lunar meteorites are exceedingly rare. Of the ~42,000 named meteorite stones found in Antarctica, where record keeping has been superb, (1976-2018), 1 in 1,000 is from the Moon (42 stones representing 22-23 meteorites; for Martian meteorites, it is 1 in 1400). Another measure of rarity is mass. The total mass of all known lunar meteorites is about 781 kg (1722 lbs). By comparison, the total mass of all stony meteorites is 92,200 kg. The mass of all 502 known and named lunar meteorites as of December 31, 2021, was only about 2.94 times the mass of the rocks >1 cm in size in the Apollo lunar sample collection.

Lunar meteorites collected in Africa and Oman are, for all practical purposes, the only source of moon rocks available for private ownership. This is because all rocks collected during the Apollo moon-landing program are property of the United States government or of other nations to which the U.S. conveyed them as gifts. Similarly, all lunar meteorites collected by the U.S. and Japanese Antarctic programs are, by treaty, held by those governments for research and education purposes only. Although there is no U.S. law specifically against the ownership of Apollo moon rocks, none has ever been (or is likely to ever be) given or sold by the U.S. government to private citizens. Even in the cases of plaques containing genuine Apollo moonrocks given in 2004 to astronauts and Walter Cronkite, NASA retained ownership of the rocks themselves.

The rest of NWA 13676, not in my collection.
You can see where my piece was removed.

Most of the moon rocks collected by the Soviet Luna 16 probe are also unavailable for private ownership, although three tiny samples were sold at auction for $442,500 in 1993. In 2022, a minuscule amount of microscopic moon dust auctioned by Bonhams for $504,375 after NASA determined that the particles are part of the first lunar sample collected by Apollo 11 astronaut Neil Armstrong. I own some moon dust from Apollo 16 for which I did not pay hundreds of thousands of dollars, described in another entry earlier in this book.

NWA 13676 is a feldspathic breccia lunar meteorite with a total mass of 698 gr. It was found in Algeria in 2020, purchased by Didi Baideri in September 2020 from an Algerian dealer, and subsequently sold to Ziyao Wang in December 2020. It was classified by the University of Washington and a specimen remains there. It consists of fine grained breccia composed of mineral clasts of anorthite, olivine, pigeonite and augite, plus feldspathic lithic clasts (including quench-textured melt clasts), set within a very fine grained, partly vesicular matrix containing kamacitic metal (with variable Fe:Ni) and chromite (with variable Ti content).

I purchased this 13.75 gr end slice from a reputable dealer in the UK. It has been polished to a high degree, showing the internal mineralogy.

Mars Cube

On October 3, 1962, a farmer in Zagami, Nigeria was nearly struck by a 40-pound meteorite as it plummeted towards Earth. Pointing to a planetary origin, the specimen had an unusually young crystallization age, contained water-bearing minerals, and evidenced a planetary-sized gravitational field on its crystalline structure. It would take 33 years though for the full story of this meteorite to be told.

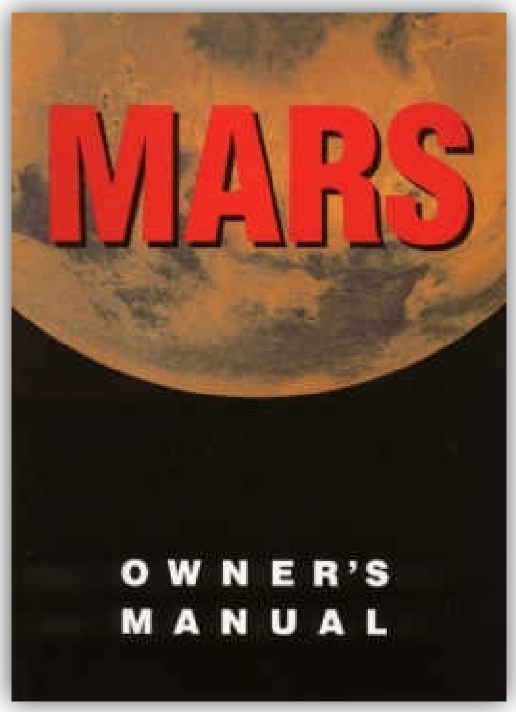
In 1995, The New York Times and Science magazine reported that gas trapped in tiny bubbles within the Zagami matrix matched the composition of the Martian atmosphere (as determined by the Viking lander in 1976), thus removing all doubt of its origin. Zagami is one of only four witnessed falls of Martian meteorites, most likely catapulted into space when a large asteroid slammed into Mars.

"Planet Mars: The Collector's Cube" was sold as "the first interplanetary collectible". The 12,000-unit limited edition was launched on QVC in 1997 by Darryl Pitt. Particles of Mars are housed in a clear glass vial suspended in a Lucite cube. "Planet Mars" came accompanied with a numbered and signed Certificate of Authenticity and a comprehensive twenty-page "Mars Owner's Manual." The vial contains 1/10 carat of "pharmaceutically milled" particles of the Zagami Martian meteorite.

At the time, QVC charged $98 for the cubes. Martian material was very scarce and valuable then, and the prices skyrcoketed to absurd heights. In 2019 one sold for $1,625 and in February of 2021 one sold for $6,000 at Christie's. Since the cube was released though, much more Martian meteorite material has been discovered, and it is now inexpensively obtainable.

Meteorites quantities also usually aren't described in terms of carats but in grams. The only time carats are commonly used, is in descriptions for tektite-type of items, derived from meteorite impacts (such as Libyan desert glass, or Moldavites). An online conversion shows 1/10 of a carat to be equivalent to .02 grams.

A "limited edition" of 12K units may have been the first clue that this was not exactly an exclusive offer, although it's not clear how many units were actually sold. As for it being "pharmaceutically milled", who knows what that means, but it was most likely a way to market cutting dust produced from slicing the meteorite itself.



The 20mg of dust in the Lucite may have been worth around $15 at the time these were launched, with the Lucites being offered at $98 each. With inflation that $98 is equivalent to around $163 today but Martian meteorite prices have dropped significantly. Those 20mg of dust might be worth maybe $5 or $6 today. So, a nice presentation, but the Lucite cube, pamphlets, and box would certainly cost much more to produce today than the value of the dust inside. A triumph of marketing and presentation over intrinsic value. Thankfully I purchased mine on eBay for $26.99 from someone who had no idea what it was and described it as a "stash vial". Unfortunately it did not come with the accompanying materials. From $98, to $6,000, to $27. Quite a ride.

Mini Museum Lucite with Carboniferous Fossil Plant, ~300 Million Years Old

This large Lucite contains a complete Carboniferous Fossil Plant displaying gorgeous yellow-orange mineralization of the plant's leaves. The fossil was recovered from a coal bed in Pennsylvania, estimated to be almost a third of a billion years old.

During the Carboniferous period, the landmass that would become Pennsylvania was located near the equator, on the western edge of the supercontinent that was forming.

Our planet was swathed in vast, steamy swamps, teeming with life both bizarre and beautiful. These ancient wetlands were choked with ferns, their delicate fronds unfurling in the humid air, reaching towards the dappled sunlight filtering through the dense canopy above.

"Carboniferous Recreation"
© *Nicolás Fernández*

These were not the humble ferns we are familiar with today, tucked away in shady corners of our gardens. In the Carboniferous, ferns reigned supreme, growing to towering heights, their trunks forming a labyrinthine network within the swampy forests. These arboreal ferns, alongside giant lycophytes and horsetails, created a verdant haven for a myriad of creatures.

The air hummed with the buzz of giant insects, their wings shimmering iridescent in the oxygen-rich atmosphere. Dragonflies with wingspans rivaling those of hawks darted through the air, while millipedes as long as a man's arm crawled amongst the fallen leaves. Amphibians, the first vertebrates to venture onto land, thrived in this humid environment, their calls echoing through the misty swamps.

The Carboniferous was a time of great change, as the Earth's continents slowly drifted together, forming the supercontinent Pangea. The warm and humid climate fueled the growth of the sprawling coal forests.

It was in these primeval swamps that the first amniotes, the ancestors of reptiles, birds, and mammals, emerged. Their amniotic eggs, a revolutionary adaptation, freed them from the constraints of water, allowing them to colonize the drier uplands.

But the Carboniferous world was not to last. As the climate shifted and the continents continued their inexorable drift, the great coal forests dwindled, their legacy buried beneath layers of sediment, eventually transforming into the coal deposits we rely on today. The giant ferns and their companions receded, their dominance eclipsed by new forms of life.

This Lucite came from Mini Museum.

Carboniferous strata such as this one in Pennsylvania hold most of the world's coal.
James St. John / CC BY-SA 3.0

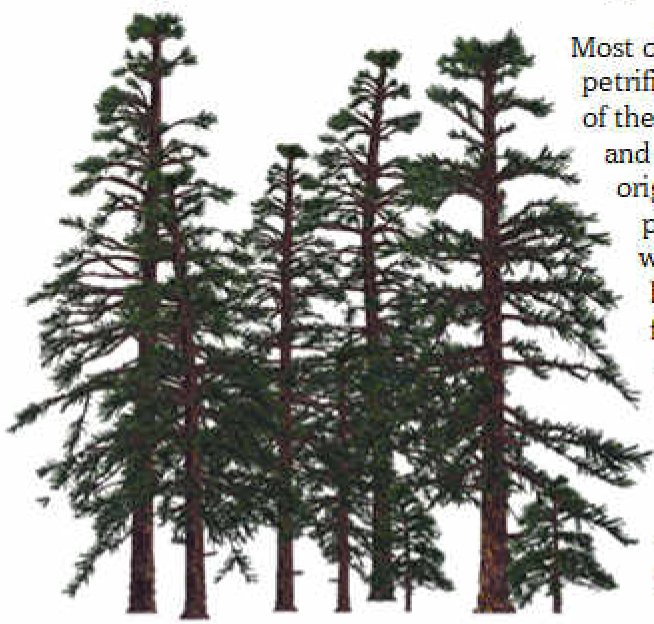
Section of Fossilized Tree Trunk, ~200 Million Years Old

One fifth of a billion years ago in the Late Triassic Epoch, in what was then Pangea and is now known as Petrified Forest National Park in Arizona, a great tree fell. It was uprooted by a great flood, or perhaps a flow of lava, then washed down from the highlands and buried by silt and volcanic ash. Groundwater dissolved silica from the ash and carried it into the log, where it formed quartz crystals that gradually replaced organic matter. Traces of iron oxide and other substances combined with the silica to create a rainbow of hues in the petrifying wood.

Thousands of millennia after the tree fell, the land where the great log was buried, known as the Chinle Formation, was lifted up by geological upheaval, and wind and rain began to wear away the overlying sediments, finally exposing the long-buried, wood, now turned to stone.

Visible tree rings.

At the time our tree lived, great herds of dinosaurs roamed through forests of tall conifers in what today is arid desert, while nearby rivers teemed with armor-scaled fish. Today, great ancient columns of petrified wood lie scattered across the dry sand. The Paiute Indians believed that the logs were the great arrow shafts of their thunder god, Shinauv. The Navajo said they were the bones of a mythological giant, called Yietso. Today, some of the great trunks still bear the annual rings that reveal their life histories in prehistoric times.



Most of the logs in the park retained their original external form during petrification but lost their internal structure. However, a small fraction of the logs and most of the park's petrified animal bones have cells and other spaces that are mineral-filled but still retain much of their original organic structure. With these permineralized fossils, it is possible to study the cellular make-up of the original organisms with the aid of a microscope. Other organic matter – typically leaves, seeds, pinecones, pollen grains, spores, small stems, and fish, insect, and animal remains – have been preserved in the park as compression fossi ls, flattened by the weight of the sediments above until only a thin film remains in the rock.

Much of the park's petrified wood is from Araucarioxylon arizonicum, an extinct conifer tree, while some found in the northern part of the park is from Woodworthia arizonica and Schilderia adamanica trees.

In addition to petrified logs, fossils found in the park have included Late Triassic ferns, cycads, ginkgoes, and many other plants as well as fauna including giant reptiles called phytosaurs, large amphibians, and early dinosaurs.

Paleontologists have been unearthing and studying the park's fossils since the early 20th century. Theodore Roosevelt created Petrified Forest National Monument on December 8, 1906. It is part of the Painted Desert, adjoining the eponymous National Park.

minniemouseaunt / CC BY 2.0

Mini Museum Lucite with Allosaurus Vertebra Fragment, ~145 Million Years Old

In the heart of the Late Jurassic period, approximately 150 million years ago, a fearsome predator reigned supreme: the Allosaurus. With its iconic skull "hornlets", this "different lizard", as its name translates, was a bipedal hunter and struck a unique and intimidating figure when compared to other carnivorous dinosaurs. The creature reached lengths of up to 32 feet, with powerful jaws lined with serrated teeth, and three-fingered hands tipped with sharp claws. A long, muscular tail counterbalanced its large head and powerful body, aiding in swift pursuit and deadly attacks.

The world the Allosaurus inhabited was vibrant with life. Pangaea, the supercontinent, was slowly fracturing, creating diverse habitats across the globe. The Allosaurus thrived in the semi-arid floodplains and savannas of North America, where lush forests provided shade and shelter for a multitude of creatures. Conifers, ferns, and cycads painted the landscape in shades of green, while rivers snaked their way through the terrain, providing life-giving water to the thirsty inhabitants.

As an apex predator, the Allosaurus sat atop the food chain. Its keen senses and powerful build allowed it to track and overpower a variety of large herbivores. Stegosaurus, with its distinctive plates and spiked tail, was a frequent target, as were the lumbering sauropods like Camptosaurus. The Allosaurus's serrated teeth were perfectly adapted for tearing into flesh, leaving little for scavengers.

Ceratosaurus and Allosaurus fighting over the desiccated carcass of another Allosaurus.
Brian Engh / CC BY-SA 2.0

Life in the Jurassic was a constant struggle for survival. Allosaurus faced competition from other formidable predators like Ceratosaurus and Torvosaurus. Battles for territory and food were brutal and even cannibalistic, leaving fossilized scars and broken bones as reminders of the harsh reality of prehistoric life.

Allosaurus fossils have been discovered across North America and even in Portugal. The vertebra from which my fragment came was recovered on private land from the Morrison formation in Utah, and is roughly 145,000,000 years old. Named the state fossil of Utah in 1988, Allosaurus is one of the most plentiful dinosaurs found there. This Lucite came from Mini Museum.

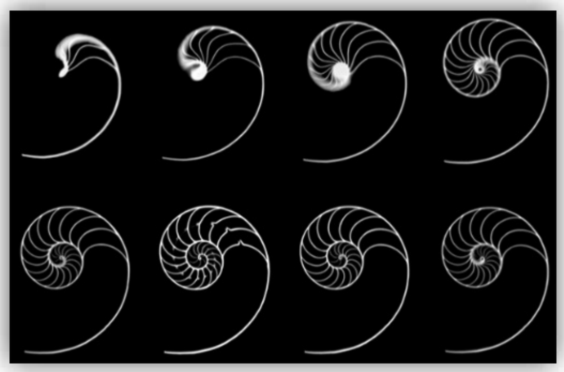
The Morrison Formation.
Anky-man / CC BY-SA 3.0

Nautilus, Madagascar, ~120 Million Years Old

This specimen is the fossilized remnant of an ancient nautilus, a pelagic marine mollusk of the cephalopod family along with octopuses, squid, and extinct ammonites. Nautilus fossils are famed for their stunning external coiled, spiral-patterned shells and colorful chambers. This fossil from Madagascar dates back to the Early Cretaceous Period, 120 million years ago, when the seas were full of Nautilus and Ammonites.

However, the earliest Nautilus fossils present in the fossil record date all the way back to the Late Triassic Period; over 200 million years ago. Nautili still exist in the present day, and they inhabit the deep coral reefs of the Indo-Pacific Ocean. These live Nautilus creatures are termed "living fossils", a rare type of creature which is very similar in biology to its ancient fossil relatives.

Florian Elias Rieser / CC BY-SA 4.0

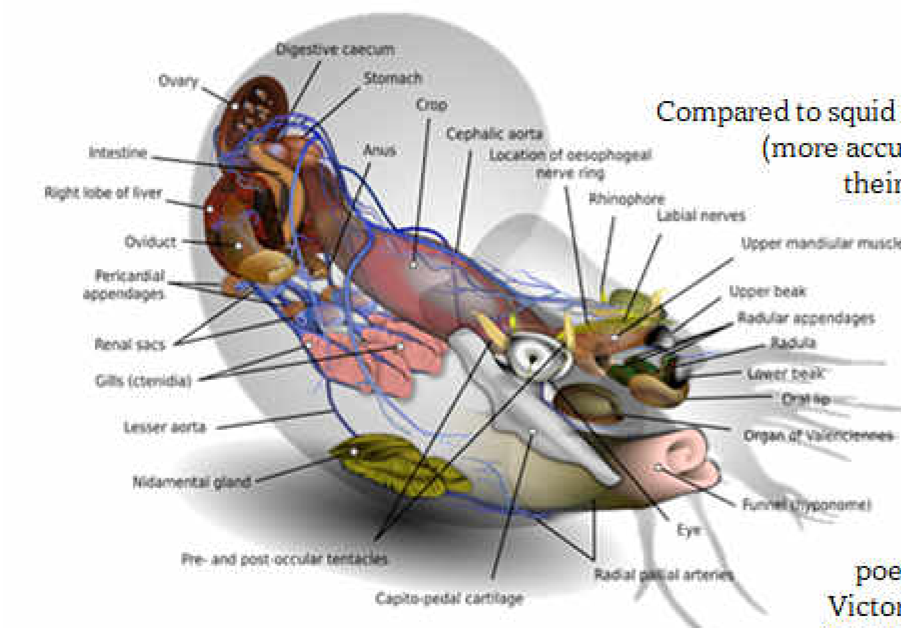


Over the last 500 million years, the evolution of Nautili has been slow and minimal, meaning that Nautilus fossils are very similar to living Nautilus creatures. Ammonites, another famous type of Cephalopod fossil, are completely extinct, so Nautili are the only Cephalopods with an external shell that swim the modern seas.

The nautilus has an external shell which protects the chambers within. As the Nautilus creature grows, its chambers expand outwards in a stunning spiral shape.

The Nautilus body remains in the hard, outermost chamber so that it can be protected, and the other chambers are used to enable the Nautilus to float and sink. Named after the Ancient Greek term for "sailor", Chambered Nautilus creatures are incredibly buoyant. When the Nautilus floats towards the ocean surface, the chambers are full of gas, helping the creature to float. When it needs to sink, a tube called the siphuncle that runs through the chambers opens, flooding them with water so that the Nautilus becomes heavier and able to sink.

Hans Hillewaert / CC BY-SA 3.0



K. D. Schroeder / CC BY-SA 3.0

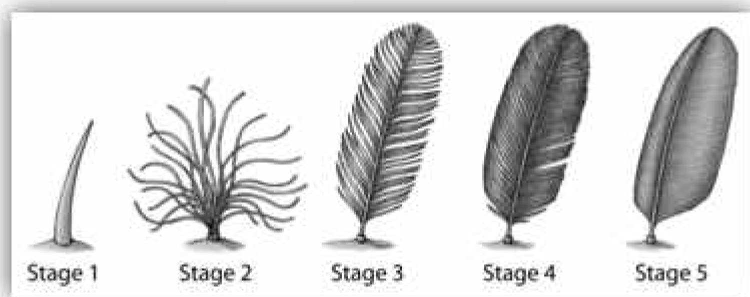
Compared to squid and octopus, Nautili have many more tentacles (more accurately known as cirri) which they use to ensnare their prey. As carnivores, Nautili feed on fish and crustaceans: they swim towards prey using jet propulsion, meaning water inside their chambers is forcefully pushed out to propel them in their desired directions.

A nautilus shell is patterned in a very similar way to the Golden Mean Spiral, the infinite Fibonacci Sequence, and the revered Golden Ratio. The Nautilus has been an important symbol in art and literature, with poetry and music inspired by its beautiful shell. The Victorians particularly revered the Nautilus, and Nautilus shells were prized in interior design.

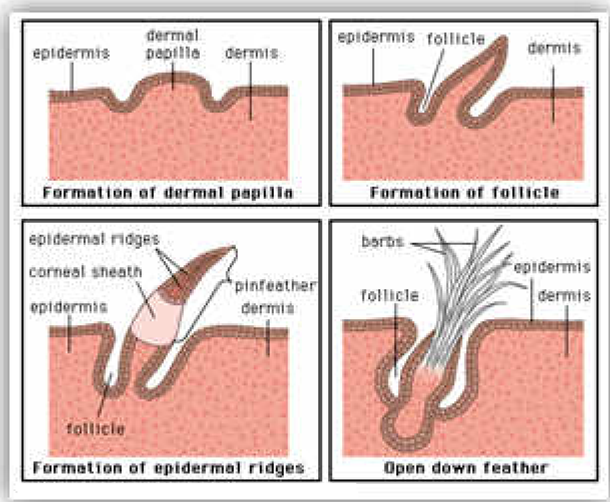
Dinosaur Feather, Myanmar, ~95 – 105 Million Years Old

Feathers are complex and novel evolutionary structures. They did not evolve directly from reptilian scales, as once was thought. Current hypotheses propose that they evolved through an invagination of the epidermis around the base of a dermal papilla, followed by increasing complexity of form and function. They evolved before birds and even before avian flight. Thus, early feathers functioned in thermal insulation, communication, or water repellency, but not in aerodynamics and flight.

Among extinct life-forms, feathers are no longer considered a unique and diagnostic characteristic of birds. Feathers with modern features were present in a variety of forms on a variety of theropod dinosaurs. At least nine Cretaceous dinosaurs had featherlike structures. The details of some are questionable, but some, such as those of Sinornithosaurus and other basal dromaeosaurs, bear a resemblance to modern pennaceous feathers. Feathered dinosaurs did not survive the end of the Cretaceous Period, but birds did, and then they flourished.



Each of these stages in feather evolution has been found on dinosaur fossils.
Stage 3 is known from cretaceous amber, like my specimen.
© *Emily A. Willoughby*



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Stage 1 - Simple fibers:
Hollow unbranched fibers, with no barbs or barbules.
Found on Sciurumimus albersdoerferi.

Stage 2 - Bundles of fibers:
Groups of unbranched fibers, each attaching to a central point.
Found on Sinosauropteryx prima.

Stage 3 - Unbranched barbs:
Rows of unbranched barbs attached to a central shaft.
Found on Sinornithosaurus millennii.

Stage 4 - Barbs and barbules:
Rows of barbs attached to a central shaft, which branch further into barbules.
Found on Protarchaeopteryx robusta.

Stage 5 - Fully-developed flight feathers:
Barbs and interlocking barbules; asymmetrical shape.
Found on Microraptor gui.

Sinornithosaurus millennii.
© *Emily A. Willoughby*

This feather embedded in Burmese amber lacks barbules, and would thus be considered a Stage 3 feather. This confirms it as a dinosaur rather than bird feather, and dates it to the Early Cretaceous.

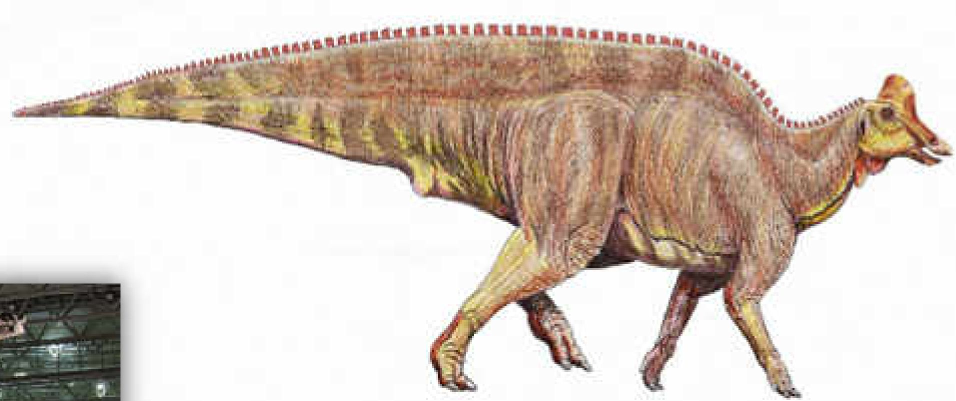
This feather likely belonged to something like the creature in the picture, Sinornithosaurus millennii.

Hadrosaur Egg, ~66 - 86 Million Years Old

Hadrosaurids (Greek: ἁδρός, hadrós, "stout, thick"), or duck-billed dinosaurs, are members of the ornithischian family Hadrosauridae. This group is known as the duck-billed dinosaurs for the flat duck-bill appearance of the bones in their snouts. The ornithopod family, which includes genera such as Edmontosaurus and Parasaurolophus, was a common group of herbivores during the Late Cretaceous Period.

Hadrosaurids are descendants of the Upper Jurassic/Lower Cretaceous iguanodontian dinosaurs and had a similar body layout. Hadrosaurs were among the most dominant herbivores during the Late Cretaceous in Asia and North America, and during the close of the Cretaceous several lineages dispersed into Europe, Africa, South America and Antarctica.

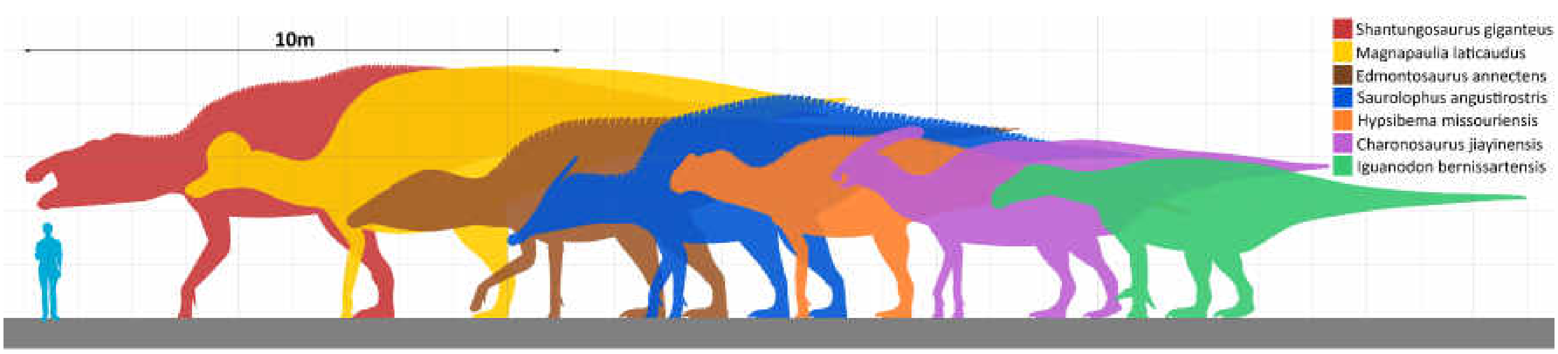
The egg originally came from China; although it is illegal to export them today this made its way to the U.S. prior to the ban by way of the fossil dealer Eons Ago USA.



Probably tasted like chicken.
Dmitry Bogdanov / CC BY-SA 3.0

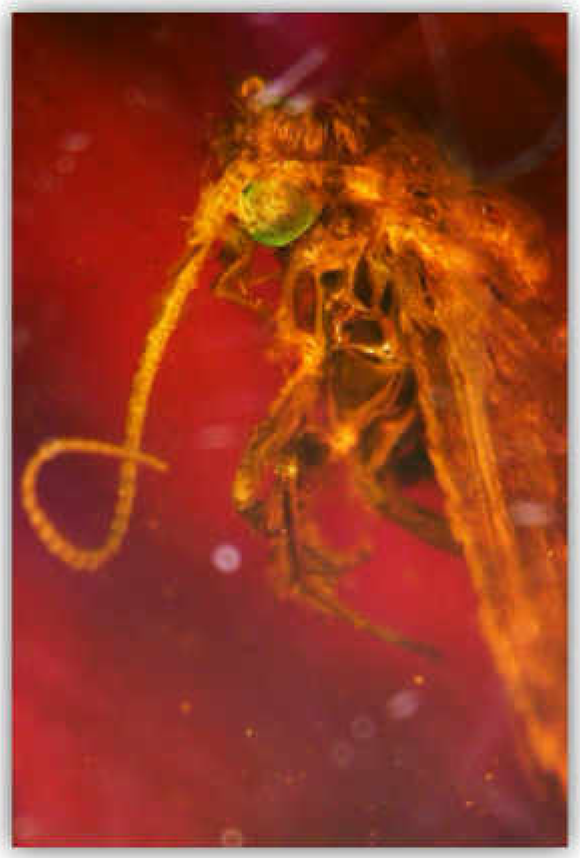
Laika ac / CC BY-SA 2.0

This specimen measures approximately 15 by 11 cm. Although species can't be determined from the outside of the egg, based on size, appearance, and other fossils found in the same region, this was probably laid by a large hadrosaur like Shantungosaurus giganteus. Based on the condition of the shell and the small size of the base, it is quite possible that this egg is unhatched and could contain a baby dinosaur.



Giant Ornithopod Scale

Insect (Lepidoptera) in Baltic Amber, ~45 Million Years Old



One day, in a warm and rainy Baltic forest about 45 million years ago, during an epoch known as the Late Eocene, this little guy with his curly hair and green eyes had a very bad day and got stuck to an injured tree. Very likely the tree resembled something similar to a Japanese umbrella pine today, and had a branch broken off in a storm or by a large animal. In order to seal the wound, the tree had exuded delicious smelling sticky resin (different from sap!) and our unfortunate friend couldn't escape once he fell into it.

At that unfathomably distant time, there existed occasional land bridges between Europe and North America. The first hooved animals like horses were beginning to appear, and rodents were starting to outcompete smaller primates. Grass was just beginning to evolve; our planet was a damp and forested place.

Eventually, as the planet slowly cooled and the continents drifted apart, glaciers knocked down the ancient trees, halting decomposition. This set the stage for the transformation of the lump of resin on the old fallen tree into this piece of amber.

The piece of raw amber.

"Rainforest in the Eocene - Paleontological deposit Messel. Germany"
©*Raúl Martín*

At first oleoresins, essential oils, had comprised most of the deposited resin. These types of oils are volatile though and were lost through the years, hardening the resin and making it less vulnerable. This hardened resin had a better chance of being fossilized, since it could resist the environment better than the sticky and pliable material as which it started out.

The resin continued to harden year upon year through a process called polymerization, where small molecules (monomers) combine chemically to produce a large network of molecules. This is a similar process to that which takes place very rapidly when you season a cast iron pan. The hardened resin is called copal, and its hardening was one of the factors necessary to produce our friend's prison.

As this copal aged, concentrations of essential oils continued to decrease while the copal progressively oxidized the resin and polymerization continued. The copal slowly turned into amber, millions of years after the first entombment of our ill-fortuned little pal.

Finally, the amber was dug up, quite likely in an open pit mine in Kaliningrad Oblast, and made its way via Lithuania to Chicago.

And our poor little fellow? He's been making the exact same face all the way from then until today, perfectly preserved and forever trapped inside.

Also pictured is a modern tree relative as well as a contemporaneous animal. Brontops Robustus happens to be a distant relative of our woolly rhinoceros a few pages further.

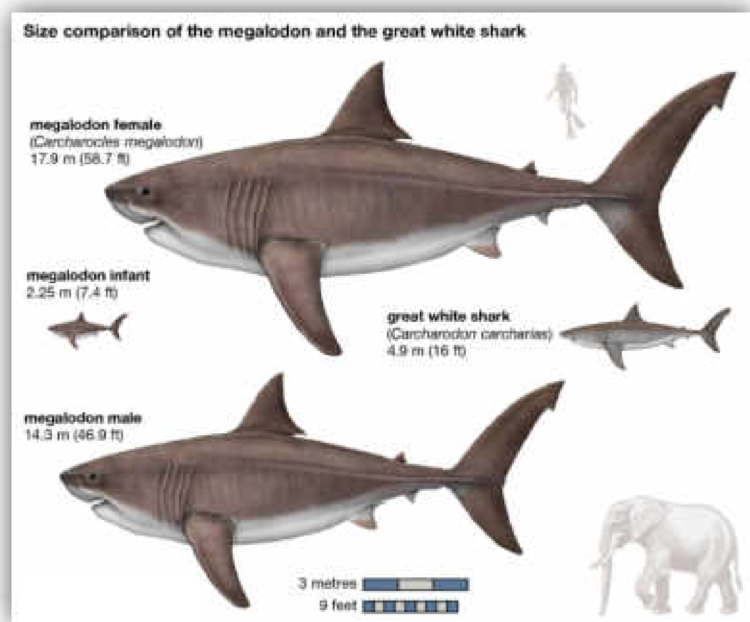
Megalodon Tooth, ~3.6 - 23 Million Years Old

A 4.9" fossilized Megalodon tooth from the Pliocene Epoch.

If you'd like to learn anything about Megalodon, including any number of lies and all sorts of wild speculation, you can find all you'll ever need during Shark Week on Discovery Channel. I won't go into detail here.

This megalodon tooth from the U.S. Atlantic coast was probably recovered by a diver at the mouth of one of the rivers in North Carolina that carry them into the sea, but there are some commercial divers for them off the coast of Georgia as well.

Based on its size, we can assume that this tooth once belonged to a yacht-sized monster nearly 40ft in length.



© *Encyclopaedia Brittanica*

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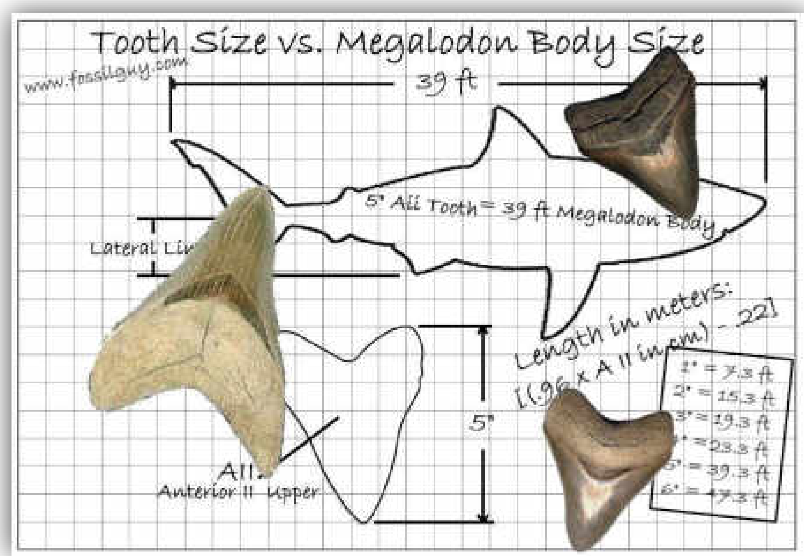
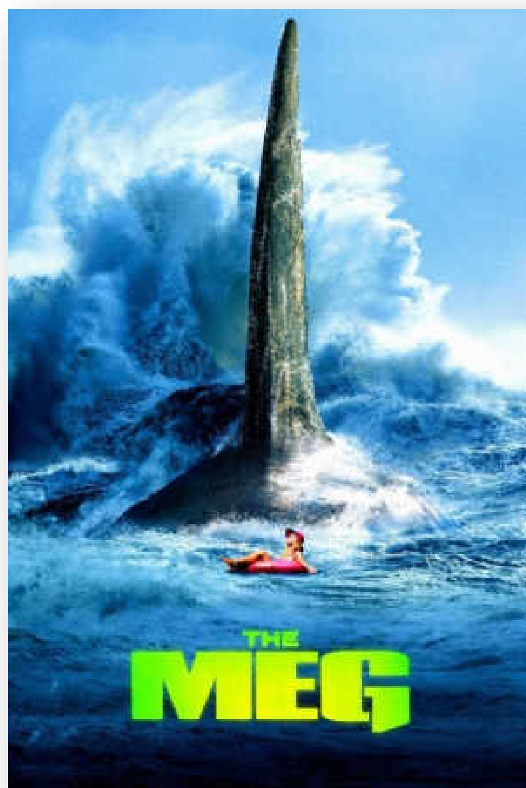




Megalodon looms large in Hollywood's imagination.
© *Warner Bros.*

Woolly Rhinoceros Tooth, ~20,000 Years Old

Note that this tooth is upside down; you can see the roots at the bottom.

One of the Pleistocene mammals depicted without fail in encyclopedias of prehistoric life and the like is the Woolly rhinoceros Coelodonta antiquitatis. Originally named in 1807, this cold-adapted, shaggy-coated rhinocerotid rhino lived from about 350,000 years until 10,000 years ago and occurred from the Atlantic fringes of Europe all the way east to Beringia, and as far south as the southern Caucasus and south-east China. Why it never moved into North America is unknown – it should have. The woolly rhinoceros may have had, during the latter part of the Pleistocene epoch, the most extensive range of any known living or extinct rhinoceros.

The woolly rhino appears extensively in the cave paintings of early humans. The fact that human beings co-existed with the woolly rhinoceros, and likely hunted them as a food source despite their formidable size and strength, adds to the fascination of these creatures for people today. It is possible that human beings, coupled with climate changes, were factors in the extinction of the woolly rhino.

As a member of the Rhinocerotidae family, the woolly rhino was an odd-toed ungulate and is a member of the Pleistocene megafauna. The genus name Coelodonta comes from the Greek for "hollow teeth" and the specific name antiquitatis comes from the Latin antiquus for "old".

This creature had thick, long fur, small ears, short and thick legs, a stocky body, and a weight of up to three tons. It had two horns on its snout, the anterior one larger than the one between its eyes and about one meter long. The front and larger horn also had a flattened shape from side to side. Both projections on the upper snout were not really true horns, but epidermal derivatives, composed of a solid mass of thickly matted hair – keratin, a hair protein – that grows from the skull without skeletal support. Abrasion marks on the horns of woolly rhinoceros fossils suggest that the horns were used to sweep snow away from vegetation so it could eat in the winter.

As the last and most derived member of its lineage, the woolly rhinoceros was supremely well adapted to its environment. Stocky limbs and thick woolly pelage made it well suited to a steppe-tundra environment. Its range expanded and contracted with the alternating cold and warm cycles, forcing populations to migrate or perish as the glaciers receded.

As with extant rhinoceroses, the woolly rhino was a herbivore. Controversy has long surrounded the precise dietary preference of Coelodonta as past investigations have found plausible both grazing and browsing modes of life. Climatic reconstructions indicate the preferred environment to have been cold and arid steppe-tundra. Pollen analysis shows a prevalence of grasses and sedges.

Didier Descouens / CC BY-SA 4.0

At Staruni in what is now Ukraine, a complete carcass of a female woolly rhinoceros, minus only the fur and hooves, was found buried in the mud, with the oil and salt preventing decomposition and allowing the soft tissues to remain intact. In 2002, fossils of four woolly rhinos were unearthed in an English quarry. Included in this find were well-preserved plants and insects, including plant material stuck to the teeth of one rhino.

Discoveries like this one are likely to become more common. As the planet warms, the permafrost – ground in the Northern Hemisphere that remains frozen all year – is beginning to thaw. As it melts, ice-age creatures like this woolly rhino that were entombed for tens of thousands of years are starting to be unearthed.

In 2014, scientists found a baby woolly rhino carcass – nicknamed Sasha – in Siberia. Sasha lived 34,000 years ago and was covered in strawberry blond-colored fur, according to the Siberian Times. The baby rhino died at the age of seven months and had two little horns.

Yakutia yielded another find in 2019: scientists discovered a 40,000-year-old severed wolf's head, complete with fur, teeth, brain, and facial tissue on the banks of a river. The woolly rhinoceros also co-existed with woolly mammoths and several other extinct larger mammals. It is believed that the animal lived socially, similar to modern forms, either alone or in small family groups.

This artifact came from Mini Museum, by way of Australia. It's absolutely magnificent, like the animal from which it must have come, and measures approximately 12 x 8 cm.

"Ice Age Tough"
© *Daniel Eskridge*

Fordite (Corvettite), ~50 Years Old

Despite its gemstone-like qualities, such as being able to be cut and polished to reveal vivid waves of color that mimic natural agate, fordite, also known as Detroit agate or motor agate, is actually a man-made material with a backstory deeply intertwined with American history. It's an intriguing and unique material.

Fordite's origin story is as colorful as its appearance, starting in the 1920s when auto manufacturers began using hand-spraying techniques to paint car bodies. This led to the accumulation of layers of colorful overspray in the paint bays. These layers of enamel paint were hardened, often baked multiple times, as cars went through curing ovens. Over time, these paint layers became cumbersome and had to be removed from equipment. Fortunately, some factory workers saw value in this material and began salvaging it.

The many layers of paint are clearly visible on the back of the cabochon.

Although the name fordite originated from the Ford Motor Company, where this material was first collected in the 1940s, it has come to represent similar byproducts from various automotive plants. For instance, there's material known as corvetteite from the Corvette assembly plant in Kentucky (this is the origin of my pieces) and pieces from Lincoln-Mercury paint slags found in a Canadian plant. The fordite from the 1960s and 1970s is especially prized for its bold hues, reflecting the era's demand for brightly colored cars, while earlier pieces tend to display more muted neutrals.

The supply of fordite is inherently limited. By the 1980s, the transition to electrostatic painting methods reduced paint overspray to almost nothing, effectively stopping the creation of new fordite. While there's a chance that significant quantities of fordite are hidden away in collections, it's also likely that much was discarded before its value was recognized.

Fordite's appeal lies in its light weight and its varied appearance, dictated by the specific automotive plant and era in which it was created. Its patterns can range from colored layers separated by gray primer bands to more intricate designs featuring dripping or striped layers, sometimes with lace and orbital patterns or surface channeling. The material can showcase opaques and metallics, with some pieces featuring bleeding layers or air bubble pits that add to their unique character. Each layer of hardened paint not only displays the changing tastes in car colors but also the technological advancements in automotive manufacturing.

Both the raw piece pictured at the top and to the right, and the polished cabochon above are in my collection.

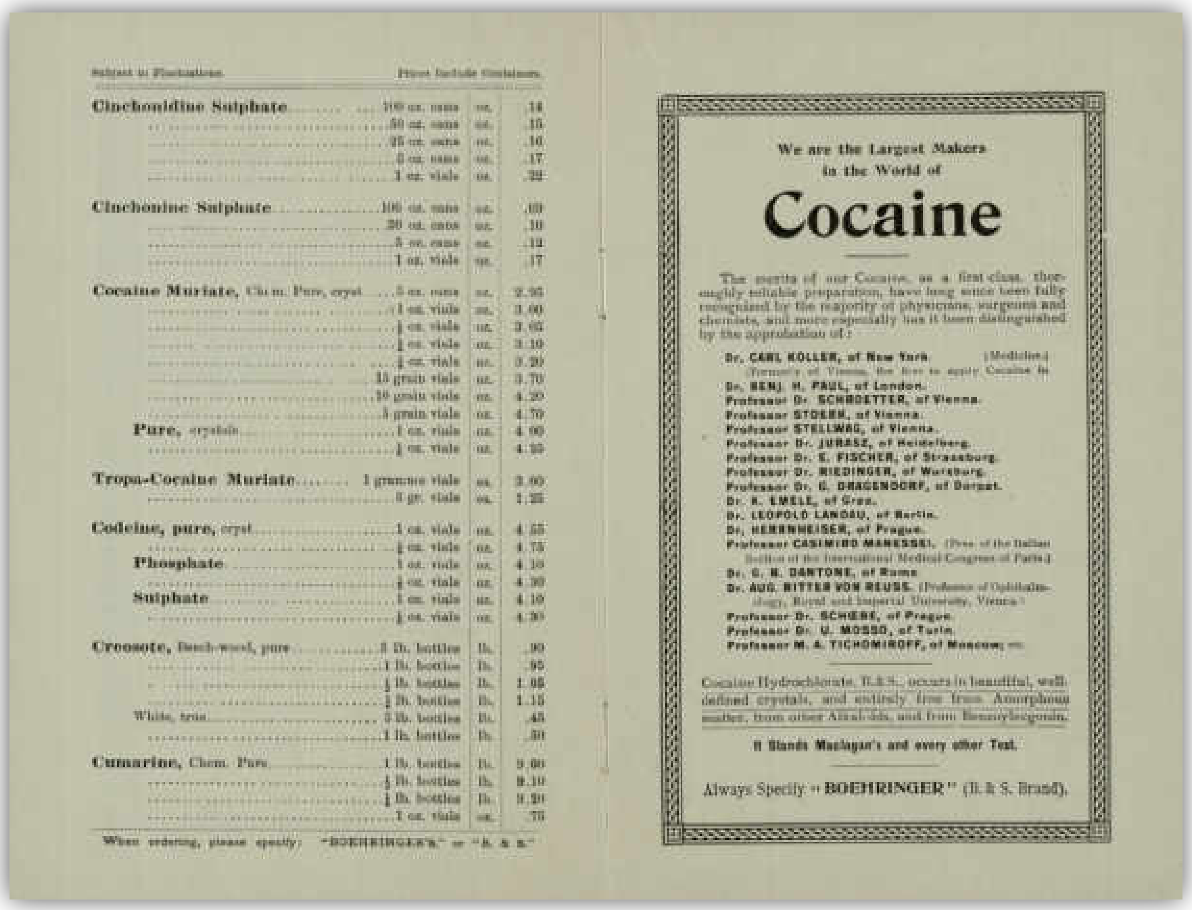
Other Interesting Stuff

Glass Paperweight of the Largest Makers in the World of Cocaine and Quinine

c. 1905 ANTIQUE COCAINE ADVERTISING This vintage glass paperweight features an attractive black and red illustration of the C. F. Boehringer & Soehne, Mannheim Germany, New York City Office, 7 Cedar Street. This chemical manufacturer was proud of its leading position in the world's cocaine market, and was a member of the original cocaine makers' cartel. The paperweights were given away as part of an advertising promotion, sometime around 1905.

In 1859 Christian Friedrich Boehringer (1791-1867) renamed his pharmaceutical firm in Mannheim, Germany, as "C.F. Boehringer & Soehne" (B&S). As advertised on this paperweight, B& S styled itself as the "largest makers in the world of Quinine and Cocaine". The company also prided itself on distributing "beautiful, well-defined crystals." From at least 1896 to 1906, B&S boasted that the "merits of our Cocaine, as a first-class, thoroughly reliable preparation, have been distinguished by the approbation of Dr. Carl Koller, of New York [and] formerly of Vienna, the first to apply Cocaine to Medicine."

Located less than 8 miles from the New York branch of B& S, ophthalmologist Koller's office likely received its share of B&S paperweights like the one above.



Cinchonidine Sulphate	100 oz. cans	oz.	.14
	50 oz. cans	oz.	.15
	25 oz. cans	oz.	.16
	5 oz. cans	oz.	.17
	1 oz. vials	oz.	.22
Cinchonine Sulphate	100 oz. cans	oz.	.09
	20 oz. cans	oz.	.10
	5 oz. cans	oz.	.12
	1 oz. vials	oz.	.17
Cocaine Muriate, Chem. Pure, cryst	5 oz. cans	oz.	2.95
	1 oz. vials	oz.	3.00
	½ oz. vials	oz.	3.05
	¼ oz. vials	oz.	3.10
	⅛ oz. vials	oz.	3.20
	15 grain vials	oz.	3.70
	10 grain vials	oz.	4.20
	5 grain vials	oz.	4.70
Pure, crystals	1 oz. vials	oz.	4.00
	½ oz. vials	oz.	4.25
Tropa-Cocaine Muriate	1 gramme vials	ea.	3.00
	5 gr. vials	ea.	1.25
Codeine, pure, cryst	1 oz. vials	oz.	4.55
	½ oz. vials	oz.	4.75
Phosphate	1 oz. vials	oz.	4.10
	½ oz. vials	oz.	4.30
Sulphate	1 oz. vials	oz.	4.10
	½ oz. vials	oz.	4.30
Creosote, Beech-wood, pure	5 lb. bottles	lb.	.90
	1 lb. bottles	lb.	.95
	½ lb. bottles	lb.	1.05
	¼ lb. bottles	lb.	1.15
White, true	5 lb. bottles	lb.	.45
	1 lb. bottles	lb.	.50
Cumarine, Chem. Pure	1 lb. bottles	lb.	9.00
	½ lb. bottles	lb.	9.10
	¼ lb. bottles	lb.	9.20
	1 oz. vials	oz.	.75

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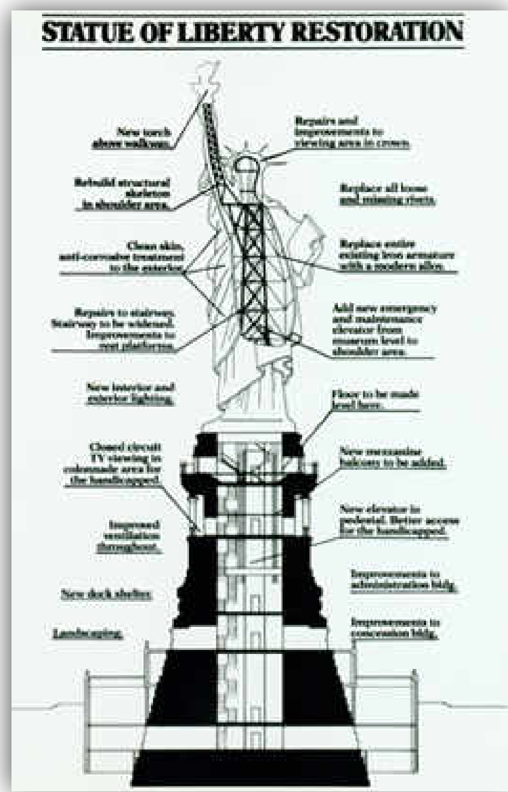
Lucite with Statue of Liberty Torch Made with Material from Statue

In 1982, four years before the Statue's centennial anniversary, the Statue of Liberty - Ellis Island Foundation was created, and Lee Iacocca, the Chairman of Chrysler Corporation, appointed its head. The Foundation was created to lead a private sector effort to raise the funds for the renovation and preservation of the Statue for its centennial in 1986. The Foundation worked with the National Park Service to plan, oversee, and implement this restoration.

A team of French and American architects, engineers, and conservators came together to determine what was needed to ensure the Statue's preservation into the next century. In 1984, scaffolding was erected around the exterior of the Statue and construction began on the interior.



Workers repaired holes in the copper skin and removed layers of paint from the interior of the copper skin and internal iron structure. They replaced the rusting iron armature bars (which joined the copper skin to the Statue's internal skeleton) with stainless steel bars. The flame and upper portion of the torch had been severely damaged by water and was replaced with an exact replica of Bartholdi's original torch. The torch was gilded according to Bartholdi's original plans.

The restoration was completed in 1986 and the Statue's centennial was celebrated on July 4 with fireworks and fanfare. On July 5th, a new Statue of Liberty exhibit opened in the base of the pedestal.

This artifact is a vintage souvenir from the 1986 Statue of Liberty Centennial, a Lucite paperweight containing a metal replica of Lady Liberty's Torch made from "authentic materials" from her 1985 renovation. This cylinder stands 4.5" tall by 2.5" in diameter and weighs 1 lb. The top reads "AUTHENTIC MATERIALS - LIBERTY - CENTENNIAL - 1886-1986".

The green torch replica inside is made with original copper left over after the Statue's renovation.

Lucite with Various Unique Weatherby Rifle Ammo Calibers

The year was 1945, and the country was euphoric over its victory in World War II, first in Europe, then in the Pacific. A brash young man from Kansas, Roy E. Weatherby, started a firearms company that 71 years later continues to be managed by his descendants. Born September 4, 1910, and living until April 4, 1988, Roy was a handloader and rifleshooter who pursued the time-honored pastime of wildcatting, or creating his own cartridges. Only a small number of his experimental cartridges made the grade when he went commercial, founding his company on his signature line of Weatherby Magnums.

At the outset, the .300 H&H was the parent case, full length for the .300 and .375 Weatherby Magnums, shortened for the .257, .270 and 7mm Weatherby Magnums, taper removed and shouldered in Weatherby's distinctive double Venturi curve. In years to come, the .340 Weatherby Magnum would be added, also based on the full-length .300 H&H case. Using their own unique cases, Roy would add the .224, .240, .378 and .460 Weatherby Magnums as well. After Roy's passing, his son, Roy E. Weatherby Jr. – "Ed" – would introduce the .416 Weatherby Magnum and the .30-.378 and .33-.378 Weatherby Magnums.

Got all that?

Promotional Lucite showing various calibers of Weatherby rifle ammo. Mostly it's just cool looking.

A Weatherby rifle.

Lucite with Early Bell Labs Solar Cell

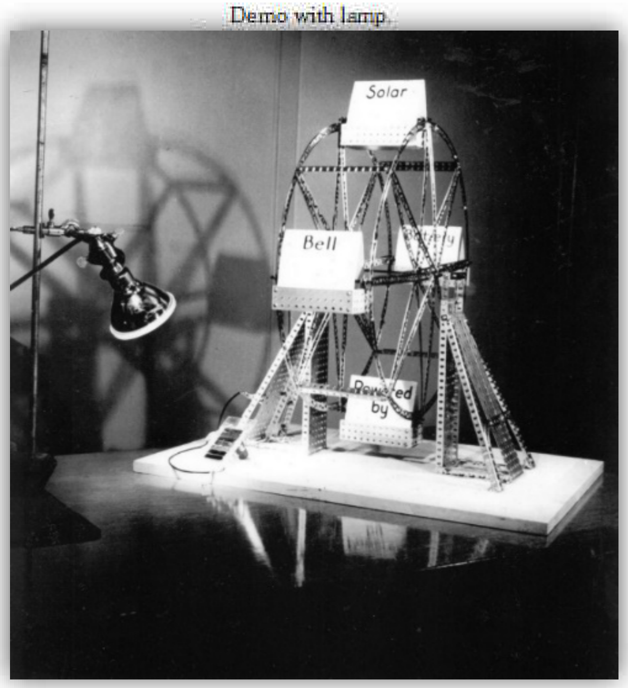
On 26 April 1954, the front page of the New York Times trumpeted: "Vast Power of the Sun Is Trapped by Battery Using Sand Ingredient". This headline foreshadowed the 2008 induction of Gerald L. Pearson into the National Inventors Hall of Fame for his co-invention of the silicon solar cell.

Efforts to capture solar energy for human use began decades before Gerald was born in Salem, Oregon, in 1905. His father was a fruit farmer with a fourth-grade education who insisted that Gerald and his two brothers go to college. Pearson studied physics at Willamette University in Salem, then earned a master's at Stanford.

By the time Pearson was hired by Bell Labs in 1929, 90 years had passed since French physicist Edmond Becquerel measured a small voltage between platinum electrodes in an acidic solution containing silver chloride illuminated by sunlight. British engineer Willoughby Smith later discovered photoconductivity in selenium in 1873, and in 1883 American inventor Charles Edgar Fritts applied gold leaf to selenium to make the first solar cell. However, its anemic efficiency, less than 1%, made it impractical.

An important experiment in silicon physics at Bell Labs in 1940 marked another a big step in solar cells. Russell Ohl was studying how impurities affected silicon properties when he found that illuminating a cracked sample of silicon with different impurity levels on two sides produced a surprisingly strong voltage across the crack. It led to Ohl's observation of the first junction of silicon regions doped with positive and negative impurities – a key to the junction diode and transistor – as well as the first silicon solar cell.

Demo with lamp



Bell Labs made military projects top priority during the war, but turned back to semiconductors in 1946, transferring Pearson into the program. After five years of war work, Pearson said, "we felt free as the wind." Pearson was interested more in the science of semiconductors than in making transistors. He did not work on the point-contact transistor that was the first type invented, but his research on semiconductor behavior and p-n junctions contributed to the junction transistor which came next. Pearson did develop the first useful silicon field-effect transistor.

Meanwhile, a practical problem roused Bell Lab's interest in solar power. The batteries used to power remote telephone equipment degraded quickly in humid regions, and in 1952 Bell asked engineer Daryl Chapin to study other power sources. Chapin thought solar cells might work, but wanted more efficiency than selenium could offer, so he asked Pearson, a friend, about alternatives.

Pearson and Calvin Fuller had been studying how impurities affect silicon's properties, important for transistors and other semiconductor devices. Fuller gave Pearson a silicon sample doped with gallium to give it positive charge carriers, and suggested that Pearson dip it into hot lithium to add negative carriers. After connecting an

ammeter to the sample, they turned on a lamp and saw the highest current flow ever recorded in a solar cell. Pearson walked to Chapin's office and told him to drop selenium and switch to silicon.
Yet, problems emerged: lithium migrated through the silicon and good electrical connections to the semiconductor were hard to make. First, they replaced the lithium with phosphorous, which helped, but not enough. Then they tried a new recipe suggested by Fuller: doping the silicon with arsenic as negative carriers, then applying a very thin layer of boron to make positive carriers and form the p-n junction very close to the surface. Those changes also made good electrical contacts, allowing them to convert six percent of the solar energy into electricity, beating the one percent that solar-energy pioneer Mária Telkes, then at MIT, had reported for thermoelectric conversion in 1947. Six percent was the target for the telephone application, though Chapin calculated that an ideal silicon solar cell could reach 23 percent of sunlight into electricity.

Closeup.

Chapin, Fuller, and Pearson submitted a letter to the Journal of Applied Physics. Around the same time, the front page of the 27 January 1954 New York Times heralded an "atomic battery" produced by the RCA Corp. in which electrons emitted by radioactive strontium-90 generated electricity from a p-n junction in silicon. The RCA Corp. invention produced a microwatt of power per square yard of solar cell.

Bell Lab's solar cell made the front page of the Times shortly after on April 26, 1954, appearing between announcement of the first large-scale test of the Salk polio vaccine and a gangland killing in New York. A square meter of Bell's solar cell converted six percent of the incident solar energy into electricity, effectively leaving RCA's atomic battery in the dust. The Times projected solar cells might someday harness the "almost limitless energy of the sun for the uses of civilization."

© Bell Labs/Alcatel-Lucent

Bell managers told Pearson the solar cell had received "the best newspaper publicity coverage ever in the history of the Bell system." But Pearson was not as impressed by the publicity, noting that the invention of the transistor earned only six inches on the Times obituary page. He told Hoddeson the solar cell "was the most important publicity-wise, but I think scientific-wise it may not have been."

Pearson measured success by how much his inventions were used. When he totaled up sales of his inventions in 1969, they had reached $260 million (nearly $1.2 billion today). His best-selling invention at the time was the silicon rectifier at $154 million, followed by p-n-p-n devices at $65 million, $18 million in thermistors, $20 million in field effect transistors, and only $5.8 million in solar cells, just over two percent of the total.

Crucially, solar cells powered the space race, since all satellites built to last more than a month required solar power. Looking back, Pearson acknowledged, "The scientific equipment on the Moon and on Mars wouldn't function if it weren't for solar cells."

Pearson died in 1987, too early to see solar rooftops, solar-power farms, or solar cells with efficiency above the 23 percent limit that Chapin predicted 67 years ago. If he was around today, the tremendous growth of solar power and its importance in controlling climate change might have changed his mind.

Lucite with Fragment of Jacques Cousteau’s Ship “Calypso”

Calypso was, according to Greek myth, the nymph who held Ulysses captive on the island of Gozo for ten years. Today, the name is linked to another legend, that of Jacques Cousteau’s ship. This famous vessel is known throughout the world, and she sailed the planet’s oceans for nearly half a century to reveal their beauty and fragility. She is the symbol of the human hope to understand Nature, the better to protect it.

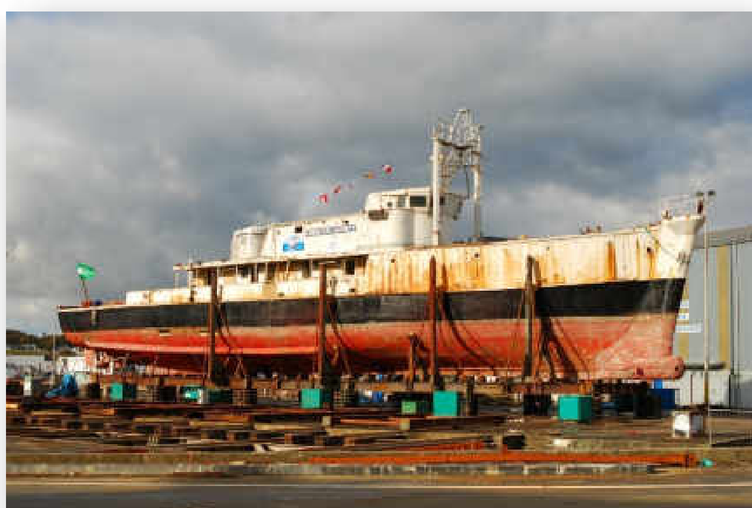
Jacques-Yves Cousteau first came across the ship, a former Royal Navy minesweeper that had been converted to a ferry and named Calypso, in Malta. The ship was christened in 1942, but her first prosaic name, J-826, belied the exceptional life she would lead. To Cousteau, she was the ideal ship for his plan to explore the seas. Thanks to the financial help of Loël Guinness, the sale contract was signed on July 19, 1950. Calypso left immediately for the shipyard in Antibes, France, where she was transformed into an oceanographic ship and a new Calypso was born. One of her many innovations was the “false nose”, or underwater observation chamber built around the prow and equipped with eight portholes.

© Cousteau Society

© Cousteau Society

In June 1951, Cousteau decided the ship was ready for her first trials off Corsica. On board, the improvised crew was made up of a few friends, as well as the whole Cousteau family: 12-year-old Jean-Michel and 10-year-old Philippe served as cabin boys. On November 24, 1951, the real adventure began. Calypso sailed from the Toulon arsenal, headed for the Red Sea to study corals. The crew brought back valuable topographic and photographic documentation and samples of theretofore unknown fauna and flora. Cousteau came back convinced that there was only one solution for understanding the sea:

“We must go see for ourselves”. Calypso was the ideal tool for that challenge. The sturdy wooden minesweeper has seen many reincarnations – as a ferry, an oceanic research vessel, a television icon and a sad victim of a 1996 collision in Singapore. Restored, hopefully she will sail again as an Ambassador for the Seas and Oceans, as Captain Cousteau wished. Since the tragic collision in Singapore, Equipe Cousteau has fought to resurrect her as an inspiration for future generations and a platform for education and science, carrying the legacy of Captain Cousteau and the Cousteau flag all around the world. Jumbo after.



Olivier Bernard / CC BY-SA 3.0

©

Cousteau was also one of director Wes Anderson's childhood heroes, and inspired him to make The Life Aquatic. Many of the details in the movie mirror Cousteau's real life. The character of Zissou was originally supposed to be named "Steve Cousteau", and besides being an ocean-documentarian like the fictitious Zissou, Cousteau also had a research vessel named the Calypso (Zizzou's is the Belafonte), which, like Zissou's ship, had a mini-sub, a gyrocopter, and a research balloon. Cousteau's crew wore red knit caps and uniforms, and his son Phillipe was tragically killed in a plane crash.

Lucite with Lichtenberg Figure from the Boeing Radiation Effects Laboratory, 1960s

Cosmic ray damage is a huge threat to equipment in space. Everything is continually bombarded by high energy charged particles such as protons. If the exposed material is a crystalline non-conductor, the cosmic ray energy can be trapped and at some later time spontaneously discharged. Tracks created in the material by the discharge can weaken it or destroy its usefulness. In the case of space shuttle tiles for example, such damage might make the tiles overheat or shorten their useful life. Similarly, these discharges could destroy semiconductors in space-based electronics systems. This was obviously of concern to both NASA and the military, and the effects of radiation on various materials have been studied intensively. My great uncle's research during the Manhattan Project, mentioned earlier in this chapter, is another example.

A Lichtenberg figure (German Lichtenberg-Figuren), or Lichtenberg dust figure, is a branching electric discharge that sometimes appears on the surface or in the interior of insulating materials. Lichtenberg figures are often associated with the progressive deterioration of high voltage components and equipment.

The study of planar Lichtenberg figures along insulating surfaces and 3D electrical trees within insulating materials often provides engineers with valuable insights for improving the long-term reliability of high-voltage equipment. Lichtenberg figures are now known to occur on or within solids, liquids, and gases during electrical breakdown. Lichtenberg figures are natural phenomena which exhibit fractal properties. The emergence of tree-like structures in nature is summarized by constructal law.

This object came from the estate of an engineer who worked for Texas Instruments and Teledyne Brown, and was Director of the Missile Defense and Space Technology Center (U.S. Army Space and Missile Defense Command). He retired at a civilian rank equivalent to Major General. I like that the Lucite material itself is the artifact.

The cheerfully Modernist
Boeing Radiation Effects Laboratory.
© *CommercialEdge*

A Lichtenberg figure on human skin.

Lucites with DNA Specimens, Each Equivalent to That of All Humans Alive in 1977

"The entire human population living on earth today received its hereditary characteristics though an amount of DNA equivalent to that embedded here".

When I was born in 1977, there were about 4,229,000,000 humans on Earth. As of this writing, there are 7,982,401,546 members of our species. For the next few years, these two Lucites together hold will more than enough DNA to describe the characteristics of all humans alive.

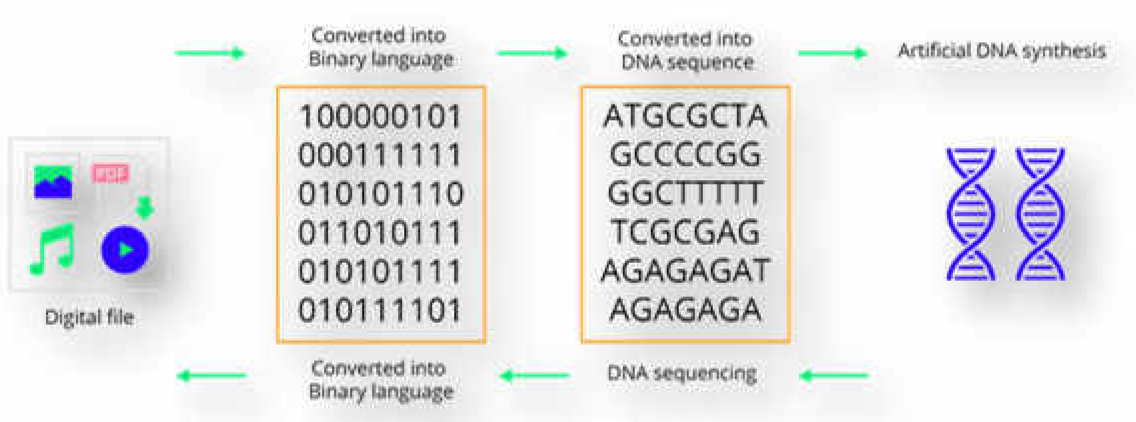
Deoxyribonucleic acid (DNA) is a molecule composed of two polynucleotide chains that coil around each other to form a double helix carrying genetic instructions for the development, functioning, growth and reproduction of all known organisms and many viruses. DNA and ribonucleic acid (RNA) are nucleic acids. Alongside proteins, lipids and complex carbohydrates (polysaccharides), nucleic acids are one of the four major types of macromolecules that are essential for all known forms of life. Some say that all four may have arrived on Earth in meteorites. Surprisingly, or maybe not, DNA could also play a role in the next generation of computing.

Humanity has a data storage problem: More data were created in the past 2 years than in all of preceding history. And that torrent of information may soon outstrip our ability to capture it using existing technology. Now, researchers have come up with a new way to encode digital data in DNA to create the highest-density large-scale data storage scheme ever. Capable of storing 215 petabytes (215 million gigabytes) in a single gram of DNA, the system could, in principle, store every bit of datum ever recorded by humans in a container about the size and weight of a couple of pickup trucks. But whether the technology takes off remains to be seen.

DNA has many advantages for storing digital data. It's ultracompact, and it can last hundreds of thousands of years if kept in a cool, dry place. And as long as human societies are reading and writing DNA, they will be able to decode it. "DNA won't degrade over time like cassette tapes and CDs, and it won't become obsolete", says Yaniv Erlich, a computer scientist at Columbia University. And unlike other high-density approaches, such as manipulating individual atoms on a surface, new technologies can write and read large amounts of DNA at a time, allowing it to be scaled up.

Scientists have been storing digital data in DNA since 2012 when Harvard University geneticists George Church, Sri Kosuri, and colleagues encoded a 52,000-word book in thousands of snippets of DNA, using strands of DNA's four-letter alphabet of A, G, T, and C to encode the 0s and 1s of the digitized file. Their particular encoding scheme was relatively inefficient, however, and could store only 1.28 petabytes per gram of DNA. Other approaches have done better. But none has been able to store more than half of what researchers think DNA can actually handle, about 1.8 bits of data per nucleotide.

DNA evolved over millions of years to hold the source code of our bodies, perhaps in the future it will serve to store our thoughts and ideas as well.



Lucite with Can of Diet Coke from Milwaukee Distributor Introduction 1983

In the summer of 1980, a Coca-Cola planning manager named Jack Carew was tapped to lead a project that had been percolating within the company for two decades but never came to fruition – to introduce a "diet" version of Coca-Cola.

Until that point, extending the Coca-Cola Trademark to another brand had been a no-no. When diet colas first entered the market, beginning with Diet Rite, the Coca-Cola Company had a long-standing policy to use the Coca-Cola name only on its flagship cola, and so its diet cola was named Tab when it was released in 1963.

But times had changed. "We needed a big idea to come out of one of the toughest decades we'd ever seen," Carew explains. Diet Coke was pegged a top priority. The project was strictly top secret; only a handful of senior executives knew about it, and team members had to agree to the assignment before getting the details.

Its rival Pepsi had no such qualms, and after the long-term success of its sugar-free Diet Pepsi (launched in 1964) became clear, Coca-Cola decided to launch a competing sugar-free brand under the Coca-Cola name that could be marketed more easily than Tab. Diet Coke was launched in 1982 and has cooled many topless construction workers (see man below taking a "Diet Coke Break") as well as fueling decades of nerdish pursuits (see Bill Gates' fridge below, which closely resembles mine).

© *Netflix*

© *Coca-Cola Company*

Bill Gates' Fridge.
© *Netflix*

© *Coca-Cola Company*

Lucite with Technophone Cell Phone – The First Pocket Sized Cellular Telephone, 1986

Technophone was a pioneering company in the mobile phone industry, known for developing the first pocket sized cellular telephone. Founded in 1984 by Nils Martensson, a Swedish entrepreneur, Technophone aimed to make mobile communications more accessible and convenient by reducing the size and weight of mobile phones, which at the time were large, bulky, and primarily installed in vehicles as car phones.

Based in the United Kingdom, Technophone made significant strides in miniaturizing mobile phone technology. One of their notable achievements was the creation of the Technophone PC105T in 1986, which at the time was one of the smallest and lightest mobile phones in the world. This innovation was a breakthrough in making mobile phones truly portable, moving away from the then-dominant car phones and large brick-sized handsets.

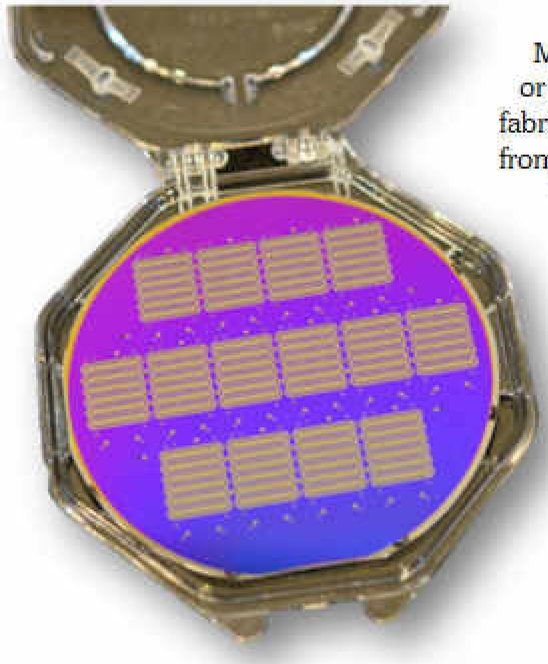
The impact of Technophone on the mobile phone industry was profound, as it helped shift the perception and usability of mobile phones towards the portable devices we are familiar with today. Their work played a crucial role in the evolution of mobile phones, contributing to the development of compact, handheld devices.

In 1991, Technophone was acquired by Nokia. This acquisition allowed Nokia to strengthen its position in the mobile phone market, eventually becoming one of the world's leading mobile phone manufacturers. The technologies and expertise from Technophone contributed to Nokia's success in the 1990s and early 2000s, particularly in the development of compact and user-friendly mobile phones.

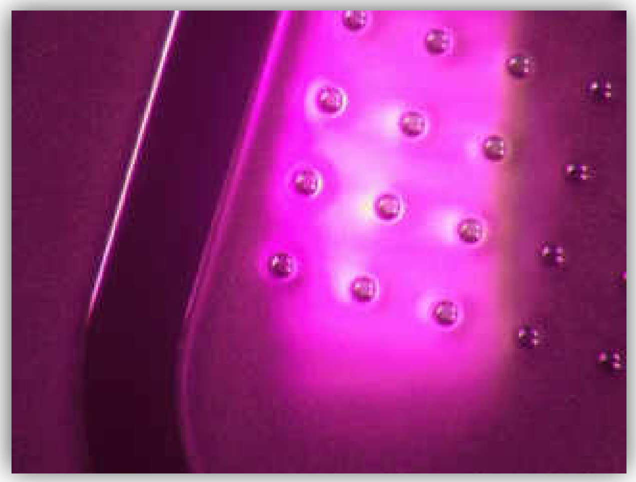
The "Iron Lady" using her Technophone.

Technophone's legacy is seen in the transformation of mobile phones from bulky, impractical devices to ssential, pocket-sized tools for daily communication. Their innovations paved the way for the development of the modern smartphone, emphasizing portability, ease of use, and widespread accessibility to mobile technology.

MEMS Silicon Wafer - Zyomyx DNA Microarray Chips

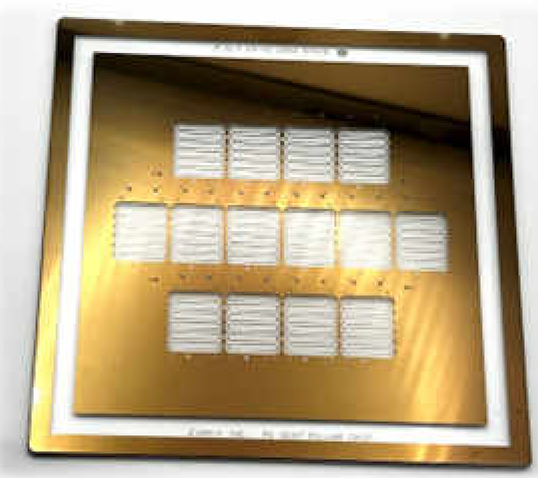


Microelectromechanical systems (MEMS) are tiny integrated devices or systems that combine mechanical and electrical components, fabricated using integrated circuit (IC) techniques, and can range in size from a few micrometers to millimeters. A special type of MEMS, "biochips" are miniaturized laboratories that can host large numbers of simultaneous biochemical reactions. One of the goals of biochip technology is to efficiently screen large numbers of biological analytes, with potential applications ranging from disease diagnosis to detection of bioterrorism agents. A microarray can be defined as a biochip surface containing miniaturized spots that react specifically with different components of the sample. Ideally, each microarray spot is pure and of known composition. Current technology enables the analysis of tens of thousands of different reactants on a single biochip.



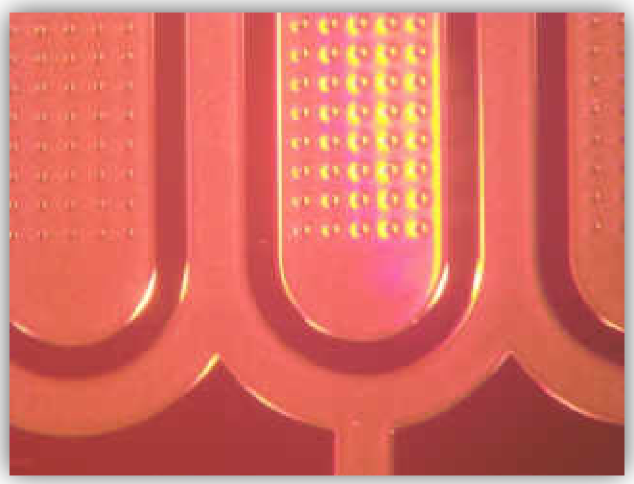
The advent of DNA chip technology in the mid-90s conveniently coincided with the sequencing of the human and many other genomes. Not only were the sequences available, but MEMS technology was ready, utilizing design, engineering and manufacturing expertise from a wide and diverse range of technical areas including integrated circuit fabrication technology, mechanical engineering, materials science, electrical engineering, chemistry and chemical engineering, as well as fluid engineering, optics, instrumentation and packaging.

Big pharma was one of the early adopters of the nascent technology, as the new tools promised to facilitate the search for expression markers and drug targets associated with cancer and other diseases. Early work on DNA microarrays at Stanford university in the late 1990s lead to the launch of Zyomyx and the development of these chips. Engineered to capture specific molecules for a fast inexpensive analysis, they are a first of their kind. The raised pillars are 50 microns in diameter, fitting about a million antibody molecules in each chip feature.



Also in my collection, the type of photo mask used to make this wafer.

Many millions of dollars were spent in development of this artifact from biotech and MEMS history.



Lucite with Michael Schumacher Formula One 2011 Race Used Bodywork

Michael competed in Formula One (F1) for Jordan, Benetton, Ferrari, and Mercedes, having made his debut at the 1991 Belgian Grand Prix as a replacement for the imprisoned Bertrand Gachot. Schumacher has a joint record seven World Drivers' Championship titles (tied with Lewis Hamilton) and, when he retired from the sport in 2012, held the records for the most wins (91), pole positions (68), podium finishes (155), and fastest laps (77). He was a god to us when we were young.

Schumacher was noted for pushing his car to the very limit for sustained periods during races, a pioneering fitness regimen, and the ability to galvanize teams around him. He and his younger brother Ralf are the only siblings to win races in F1 and the first siblings to finish first and second in the same race, a feat they repeated in four subsequent races. His son Mick is now an F1 driver too, although he hasn't done very well.

Michael Cooper / ALLSPORT / CC BY-SA 1.0

An author once observed that a "measure of a driver's capabilities is his performance in wet races, because the most delicate car control and sensitivity are needed". Some of Michael's best performances occurred in such conditions, earning him the nicknames "Regenkönig" or "Regenmeister". He was also known as "the Red Baron", because of his red Ferrari and in reference to the German flying ace Manfred von Richthofen. We call him "Schumi".

The world was left reeling in 2013 when Michael suffered a horrifying head injury that would change his life forever. He had retired from sport just months earlier and was enjoying a skiing holiday in the French Alps. While skiing off-piste, Michael fell and hit his head on a rock, suffering a horrific injury despite wearing a helmet.

He was air-lifted to a hospital in Grenoble, and after undergoing two surgeries was placed in a medically induced coma for 6 months to help reduce the swelling of his brain. Michael was eventually moved to another hospital in Lausanne, Switzerland, and after coming out of his coma after 250 days was allowed to return to his Lake Geneva home.

Morio / CC BY-SA 3.0

It's there that he is now reportedly cared for by his devoted wife Corinna and a team of medical staff.

Jewish Space Laser Activation Switch

In early 2021, "Jewish Space Laser" started trending on Twitter. Apparently, this was ignited by a social media post from first-term Representative and many-times-over Dumb Bitch Marjorie Taylor Greene (R-Georgia). Her Facebook post was actually from 2018, but had floated back to the surface of the meme toilet a few years later.

In her post, Taylor Greene suggested that the 2018 California wildfires may not have been due to climate change leaving vegetation drier and more combustible. Instead, she advanced the theory that some sort of "space laser" had been used to intentionally set things on fire.

As the tweet with Taylor Greene's original post (pictured on the next page) shows, she suggested that this space laser may have concentrated the sun's energy and created a solar beam that then set parts of California ablaze. Real scientists have long said that climate change has left many regions drier than before, but why not blame it on laser beams? And Jews?

So why does the trending phrase have the word "Jewish" in front of it? Well, Taylor Greene's post suggested that the Rothschild banking firm is behind a supposed corporate cabal that engineered this whole space laser plot. The old Rothschild family explanation…. As Zack Beauchamp wrote for Vox, anti-Semitic conspiracy theories about the Rothschild family controlling the world have frequently surfaced in the past. Beauchamp explained that this was not "an isolated anti-Semitic incident for Greene." In fact, the Editorial Board for USA TODAY wrote that "her Facebook account contained racist, Islamophobic and anti-Semitic views".

Beauchamp stated that Taylor Greene's "space laser" theory is "the latest in a long line of conspiracies about the Rothschild family, and those conspiracies are always, at root, anti-Semitic: Since the 19th century, people have used claims that this one particular wealthy family controls the world to cast aspersions on Jews in general."

Marjorie Taylor Greene
November 17, 2018

As there are now over 70 people confirmed dead and over 1,000 missing, the fires in CA are a horrific tragedy. I'm praying for all involved!
I'm posting this in speculation because there are too many coincidences to ignore, and just putting it out there from some research I've done stemming from my curiosity over PG&E stocks, which tanked all week then rallied Thursday night after CA official announced they would not let PG&E fail. I find it very interesting that Roger Kimmel on the board of directors of PG&E is also Vice Chairman of Rothschild Inc, international investment banking firm. I also find interesting the long history of financial contributions that PG&E has made to Jerry Brown over the years and millions spent in lobbying. What a coincidence it must be that Gov Brown signed a bill in Sept 2018, protecting PG&E and allowing PG&E to pass off its cost of fire responsibility to its customers in rate hikes, and through bonds. It also must be just a coincidence that the fires are burning in the same projected areas that the $77 billion Dollar High Speed Rail Project is to be built, which also happens to be Gov Brown's pet project. And what are the odds that Feinstein's husband, Richard Blum is the contractor to the rail project! Geez with that much money, we could build 3 US southern border walls. Then oddly there are all these people who have said they saw what looked like lasers or blue beams of light causing the fires, and pictures and videos. I don't know anything about that but I do find it really curious PG&E's partnership with Solaren on space solar generators starting in 2009. They announced the launch into space in March 2018, and maybe even put them up before that. Space solar generators collect the suns energy and then beam it back to Earth to a transmitter to convert to electricity. The idea is clean energy to replace coal and oil. If they are beaming the suns energy back to Earth, I'm sure they wouldn't ever miss a transmitter receiving station right??!! I mean mistakes are never made when anything new is invented. What would that look like anyway? A laser beam or light beam coming down to Earth I guess. Could that cause a fire? Hmmm, I don't know. I hope not! That wouldn't look so good for PG&E, Rothschild Inc, Solaren or Jerry Brown who sure does seem fond of PG&E. Good thing for Solaren that Michael Peevey is on their board since he is former President of California Public Utilities Commission, California's most powerful energy regulatory agency. Great connections right there!
Also I will say whoever was able to buy that PG&E stock at the bottom before that announcement was made when stocks rallied sure did well on their investment. I wonder how you get privy to that kind of info? You must have to know somebody right? Seems like there's a lot of connected people in this crowd. And with these space solar generators, I really hope they have very good aim beaming the suns power down to Earth...
But what do I know? I just like to read a lot

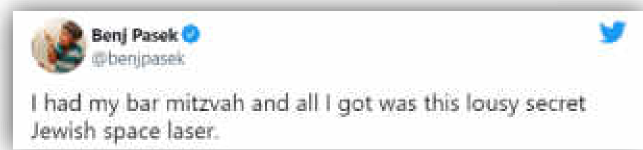
While people were understandably upset about Taylor Greene's post, the absurdity of the space laser conspiracy theory about the wildfires did bring some outstanding responses on social media.

For example, since Taylor Greene did not include any illustrations of the space laser, the Internet as usual tried to help, as seen in some of these pictures.

My personal Jewish Space Laser Activation switch comes from Concord Aerospace and is modeled after an Apollo Command Module switch.

Marjorie is also pictured below harassing a teenage survivor of the Parkland, FL school shooting.

© *20th Century-Fox*


Benj Pasek
@benjpasek

I had my bar mitzvah and all I got was this lousy secret Jewish space laser.

You can't fix stupid, but you can elect it to office.

© *Twitter/@fred_guttenberg*

Mini Museums

What's a Mini Museum?

© Mini Museum

In the introduction, I mentioned that I became addicted to collecting objects encased in Lucite after buying something called a "Mini Museum." Allow me to explain.

The idea for these tiny worlds of wonder germinated when a fellow by the name of Hans Fex was in second grade in 1977. His late father, Dr. Jörgen Fex (1924-2006), was a research scientist and a director at the National Institutes of Health. Prior to that, he held prestigious positions in Poland, Australia, and elsewhere in the U.S. He was a polyglot who spoke Italian, French, Swedish and German.

Every scientific magazine was at young Hans' arm's reach and his father kept an abundance of artifacts in his office and at home. As residents of Northern Virginia, the family frequented the Smithsonian museums and saw dinosaur bones, meteorites and other scientific and historic objects almost every weekend.

When the younger Fex was 7 years old, Dr. Fex went to Malta and returned with some artifacts that he embedded into an epoxy resin. The young Fex had never seen that before, but thought it was beautiful. It also ignited the "aha!" moment of how to contain little bits of his collection in a tiny space and show it to his friends. This was a way to share the treasures with other children. "I soon thought about children from all walks of life: every color and every country around the world," he recalls.

Science wasn't his only love. Hans says he started designing toys as a child, and when he was with ThinkGeek, a Fairfax-based toy and apparel company, he worked on a T-shirt that doubled as a drum kit. It was washable once you removed the power pack and drum decal.

Fex kept the treasures-in-resin idea in the back of his head. He says he "met scientists, museum curators, astronauts and other adventurers. With their help I've been able to assemble an incredible collection" of interesting souvenirs from all over. With his network of connections in the scientific community and his design skills gained at ThinkGeek, Fex decided to finally launch his long-held dream and teamed up with partners Jamie Grove and Willie Vadnais, whom he had worked with at ThinkGeek, to turn Mini Museum into a reality.

© Mini Museum

They anticipated they'd make and sell a few hundred. But when they announced their idea on Kickstarter, the idea quickly built buzz and they raised an eye-popping $750,000 in the first eight days. The total soared to more than $1.2 million, putting the first Mini Museum in the top 10 Kickstarter campaigns.

Each individual "Mini Museum" is a collection of rare and unusual artifacts from around the world and across the universe of time. The artifacts in a Mini Museum are encased in an individually numbered limited edition acrylic block that's about 5x4x1-inches. It's "small enough to put in your pocket or display on your desktop, mantle or coffee table," Fex says.

The first Mini Museum launched 2014, the Fifth Edition was released in 2023. Each edition begins with a Kickstarter campaign, all have performed well. The company also sells larger artifacts such as the woolly mammoth tooth, encased dinosaur and fern fossils, and the Manhattan Project shield window fragment elsewhere in this book.

Mini Museum First Edition

This First Edition was released as a crowdfunded project a few years before I bought my first Lucites. I acquired it from Mini Museum when they released a number of reserve units they had held back.

It contains 33 different specimens:

- Oldest Matter Ever Collected (c. 4,568,000,000 y/o)
- Lunar Rock (Meteorite from the Moon)
- Chelyabinsk Meteorite
- Dinosaur Egg (Shell)
- Dinosaur Dung
- K-Pg Boundary (Mass Extinction Event)
- Dracula Soil (Vlad III's Castle, Transylvanian Alps)
- Titanic (Coal from Wreck)
- Trinitite (First Nuclear Bomb Test)
- Human Skull
- Corinthian Leather
- Martian Rock (Meteorite from Mars)
- Alleged cow Killer (Meteorite)
- Earliest Life (c. 3,430,000,000 y/o Strelly Pool Stromatolite Fossil)
- Triceratops (Brow Horn)
- Baltic Insect in Amber (c. 40-60,000,000 y/o)
- Mammoth Hair
- Mummy Wrap (c. 350 BCE)
- Abraham Lincoln's House (Foundation Brick)
- Berlin Wall
- Human Brain
- Mt. Everest (Rock)
- Fossil Palm Tree from Antarctica
- Sauropod (Vertebrae)
- Tyrannosaurus rex (Tooth)
- Duckbilled Dinosaur
- Pterosaur Wing Bone
- London Bridge
- Raw Gold Nugget
- Sand from Waikiki
- Tunguska Event (Surviving Tree)
- Apollo 11 Command Module Foil (First Manned Lunar Landing)
- "Gratitude" - a Microfilm With the Names of all 5000 Original Project Backers.

A fun fact is that the "Oldest Matter Ever Collected" in this First Edition is now predated by the "Extraterrestrial Amino Acids" in the Fourth Edition by 200,000 years. This is because those ancient amino acids had not yet been discovered when the First Edition was released.

Mini Museum Second and Third Editions

- Asteroid Belt (c. 4,500,000,000 y/o)
- Stegosaurus (Plate)
- Mammoth Meat (19,551 y/o)
- Raw Emerald (Colombia)
- Bronze Age Dagger (12th Century BC)
- Medieval Chain Mail (15th Century)
- Petrified Lightning (Fulgurite)
- Martian Atmosphere (Zagami Meteorite)
- Libyan Desert Glass (c. 28,500,000 y/o)
- Mt. Fuji (Lava)
- Japanese Star Sand (Foraminafera Microfossils)
- Dimetrodon Spine Sail
- Ammonite
- Dinosaur Skin
- Hell Pig Jaw (Entelodont)
- La Brea Tar Pit
- Neanderthal Hand Axe
- Oasisamerica (Ancient Ceramics)
- Shipwrecked Pieces of Eight
- Hindenburg (Airship Skin)
- Golden Gate Bridge
- Olympic Relay Torch
- Astronaut Mix Tape (Skylab, 1973)
- First Super Computer (Cray-1)
- Star Wars Episode IV (Krayt Dragon)
- Moon Tree (Apollo 14)

- Space Gems (4,557,000,000 y/o)
- Oldest Earth (4,374,000,000 y/o)
- Great Oxygen Event (3,020,000,000 y/o)
- Oldest River (Finke, 400,000,000 y/o)
- Jurassic Tree
- Crinoid (170,000,000 y/o)
- Spinosaurus (Spine)
- Ankylosaurus (Bone)
- Mosasaur (Jaw)
- San Andreas Fault
- Megalodon (Tooth)
- Moldavite (14,400,000 y/o)
- Giant Sloth (Claw)
- Dire Wolf (Bone)
- Egyptian Papyrus
- Viking Axe (10th Century)
- Samurai Sword (14th Century)
- Venice (14th Century)
- Rough Opal (Australia)
- First Transatlantic Cable
- Alcatraz
- WWII Enigma (Rotor)
- Fordite (Motor Agate)
- The Beatles (Cavern Club)
- SR-71 (Blackbird)
- Pelé (Soccer Ball)
- Charles & Diana (Royal Wedding Cake)
- Steve Jobs (Turtleneck)
- Space Station Mir (Cosmonaut Food)

This is where my problem started. I bought the Mini Museum Third Edition from Kickstarter and thought it was so cool that I began collecting all the other Lucites you see in this book.

Mini Museum Fourth & Fifth Editions

- Extraterrestrial Amino Acids (c. 4,568,200,000 y/o)
- Lunar Highlands (c. 3,200,000,000 y/o)
- Copper Crystals (c. 300,000,000 y/o)
- The Great Dying (c. 252,280,000 y/o)
- Pangea (c. 200,000,000 y/o)
- Dinosaur Food (Cycad)
- Plesiosaur (Paddle)
- Raptor (Dromaeosaurid Bone)
- Mega Croc (Sarcosuchus Armor)
- Saber-Tooth Tiger (Smilodon Bone)
- Giant Beaver (Castoroides Tooth)
- Doggerland Mammoth (Tooth)
- Elephant Bird (Aepyornis Eggshell)
- Amazon River
- Stonehenge (Bluestone Quarry)
- Mummy Beads (1st Millennium BCE)
- Roman Bath (Hypocaust Flue)
- Knight's Sword (14th Century CE)
- Aztec Empire (Obsidian Tool)
- Lusitania (Deck Chair)
- Winston Churchill (Fur Muff)
- Hollywood Sign
- Manhattan Project (Shield Window)
- The White House
- Muhammad Ali (Punching Bag)
- Concorde (Jet Rotor)
- Rough Sapphire (Myanmar)
- First Space Shuttle (Columbia Flown)
- Human Heart

- Stellar Heart – Muonionalusta Meteorite (4,565,300,000 y/o)
- Martian Dust Storm – Shergottite, NWA 7397
- Starry Night – Lunar Meteorite, NWA 13951
- Magma Ocean – Isua Greenstone (3,600,000,000 y/o)
- Cauldron Of Life –Hydrothermal Vents (2,711,000,000 y/o)
- Rough Ruby – Mozambique (500,000,000 y/o)
- Conquest Of Land – First Land Plants (433,000,000 y/o)
- Dunkleosteus – Placoderm Skull (358,000,000 y/o)
- Coelacanth – "The Living Fossil" (240,000,000 y/o)
- Carcharodontosaurus – Tooth
- Permian, Daspletosaurus, Oviraptor, and Alamosaurus Bones
- Woolly Rhinoceros – Bone
- Glyptodon – Osteoderm Scute
- Darwin Glass – Tektite (816,000 y/o)
- Dawn Of Creativity – Red Ochre
- Early Modern Humans – Stone Tool Core (35,000 y/o)
- Lost Kingdom – Luristand Bronze Sword (1000 BCE)
- Roman Siege Engines – Ballista Shot (300 CE)
- Ottoman Empire – Kemha Silk (1500 CE)
- Monticello – Home Of Thomas Jefferson
- Old Ironsides – USS Constitution
- Amelia Earhart – Vega 5b, First Solo Transatlantic Flight
- Empire State Building – Window Mullion
- Cold War Espionage – Soviet Spy Camera Button
- Walt Disney – Disneyland Main Street U.S.A. Apartment
- Queen Of The Skies – Boeing 747
- Woodstock – The Original 1969 Stage
- Nuclear Arms Race – Trident 1 C4 Missle
- Sony Walkman – Personal Music Revolution
- Mount Everest Climbing Rope
- Gateway To The Stars – Kennedy Space Center Launch Complex 39a

Mini Museum Dinosaurs (Oceans Coming Soon)

- The Great Dying Extinction Event
- Tethys Ocean
- The Breakup of Pangaea
- Gondwana
- Laurasian Ammolite
- Dinosaur Eggshell
- Dinosaur Footprint
- Dinosaur Skin
- Dinosaur Food
- Dinosaur Dung
- Plesiosaur Paddle
- Pliosaur
- Ichthyosaur
- Mosasaur Tooth
- Brachiosaurus
- Diplodocus
- Cretaceous Insect in Amber
- Atlasaurus
- Apatosaurus
- Iguanodon
- Stegosaurus Plate
- Triceratops Brow Horn
- Ankylosaurus Armor
- Pachycephalosaurus Dome
- Hadrosaur
- Pterosaur Wing
- Allosaurus
- Spinosaurus
- Raptor
- Tyrannosaurus rex Tooth
- Death of the Dinosaurs (Deccan Traps & K-Pg Boundary Event)

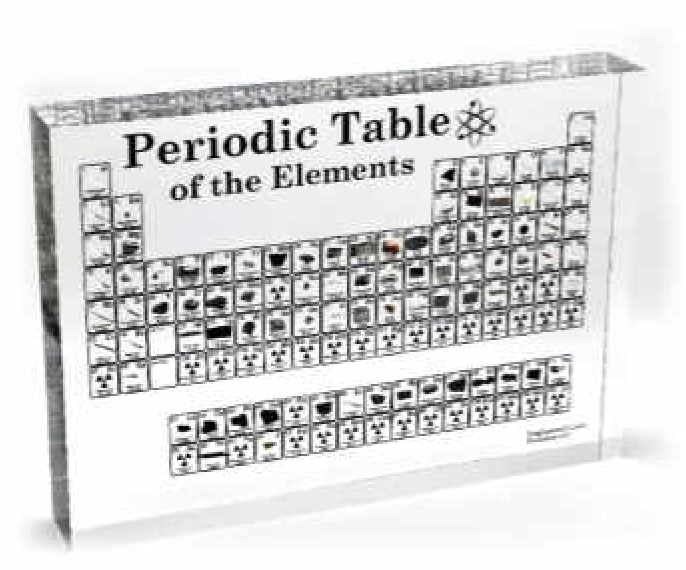
Heritage Personal Museums

- Revolutionary War Lead
- USS Constitution Wood
- Civil War Bullet
- Wright Brothers Flyer Fabric
- SR-71 Titanium
- Space Shuttle Insulation
- Apollo 11 Command Module Metal
- Sand from Pearl Harbor
- D-Day Barbed Wire
- Sand from Iwo Jima
- Trinitite (The Manhattan Project)
- Berlin Wall
- Titanic Coal
- Great Wall of China Fragment
- Ancient Greek Pottery
- Coin from the Roman Empire (c. 300 AD)
- Pompeii Ash
- Egyptian Mummy Linen (c. 100 BCE)
- Woolly Mammoth Hair
- Mini Shark Tooth Fossil
- Megaolodon Tooth
- Petrified Wood from Antarctica
- Insect Embedded in Amber
- Ankylosaurus Armor
- Tyrannosaurus Rex Tooth
- Dinosaur Egg Shell & Coprolite
- Triceratops Brow Horn
- Plesiosaurus Bone
- Moldavite
- Stromatolite
- Martian Meteorite
- Carbonaceous Chondrite

- Pallasite Space Crystals (4,500,000,000 y/o)
- Campo del Cielo Iron Meteorite
- Petroleum Quartz
- Sahara Desert Fossilized Coral
- Early Petrified Wood (Callixylon, c. 385,000,000 y/o)
- Sauropod Vertebrae Fossil
- Stegosaurus & Hadrosaur Fossil Bones
- Fossil Star Sand Taketomi, Japan
- K-Pg Boundary Extinction Event
- Woolly Rhino Horn (c. 50,000 y/o)
- Woolly Mammoth Tusk (c. 22,000 y/o)
- Indus Valley Terracotta (Cradle of Civilization)
- Egyptian Mummy Beads (c. 2000-150 B.C.)
- Mayan Jade
- Viking Iron Axe Head
- Easter Island Stone Rapa Nui Mo'ai Stone
- Incan Textile
- Château d'If Prison Stone
- HMS Victory Oak (Battle of Trafalgar)
- French Revolution Money (Assignat)
- East India Company Copper
- Battle of Waterloo Musket Ball Lead
- Krakatoa Lava (Anak Krakatoa)
- De Havilland D.H. 4 Fabric (WW1 Plane)
- Ammonite Fossil (c. 66-409,000,000 y/o)
- Great Depression Shovel (Works Progress Administration)
- V2 Rocket Shrapnel
- Hiroshima Melted Roof Tile (c. 1945)
- Lockheed U-2 Spy Plane Metal
- Vostok 1 Flown Metal (First Man in Space Yuri Gagarin)
- Chernobyl Medic Box Metal
- Neolithic Arrowhead (c. 10,000-3,000 B.C. Sahara Region)

From the same people who made my Plutonium Element Cube, described earlier, Heritage Personal Museum / Engineered Labs – the Mini Museum copycat. This product is really cool though. When I couldn't afford or find First and Second Mini Museums (the Third Edition was my first), these covered the gaps pretty well.

Lucites with Periodic Table and Noble Gases

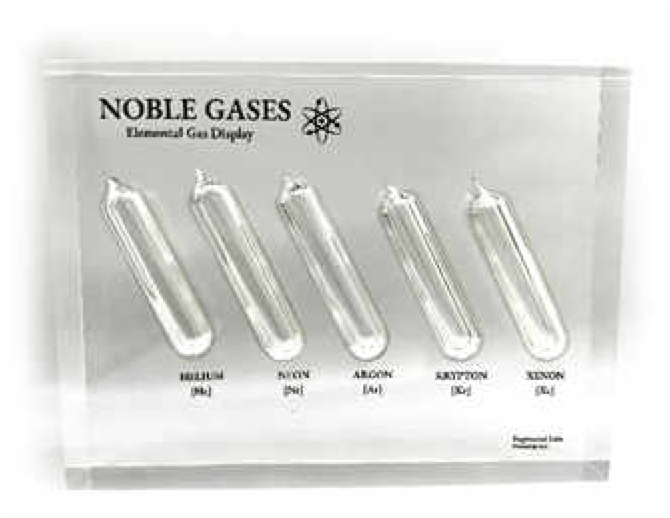


According to Engineered Labs, this is the most complete and most stunning periodic table collection on the market today. There are several improvements that make this new edition superior to their original periodic tables:

- Pure alkali metals in micro glass ampules
- All gaseous elements in glass ampules
- Large precious metal samples
- Native gray diamonds for the carbon sample
- Native sulfur crystals
- Ferrous meteorite for the iron sample
- Halogens in ampules (Chlorine, Bromine, Iodine)
- Pure mercury metal in glass ampules
- Pure europium metal in glass ampules
- Antique watch hands embedded for the radium sample

- Dimensions: 5.125” x 7.25” x 1.0” (130mm x 184mm x 25mm)
- Material: Lucite Acrylic (Made in the USA)
- Element Embedments: 85 elements
- Non-pure Elements: Fluorine (represented by natural fluorite), Bromine (decomposition reaction produces bromine gas), Radon (represented by granite), Uranium (represented by uranium glass or Autunite ore), Thorium (represented by thoriated metal).
- The collection contains 85 individual element samples. Due to its rarity and radioactivity, Technetium was excluded from the collection as was Promethium. Except for Uranium and Thorium, elements 84 (Polonium) through 118 (Oganesson) were also excluded. I do own samples of Plutonium, Polonium, and some nasty isotopes of Cesium and Strontium, see Misadventures with Atoms.
- Ampules of the gaseous elements (Xenon, Krypton, Argon, Neon, Helium, Oxygen, Nitrogen, and Hydrogen).

A separate Lucite contains larger samples of the noble gases, which can be excited by placing them near a Tesla coil. Pretty neat.



Inspiration

Cabinet of Wonders: The Gaston-Louis Vuitton Collection

When Gaston-Louis Vuitton died, the contents of his office were packed up, stored away, and eventually forgotten.

Vuitton (1883-1970), the grandchild of the luxury trunk maker Louis Vuitton, ran the eponymous company for more than 50 years and was "the esthete of the family," said Patrick Mauriès, a French writer and historian. Over time, as the head of a company that made suitcases, he amassed "a bizarre assemblage of objects related to travel, which he kept in his home and his office," Mauriès, said. "It was sort of a mess – it was stacked by the door, around his desk, and so on."

The collection included board games (Jeu de Paris, a French version of Snakes and Ladders), 19th century carpet bags, and more than 800 tsubas, a Japanese sword guard that is often composed of an ornate piece of metal that delineates the sword's edge and its handle.

Because his heirs chose to store it away rather than sift through it, the collection – left untouched for decades – became a sort of time capsule from one of the company's most vital, creative periods. Now, the company, which at this point is owned by LVMH, the luxury goods conglomerate controlled by Bernard Arnault, has "rediscovered" Gaston Vuitton's collection and catalogued all in a new book, Cabinet of Wonders: The Gaston-Louis Vuitton Collection, edited by Mauriès.

The reasons, at least from the company's perspective, for publishing it are straightforward: The collection hearkens back to the days when Louis Vuitton connoted creativity, not airport kiosks. "I think they're trying to show every aspect of the Louis Vuitton history," Mauriès said. "So with this, they're now trying to show something that's less well known, let's call it the company's esthetic aspect."

For those less interested in a luxury chain's brand identity, the book still has value. Page after page of Gaston's collection – much of which is of negligible monetary value – reveals a cross-section of the esthetic and material concerns of a highly cultured European, the likes of which are rarely seen in such comprehensive, unsparing detail.

"Gaston's taste was bound to a certain period," Mauriès said. "For the first half of the 20th century, you have these collectors who were interested in the artisanal component of creation." At the time, he said, "the collection didn't seem that remarkable, but now people are beginning to see that even if the objects seem a little dated, they have a coherence, and they're worth showing as a whole."

As the first male heir of the third generation of the family, Vuitton was destined to work at the company, but he developed a broad range of hobbies: designing furniture, sketching landscapes, and taking photographs. He also began to collect art, ranging from African masks to Art Deco crystal, and he was a prolific reader, dazzled by the fiction of writers such as J.K. Huysmans.

Despite the fact that two world wars, the Russian Revolution, and a devastating recession kept his company in a near-constant state of flux, Vuitton found time to exhibit his paintings and to design perfume bottles.

He was, though, first and foremost a prosperous merchant, and his extracurricular passions invariably found their way into day-to-day-commerce. His membership in the Société des Artistes Indépendantes lead to collaborations with lesser-known artists. André Ballet, best known for his book plates, designed crystal bottles for Vuitton; Roger Foy, brother of the illustrator André Foy, carved African-inspired ivory knobs for Vuitton walking sticks; and Gaston Le Bourgeois, best known as an Art Deco sculptor, painted panels for Vuitton's London store.

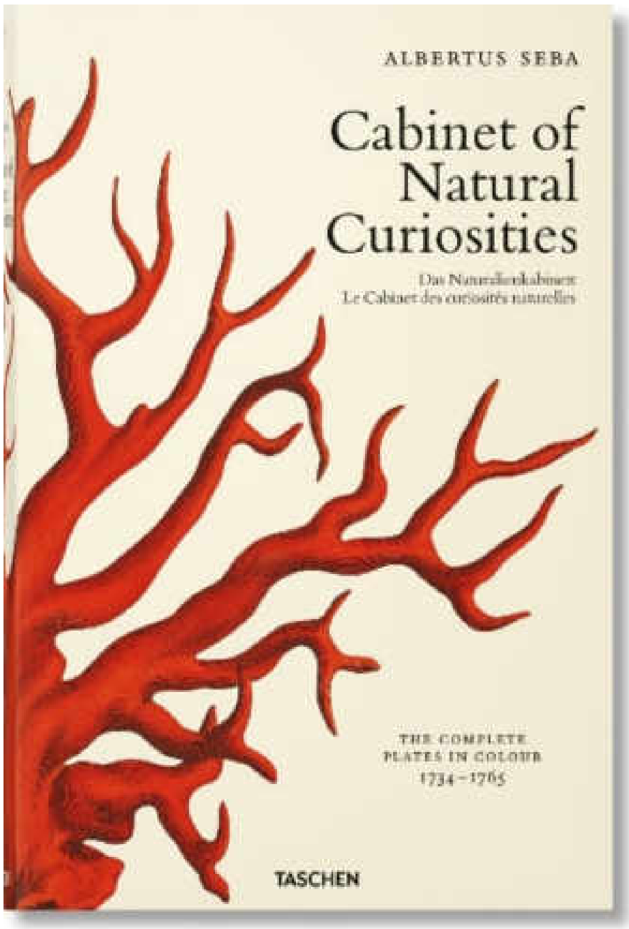
It was in his store's window displays that Vuitton's collection really came in handy. Over the decades, he collected hundreds of trunks – everything from massive steel cases to tiny, 16th century embossed metal and red silk boxes from Switzerland. A lovely, early 17th century leather trunk Vuitton bought in 1922, for instance, was "one of the most exhibited items in the collection," appearing multiple times in the windows of the Vuitton store on Paris's Champs-Élysées and in the windows of Saks Fifth Avenue in New York.

While other objects displayed in the book, such as wooden figurines, dolls, and model cars, served a similar purpose, much of the book comprises ephemera that, until recently, was probably considered solely of interest to Vuitton alone. A few pages are devoted to vintage handsaws, and more than a few are dedicated to monograms of clients that Vuitton kept in his archives. It's a far cry from Louis Vuitton's current iteration as a fashion behemoth with from $8 billion to $9 billion (US) in annual sales.

There are also delights: A spread in the book highlights some of the magnificent covers of L'Oeil, the influential art magazine run by Georges and Rosamond Bernier. Elsewhere are fabulous nécessaires, or toiletry boxes, including a stunning 60-piece set from around 1815, which contains silver, crystal, and mother-of-pearl accessories.

It's an esoteric, oddly personal collection of objects, one that evinces the hobbies and preferences of Vuitton better than any hagiography ever could. "You can't see this collection in person, just in the book," Mauriès said. "It's about a very specific kind of taste."

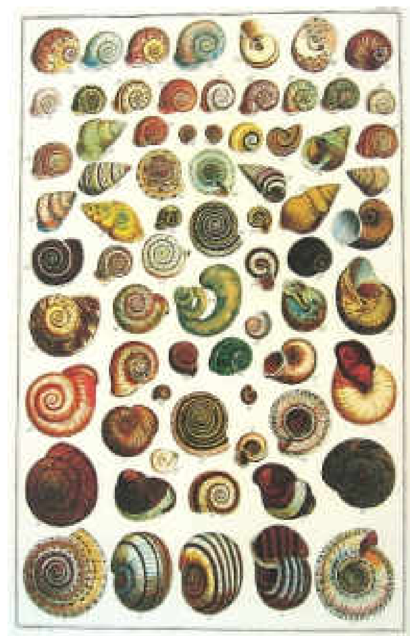
Albertus Seba: Cabinet of Natural Curiosities

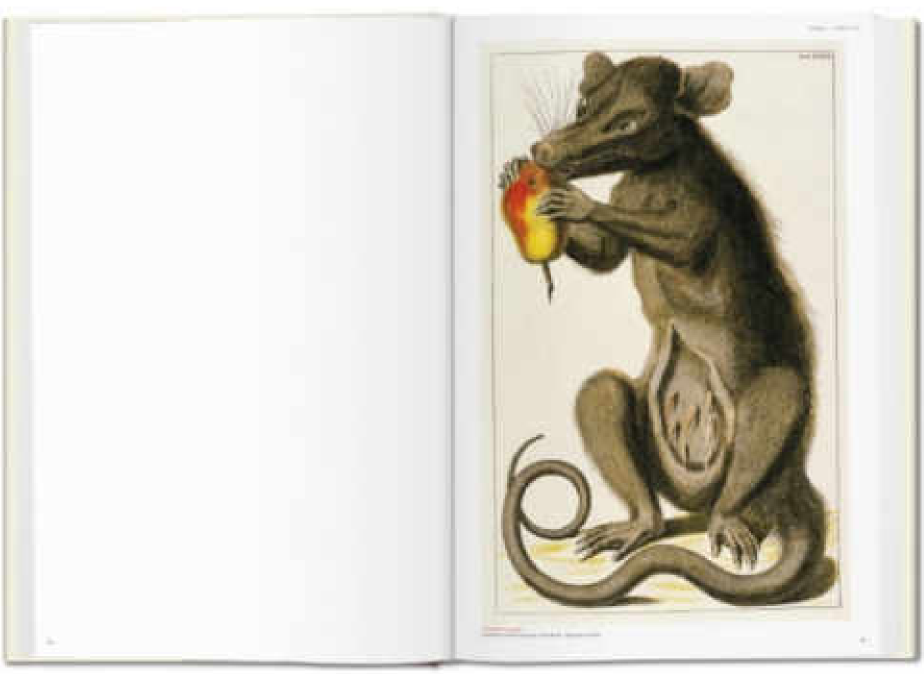


Albertus Seba's Cabinet of Curiosities is one of the 18th century's greatest natural history achievements and remains one of the most prized natural history books of all time.

Though it was common for men of his profession to collect natural specimens for research purposes, Amsterdam-based pharmacist Seba (1665-1736) had a passion that led him far beyond the call of duty. His amazing, unprecedented collection of animals, plants, and insects from all around the world gained international fame.

In 1731, after decades of collecting, Seba commissioned illustrations of each and every specimen and arranged the publication of a four-volume catalogue detailing his entire collection – from strange and exotic plants to snakes, frogs, crocodiles, shellfish, corals, insects, butterflies, and more, as well as fantastic beasts, such as a hydra and a dragon.





This superb, complete reproduction is taken from a rare hand-colored original. The introduction offers background information about the fascinating tradition of the cabinet of curiosities to which Seba belonged and an additional annex, written by contemporary biologists, provides descriptions of the marvelous and myriad specimens.

”A powerful testament to nature’s beauty and diversity.” – Chicago Tribune

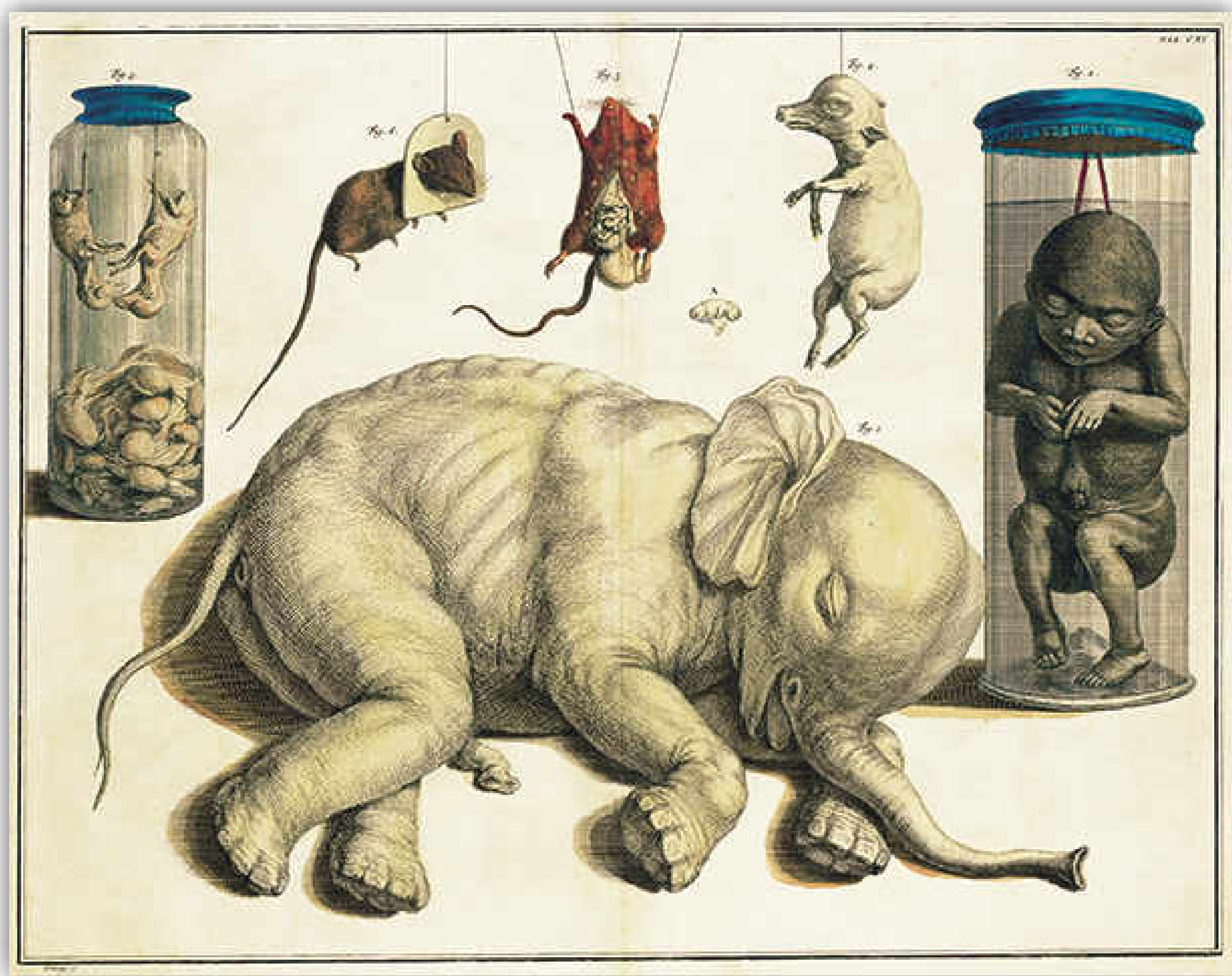
“Seba’s whimsical, lushly detailed illustrations of snakes, butterflies, and myriad other creatures have a vintage charm that will seduce science buffs and aesthetes alike.” – Vogue

“A gorgeous testament to the wonder with which the Old World surveyed the New.” – The Wall Street Journal

“A vast and beguiling tome.... Any one of the reproductions could be framed as a picture in its own right.” – The Times

“Snakes alive! What a cabinet of creepy-crawly curiosities.” – The Independent

“A lavishly presented reprint.” – The Art Newspaper



Massimo Listri: Cabinet of Curiosities

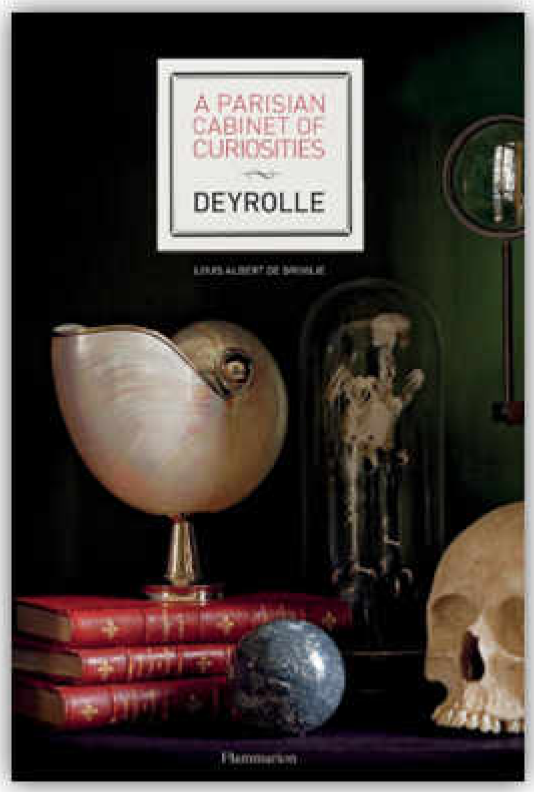
The Wunderkammer, or “cabinet of curiosities”, saw collectors gathering objects from many strands of artistic, scientific, and intellectual endeavor, in an ambitious attempt to encompass all of humankind’s knowledge in a single room.

From the Grand Duke Francesco I de’ Medici and Holy Roman Emperor Rudolf II to Archduke Ferdinand II of Habsburg, these aristocratic virtuosos acquired, selected, and displayed the objects in real-life catalogues that represented the entire world-spanning architecture, interior design, painting, sculpture, gemology, geology, botany, biology and taxonomy, astrology, alchemy, anthropology, ethnography, and history.

Marvel at the unicorn horns (narwhal tusks), gems, rare coral growths, Murano glasswork, paintings and peculiar mechanical automata. Browse through illustrations of exotic and mythical creatures and discover the famed “Coburg ivories”, an astounding collection of crafted artifacts. These collections are nothing short of a journey through time, from the Renaissance and Age of Discovery, the Mannerist and Baroque periods, up to the present day. Although many of these cabinets of curiosities no longer exist, others have been meticulously reconstructed, and new ones – such as mine – born.

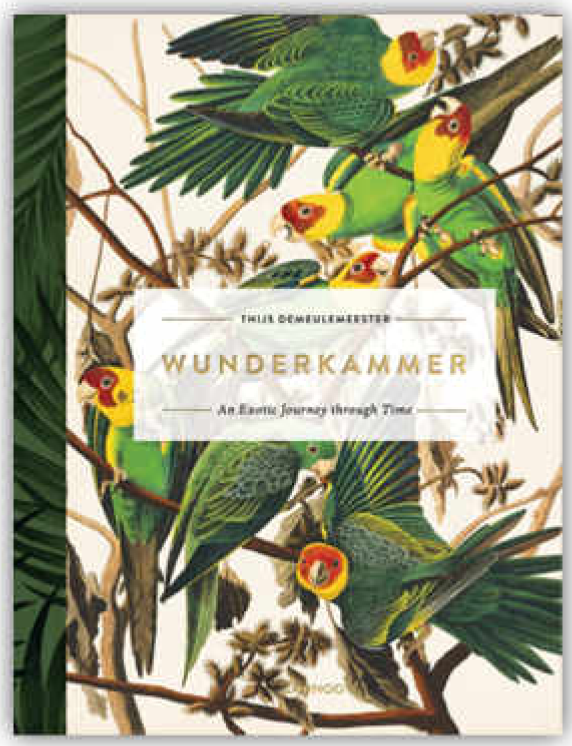
These marvelous cabinets of curiosities can now be explored by all. To realize this mammoth undertaking, Massimo Listri traveled to seven European countries over several decades; the result is a set of gorgeous photographs, an authoritative yet accessible introduction, and detailed commentary on each of the 19 chambers highlighting the most remarkable items in each collection. Discover how these timeless treasures both describe and defined civilization, the modem concept of the museum, and our very knowledge of the universe.

More Wunderkammern



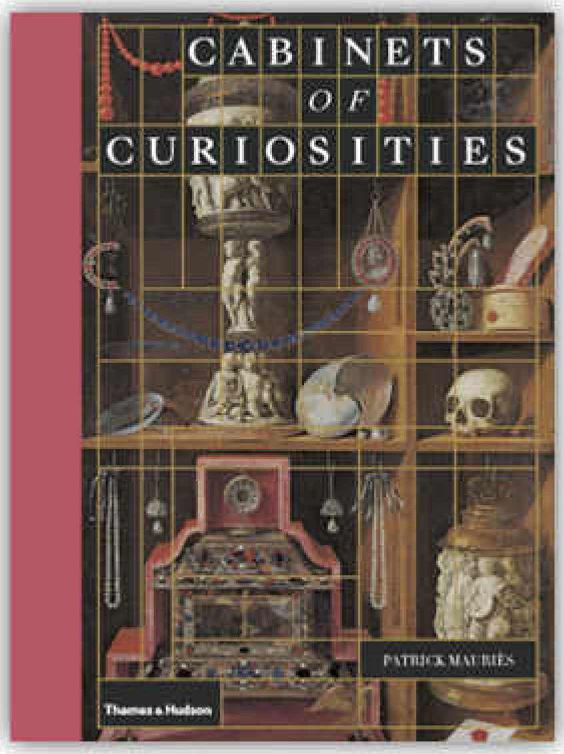
With an abundance of preserved flora and fauna, taxidermy, and otherworldly creations, the Deyrolle boutique in Paris is dedicated to showcasing the beauty of nature. A family venture, Deyrolle has a 185-year history that is a Pandora's box of scientific and aesthetic discoveries. Deyrolle flourished under the nineteenth-century passion for natural history, garnering celebrity devotees from Dalí to Nabokov, and quickly established itself as a center for education and research. Prince Louis Albert de Broglie's "A Parisian Cabinet of Curiosities" provides fascinating insight into the history and day-to-day workings of this unique Parisian institution, where extraordinary curiosities highlight the intersection of science and art.

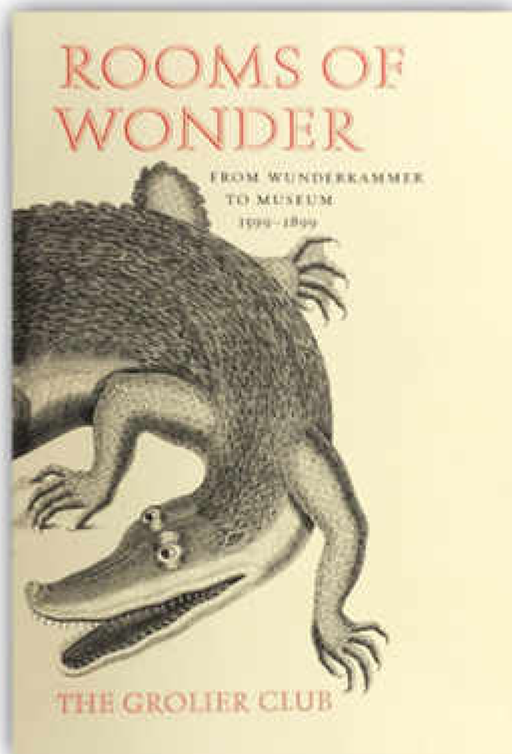
Cabinets of wonder are once again in fashion. Shops, restaurants, and private residences echo these cabinets in their interior design, by making use of the eclectic vintage objects commonly featured in such collections. Christines Davenne and Fleurent's "Cabinets of Wonder" showcases exceptional collections in homes and museums, with more than 180 photographs, while also explaining the history behind the tradition, the best-known collections, and the types of objects displayed. Offering both a historical overview and a look into contemporary interior design, this extravagantly illustrated book celebrates the wonderfully odd world of cabinets of wonder.



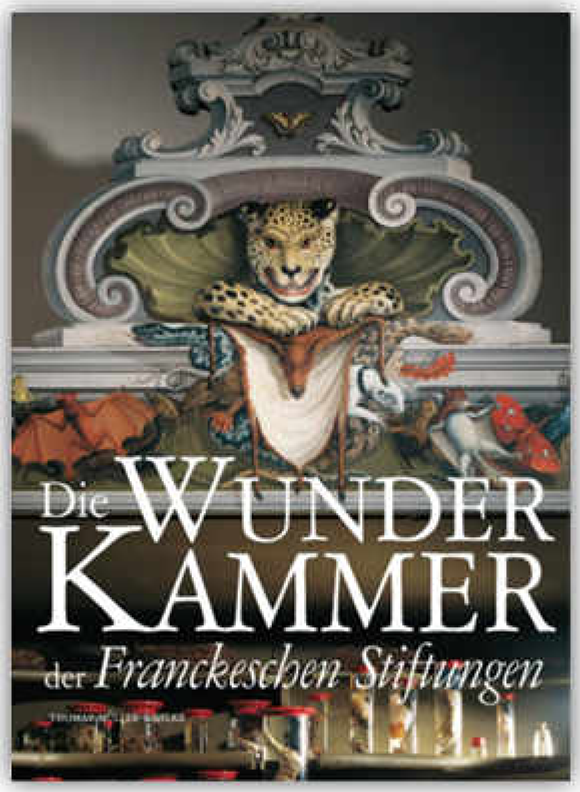
Design webshops, expos, interior design stores: they all try to bring back the memory of the centuries-old tradition of the Cabinet of Curiosities. Thijs Demeulemeester's "Wunderkammer" is a Wunderkammer in itself, showcasing the most beautiful exotica, which explorers and adventurous merchants brought back from all over the world for rich collectors. Be amazed by beautiful seashells, stuffed animals, sculptured ostrich eggs, botanical drawings, 'dragons' preserved in formaldehyde, and bewildering Indiana Jones-like stories. A fascinating New World presented itself to them, and in this book, if you can deal with some preaching on the ills of colonialism, you'll see it through their eyes.

Unicorns' horns, mermaids' skeletons, stuffed and preserved animals and plants, precious metals, clocks, scientific instruments, celestial globes—all knowledge, the whole cosmos, arranged on shelves in a single room. Such were the cabinets of curiosities of the seventeenth century, the last period of history when man could aspire to know everything. The collectors were archdukes and kings—the Emperor Rudolf II was the prince of all collectors—rich merchants and scholars, and their collections ranged from a single crowded room to whole palatial suites. Patrick Mauries' "Cabinets of Curiosities" traces the history of these unique spaces, receptacles, and fascinating contents within, from their first appearance in inventories and engravings commissioned by Renaissance nobles, such as the Medicis or the Hapsburgs, via those of the Dane Ole Wurm and the German polymath Athanasius Kircher, to the 17th century scientist Elias Ashmole and Dutch collector Levinus Vincent. The author chronicles the amazing history of these rooms of wonders in this ingeniously erudite survey. Not many of the rooms survive, but there are pictorial records, and their contents still exist and are among the treasures of museums all over the world.





The proud owners of Wunderkammers sometimes published elaborate illustrated catalogues to document their collections. Rooms of Wonder showcases dozens of the rarest and most important of these books, drawn from the private library of curator Florence Fearrington, as well as from collections at Harvard's Houghton Library, the Getty Research Institute Library, and the Peabody Library at Johns Hopkins University. Also represented are tourists' accounts of Wunderkammers, broadsides advertising traveling exhibitions, auction sale catalogues, and eighteenth- and nineteenth-century advertisements for and tickets of admission to commercial ventures put together by such showmen as P. T. Barnum. Published in support of the 2012–13 Grolier Club exhibition, this catalogue takes readers on a tour of these remarkable rooms.



In 1698, August Hermann Francke opened an art and natural history chamber in an orphanage, in order to illustrate the real life lessons he had introduced. Today, the approximately 3000 natural objects, curiosities, and artefacts in this unique collection show visitors the world from a forgotten perspective. As an early modern museum space, the chamber represents the comprehensive knowledge of the cosmos as it existed in the Baroque. In the original and richly decorated collection cabinets there are such valuable objects as a whole Seychelles nut, the earliest Mongolian manuscript documented in Germany, and a South Indian folding altar from the 18th century, next to a Hungarian cheese, a tattooed fish and all kinds of other curiosities. In 150 partly large-format photographs by Klaus E. Goltz, Thomas Muller-Rahlkes' "Die Wunderkammer der Franckeschen Syiftungen" opens up unique insights into this overwhelming collection.

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Acknowledgements

This book is not a scientific paper nor was it ever intended for commercial or academic publication, and as such I took no effort whatsoever to attribute, footnote, properly quote, or even unnecessarily write anything myself. I paraphrased liberally and made unabashed use of ChatGPT and Google Gemini. Most pictures were taken with my cellphone, the others should be either in the public domain or properly licensed and attributed.

I leaned heavily on sources like Wikipedia, collectSpace, eBay, seller websites, manufacturer websites, Chips Etc., the Computer History Museum, other tech, nuclear, space, and computing history sites, NASA, the DoE, and various other government agencies, Roscosmos, Mini Museum, news outlets, CoinWeek, various blogs, and anywhere else I could find interesting information.

I wish to express my thanks to all the authors, illustrators, photographers, and other creators who contributed directly and indirectly to this catalogue.

Violence & Power

Advent of Computing & Misadventures with Atoms

Conquest of Space, Shuttle – SpaceX

Conquest of Space, Mercury – Skylab

Some rocks, Mini Museums, and a spaceman

My office, when my collection was much smaller

My Cabinet is always growing and evolving, Scan below for a free PDF of the latest version.

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