▶ The configuration of the control center, access portal, blast lock and silo were exactly the same from site to site. Other topside features varied in location.

CHAPTER 2

CONSTRUCTION

At the time of Titan II's birth, U.S. relations with the U.S.S.R. were not very good. In 1956 Soviet premier Nikita Khrushchev made his infamous "we will bury you" remark. In 1957 the Soviets launched Sputnik, and for most of 1958, politicos were consumed with the "missile gap." In 1959 Vice President Richard Nixon had a run-in with Khrushchev in the famous "kitchen debate." In 1960 Khrushchev was banging his shoe on his desk at the United Nations. The failed U.S. Bay of Pigs invasion of Cuba made things even worse in 1961. Indeed, there was a clear sense of urgency in the construction of Titan II launch sites, an urgency made absolutely visceral by the Cuban Missile Crisis, which occurred in 1962, near the end of construction.

To save time, engineers used a scheme called *concurrence*. In most construction projects, engineers complete all the design and work out all the bugs, then hand the blueprints to the construction crews. In concurrence, design and construction happen at the same time. The blueprints are grabbed from the drawing boards almost before the ink is dry—the engineers are always just one step ahead of the construction workers.

There is a well-known engineering maxim that says you can have things fast, cheap, or right, but you can't have all three at once. For example, if you want something fast and cheap it won't be right. Or, if you want something cheap and right it won't be fast. In the case of the Titan II, the Air Force wanted it fast and right, which meant it wouldn't be cheap.

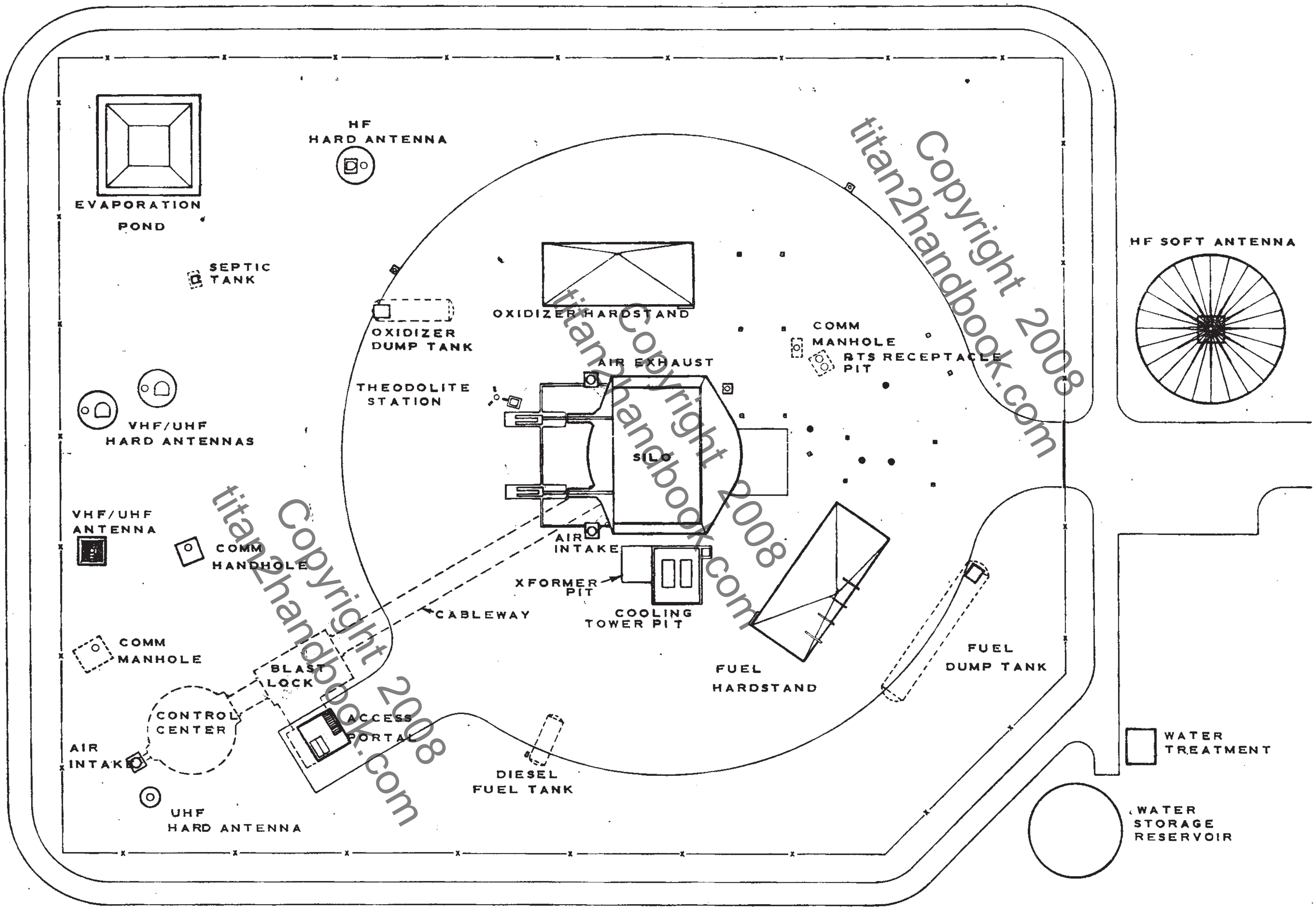
Concurrence saves time but is expensive because all the bugs get worked out with a jackhammer instead of an eraser. Every day contractors would ask "What do we tear out today that we installed yesterday?" There were hundreds of change orders resulting in thousands of modifications. Yet everyone understood that "the race must be won," and a multitude of problems not withstanding, concurrence worked. From the first shovel in the ground to the last crew to go on alert, the entire project—54 sites in three states—took just three years, almost to the day, to complete.[1] The Titan Missile Museum's complex, 571-7, took 29 months to build, and was put on alert July 15, 1963.[2]

Titan II launch sites were built in the vicinity of Little Rock AFB near Little Rock, Arkansas; McConnell AFB in Witchita, Kansas; and Davis-Monthan AFB in Tucson, Arizona. Each of these three bases was assigned 18 missiles (plus one spare), referred to as a Strategic Missile Wing (SMW). Each wing was subdivided into two groups of nine missiles known as Strategic Missile Squadrons (SMS).

Construction occurred in three phases.

Phase One

In Tucson, heavy construction began on December 9, 1960 and was completed at all 18 sites just a few days before Christmas in 1961. As the term "heavy construction" implies, Phase One included all the excavation and concrete work. At any particular complex, Phase One


HF SOFT ANTENNA
WATER TREATMENT
WATER STORAGE RESERVOIR
FUEL DUMP TANK
HF HARD ANTENNA
EVAPORATION POND
SEPTIC TANK
OXIDIZER HARDSTAND
COMM MANHOLE
RTS RECEPTACLE PIT
OXIDIZER DUMP TANK
AIR EXHAUST
THEODOLITE STATION
SILO
VHF/UHF HARD ANTENNAS
VHF/UHF ANTENNA
COMM HANDHOLE
AIR INTAKE
XFORMER PIT
COOLING TOWER PIT
CABLEWAY
FUEL HARDSTAND
COMM MANHOLE
BLAST LOCK
CONTROL CENTER
ACCESS PORTAL
AIR INTAKE
DIESEL FUEL TANK
UHF HARD ANTENNA

▲ The "bathtub" with outline of the silo (right) and control center (left).

USAF PHOTO. TMM ARCHIVES.

construction took from seven to ten months, depending on the difficulties encountered in digging. Some "real property" was also installed during this phase. For example, the emergency generator was so large and heavy that it was installed upon completion of silo level 3 by lowering it into the unfinished silo with a crane. The rest of the silo was then built around it. Several pieces of equipment were installed in this way, and once installed they could not be removed, at least not in one piece, and in some cases, not under any circumstances.

Phase Two

Real Property Installed Equipment (RPIE) started at a given complex as soon as Phase One was completed. RPIE included all of the essential infrastructure: electric power systems; miles of electric wiring and conduits; lighting; plumbing; heating, ventilating and air conditioning systems; hydraulics; and so forth. Phase Two construction took about a year at each site.

Phase Three

Installation and Checkout started early in February 1962 and was complete at all Tucson sites by the middle of December. In Phase Three, contractors handed the keys to the Air Force. The Air Force then installed all of the electronics and communications systems in the launch control center (LCC), put in the hookups for the missile, and installed the missile itself. All Tucson sites were fully operational and on alert by October 1963. The 390th Strategic Missile Wing (SMW) in Tucson, composed of 18 launch facilities, was declared fully operational in December that same year.[3]

Hardening

The whole idea behind basing ICBMs in silos is to protect them from attack. The word

▲ With construction well underway, the blast lock and access portal (left) begin to take shape.

heard most often in describing the construction of the launch sites is "hardened." Hardening refers to strengthening the complex so as to survive a nuclear attack, and can take several forms, the most obvious of which are massive amounts of concrete and steel. These offered protection against the powerful shockwaves that result from nuclear explosions. Concrete and steel also offered significant protection against two other nuclear effects. Nuclear weapons can generate both powerful electric and magnetic waves called *electromagnetic pulses* (EMP) and *prompt radiation* in the form of gamma rays, x-rays, and neutrons. EMP waves can burn out or disrupt sensitive electronic equipment such as missile guidance systems, while prompt radiation can be damaging to both equipment and humans. The effects of both can be blunted—but not entirely eliminated—with thick concrete walls and heavy metal shielding. Both were used extensively in Titan II launch sites.

There are two important points here: 1) any given amount of hardening will be effective only for a detonation beyond some specific distance from the silo, and 2) hardening costs money. Since no known structure is capable of withstanding a direct hit, the key question becomes "How much is enough?" Because there are so many variables in the equation, there is no simple answer.

Based on the presumed accuracy and yield of Soviet missiles, Titan II planners settled on hardening the sites to 300 pounds per square inch (psi) (21 kg/cm^2).[4] This meant that the site could withstand a shockwave generating 300 psi on the silo closure door and the ground covering the rest of the complex. In practical terms this translated (at least in theory) to withstanding a 10-megaton bomb exploding about 4700 feet (1.4 km) from the complex or a 20-megaton bomb at a distance of about 5800 feet (1.8 km).[5]

▲ Ring beams formed the outline of the silo wall, and supported the silo's exterior steel shell. Note bulldozer at bottom, and lift bucket.

This does not necessarily mean that the missile would still be "good to go" after such a nearby strike, only that the complex itself would suffer no structural damage. Clearly, the shockwave traveling though the ground could "rattle" the silo so severely that, even with a spring suspension system to protect it, the missile might be rendered inoperative or sufficiently inaccurate to strike the intended target.[6]

As a hedge, engineers separated the silos by a minimum of 8 miles (14.5 km) so that one bomb could not destroy more than one silo.[7] That said, it is interesting to speculate that the Titan IIs may have been launched very early in a nuclear conflict and that their silos might have been empty by the time enemy bombs began to fall.

The vagaries of a nuclear exchange are many, and in the end engineers simply had to make the most educated calculations they could and hope for the best.

General Layout

The location of the access portal, blast lock, launch control center (LCC), silo, hardstands and related structures were identical at every complex. The LCC and silo were separated by a distance of about 250 feet (76 m), and the silos were oriented so that the doors opened from east to west. The LCC joined the silo through a *cableway*, a steel tunnel, which was oriented on a bearing of about 240 degrees relative to the silo: roughly west southwest.[8]

Placement of the many antenna systems varied from complex to complex but for practical reasons antennas tended to be clustered in the vicinity of the LCC.

▶ The silo was composed of 9-levels.

The Bathtub

Construction of the launch sites began with the excavation of what was referred to as the "bathtub." The bathtub was a large oblong cut into the ground, typically some 400 feet (120 m) long, 200 feet (60 m) wide, and about 40 feet (12 m) deep.[9] The actual size depended to some extent on the difficulty encountered in digging. For example, at hard rock sites the bathtub was often much smaller.[10] The major components of the complex—the access portal, blast lock, control center and silo—were all located within the bathtub. Once the bathtub was completed, further excavation of the silo and control center began.

The Silo

The silo was excavated to a depth of about 155 feet (47 m) and was accomplished with a bulldozer essentially scraping its way down in ever-deepening circles, the dirt being removed with a lift-bucket.[11]

On the way down, steel ring-beams were installed every few feet to form the basic outline

▲ Another view of the silo ring beams. The two "wings" will permit installation of air shafts and shock delay pipes.

BOTH: USAF PHOTO. TMM ARCHIVES.

and structure of the silo wall. At the bottom of the silo, a ¼-inch (6 mm) thick steel plate floor was installed for electromagnetic pulse (EMP) shielding. Extending up from this floor, steel plates were attached to the ring beams to form a metal cylinder that extended all the way to the surface.[12]

Between this outer steel shell and temporary movable internal wooden structures called *slip forms,* workers placed a massive framework

▶ In most cases this sign was located on the main gate of the complex. While the warning seems stern enough, some versions added "USE OF DEADLY FORCE AUTHORIZED," to make sure people got the message.

CHAPTER 3

TOPSIDE

Titan II launch sites were located on about ten acres (4 ha) of land, but only the center three acres (1.2 ha) or so were used to house the silo, control center, and related facilities and equipment. The remainder of the land was mostly buffer. An seven-foot (2 m) tall fence topped with barbed wire served as a perimeter and provided security for the central portion of the complex. The area inside the fence was maintained with a gravel surface and had none of the pathways seen at 571-7 today. These pathways were installed for the safety and convenience of visitors.

It is important to understand that none of the equipment seen topside at the Titan Missile Museum was present on a typical day. This includes all the trucks, cars and trailers, and all of the equipment associated with the loading and unloading of propellant. The special equipment necessary for propellant handling was brought to the complex only as required, and on a normal day someone looking through the fence would see only the silo door and the various poles and antennas situated about the surface. There would be no sign of crews or maintenance teams.

▼ Concrete hardstands served as parking surfaces for propellant tank trucks and holding trailers. A "conditioning trailer" sits at left.

◀ Propellant was loaded into the missile by gravity via stainless steel piping. The larger of the two pipes in the foreground is for stage one, the smaller one for stage two.

Propellant Hardstands

On the north and east sides of the silo were two large rectangular concrete pads called

▲ Contractors put the finishing touches on a complex near Wichita, Kansas.

USAF PHOTO, TMM ARCHIVES.

▶ Water spray nozzles on the fuel hardstand for dilution of spills or fire suppression. No such nozzles were present on the oxidizer hardstand.

hardstands. These served as parking areas for the tank trucks and holding trailers used to load and unload missile propellant. Fuel was loaded from the east hardstand and oxidizer from the north. The most obvious difference between the two was the fuel hardstand's water spray nozzles. These nozzles were used for fire suppression and to wash down equipment if a fuel spill occurred. In the early days of the program, the fuel and water runoff was directed into a drain that emptied either at grade level just east of the hardstand or into underground dump tanks (discussed shortly).

The oxidizer hardstand had no water spray system. Mixing water with oxidizer would result in a considerable volume of poisonous vapor characterized by a large red-orange cloud, referred to informally by many Air Force personnel as a "BFRC" (Big [-expletive-] Red Cloud).

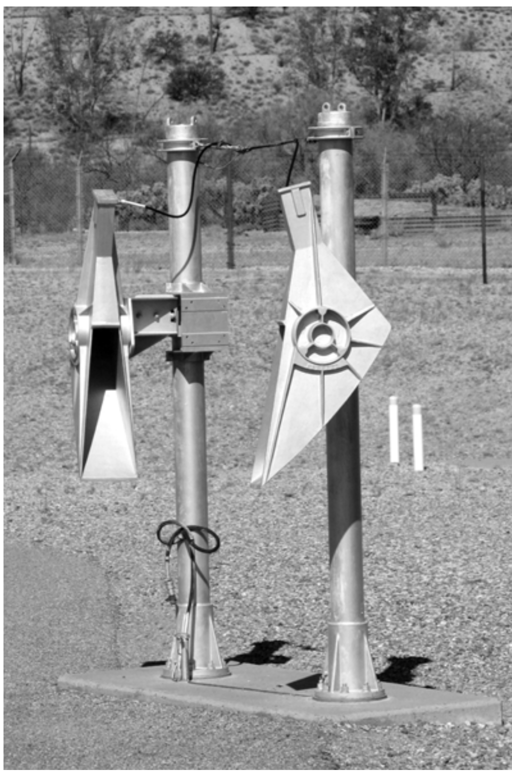
Security Equipment

No guards were stationed topside, and no TV cameras provided the crew with a view of the complex. The perimeter fence kept out most animals and all but the most determined intruders (though intruders were never a significant problem). Outside the fence there

▶ A plume of highly toxic nitrogen tetroxide vapor wafts away from an oxidizer transport trailer during a PTS operation. A certain amount of venting was unavoidable.

USAF PHOTO, TMM ARCHIVES.

▶ The “tipsie” security system projected a motion-sensing radar beam around the silo and over the control center air intake shaft.

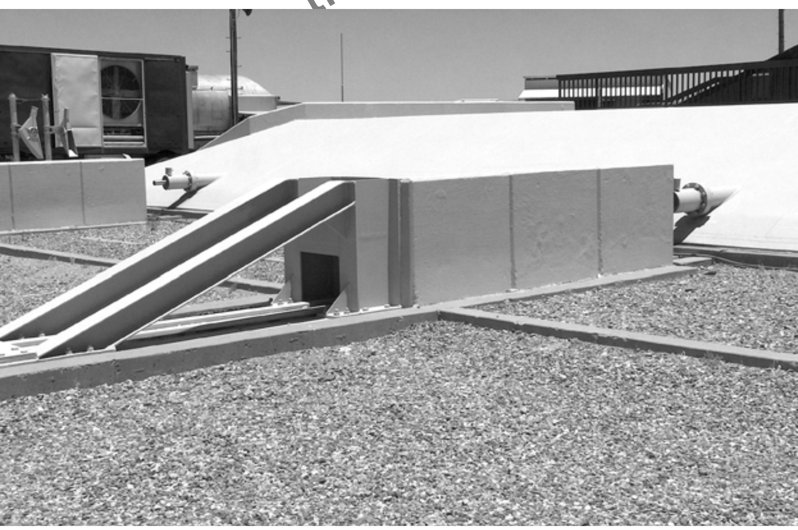


was no form of security. Inside the fence security was maintained with the AN/TPS-39 radar surveillance security system.[1] Because of the “TPS” in the designation, virtually everyone took it to mean “territorial protection system.” In reality, TPS stood for something quite different. According to the Department of Defense Standard Practice, Joint Electronics Type Designation System (MIL-STD-196E) the T stood for transportable (nevermind that it wasn’t), the P for radar (R had already been taken by “radio”), and the S for search. Still, territorial protection system made perfect sense to everybody who didn’t know otherwise. Air Force personnel reduced TPS to “tipsie” and the nickname quickly became common usage.

Pairs of tipsie units were located at each corner of the silo, and also over the LCC air intake shaft. Radar beams sent between these units created an electronic motion sensor. If a moving object disturbed any of the beams, the system set off an alarm in the control center. The crew on alert would not come topside to investigate. They would call the wing command post (WCP), and the WCP would dispatch the security police. The launch complexes were associated into groups of three sites called sectors. The sites were located such that security police were rarely more than 20 minutes away from any complex in a given sector.

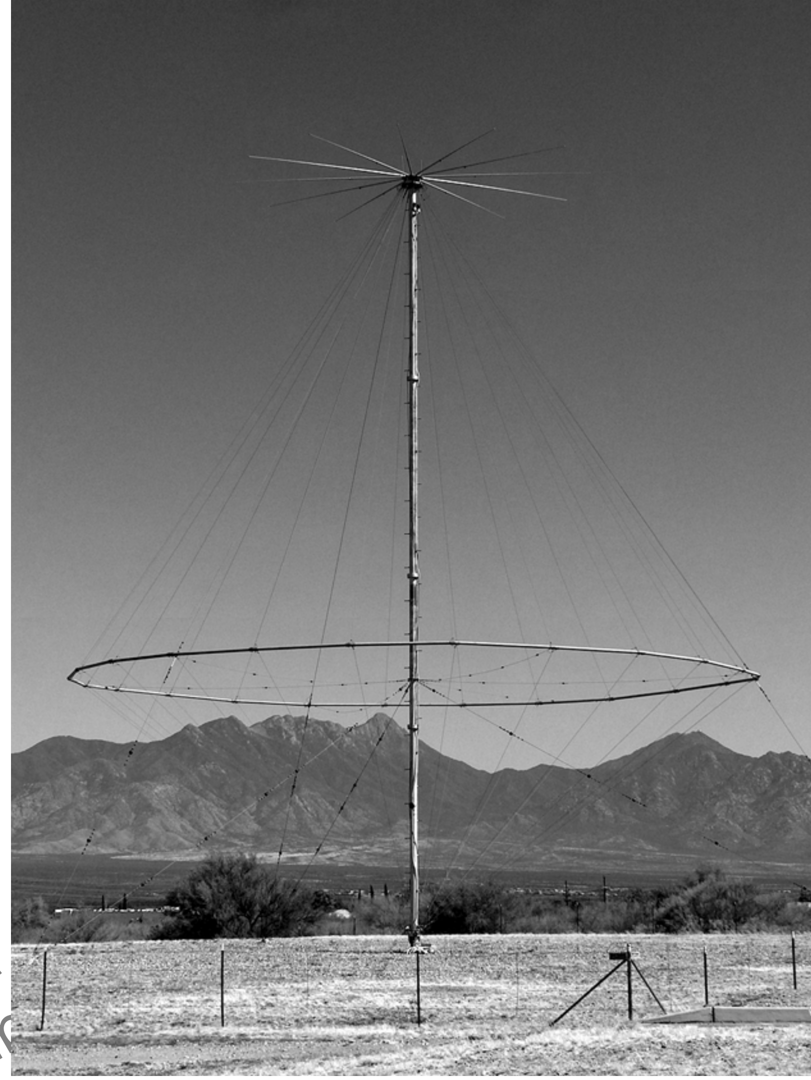
Twenty minutes might sound like a long response time, but there was usually no real hurry. While the Air Force was not happy about people snooping around inside the fence, it also realized there wasn’t much a would-be saboteur could do on the surface to interfere with a launch.[2] Over the history of the program there were very few instances of genuine intrusions topside, and none at all underground. In the early years virtually all trips of the tipsie system were false alarms caused by large birds, heavy rain or other anomalous sources.[3] The system was eventually desensitized to reduce false alarms.[4]

The tipsies had their own battery backup



▲▲ Silo door being moved from fabrication site to silo.

▲Bumpers and shock-absorbing pistons brought the door to a stop. The large concrete cubes were installed by the museum to assure the Soviets that the door could no longer be fully opened.



▲ The notoriously hard-to-photograph HF discage antenna was made by Collins Radio and covered from 3 to 30 MHz.

system and could continue to operate for two hours in the event of a complete power failure.[5] If the batteries went dead, guards would be posted.

Silo Door

The silo door weighed an estimated 743 tons (674 metric tons) and could be fully opened in about 20 seconds. At 571-7 the silo door is exactly halfway open. Large exhaust ducts on the north and south sides of the silo, which vented the missile's exhaust during launch (see photo page on 89) have been covered with concrete, as have the rails on which the silo door rode. Part of the rails can still be seen where they emerge from under the west side of the door. When 571-7 became a museum large concrete blocks were installed on the rails to ensure that the door could no longer be opened all the way. The blocks were added as part of an agreement with the Soviet Union to help establish the site as a "non-counter," meaning that it would not be included in the number of active missile launchers permitted to the United States by treaty.

A complete discussion of the silo door can be found in Chapter 2.

Communications Antennas

A Titan II launch crew had a lot of tasks to keep them busy while working underground, but one of their primary occupations was to listen for the order to launch their missile. It follows then, that staying in touch with higher headquarters was of primary importance. To

◄ A hawk scouts for lunch atop the discage antenna.

CHAPTER 4

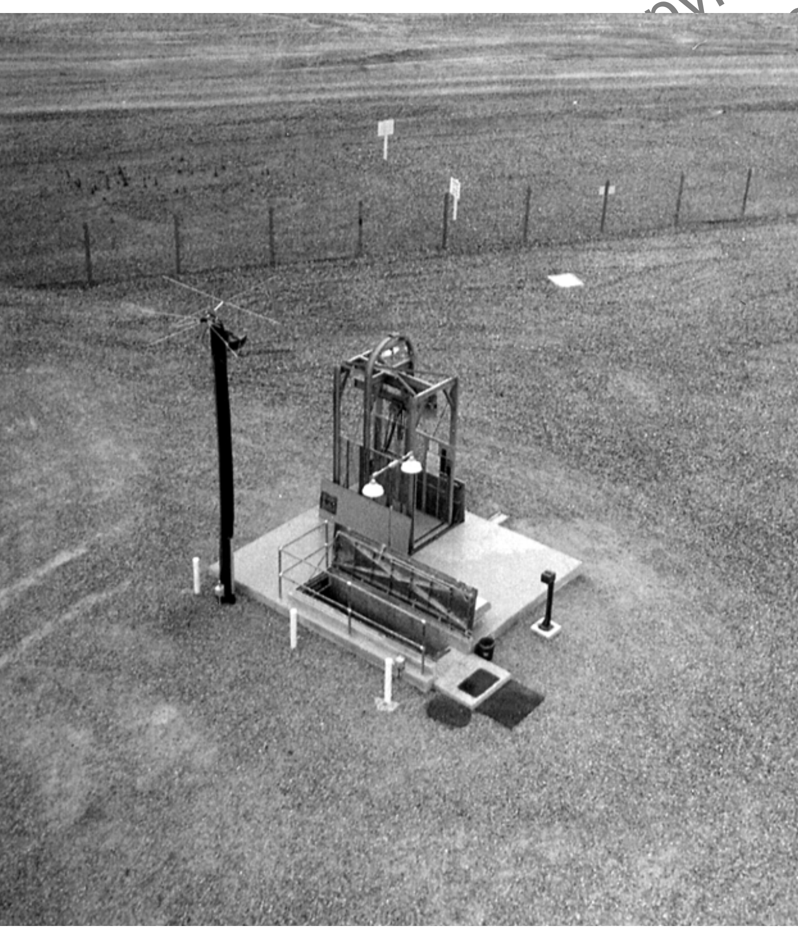
GOING UNDERGROUND

Although it was built with steel reinforced concrete walls more than a foot (30 cm) thick, the access portal was regarded as soft. If a nuclear bomb exploded nearby it is likely the structure would have collapsed.

The access portal was approximately 16 feet (5 m) square and about 35 feet (10 m) deep. Major components of the portal included the outer stairwell and stairwell cover (usually left open); the outer portal door and phone; the entrapment area, telephone and closed-circuit TV camera; the stairway; the elevator; and a blast door with its associated phone. Also located within the access portal was an exhaust fan with its vent hood on the "roof" of the portal and a sump pump located at the bottom of the elevator shaft.

Signs both inside and outside the outer portal door at sites near Tucson warned the unsuspecting to watch for rattlesnakes. Rattlesnakes were a danger unique to the Tucson sites and are still a hazard today. Now and then, especially during the hot summer months, snakes would slither down the steps to keep cool on the shady concrete at the foot of the access portal door. This could come as a big surprise, especially for those exiting the complex. Snake-handling sticks were standard equipment.

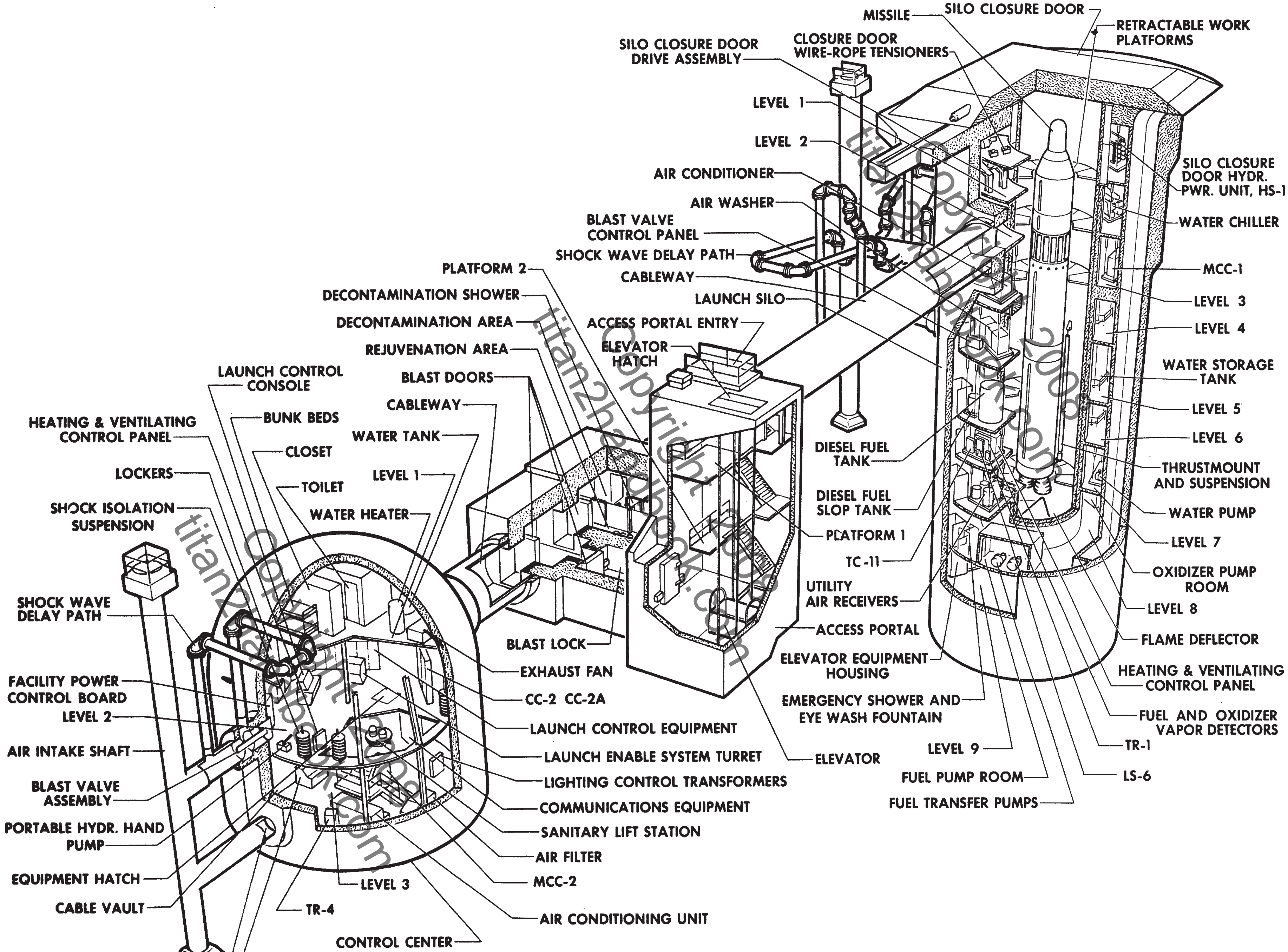
Personnel arriving at the complex would first call the LCC from the perimeter gate phone. The gate was then "buzzed" open from the LCC and rolled clear by an oncoming crew or maintenance-team member. A second call was then made from a phone just outside the access portal outer door. Another security detail: there was a three minute time limit between the first and second phone call! When the access portal door was buzzed open, personnel entered



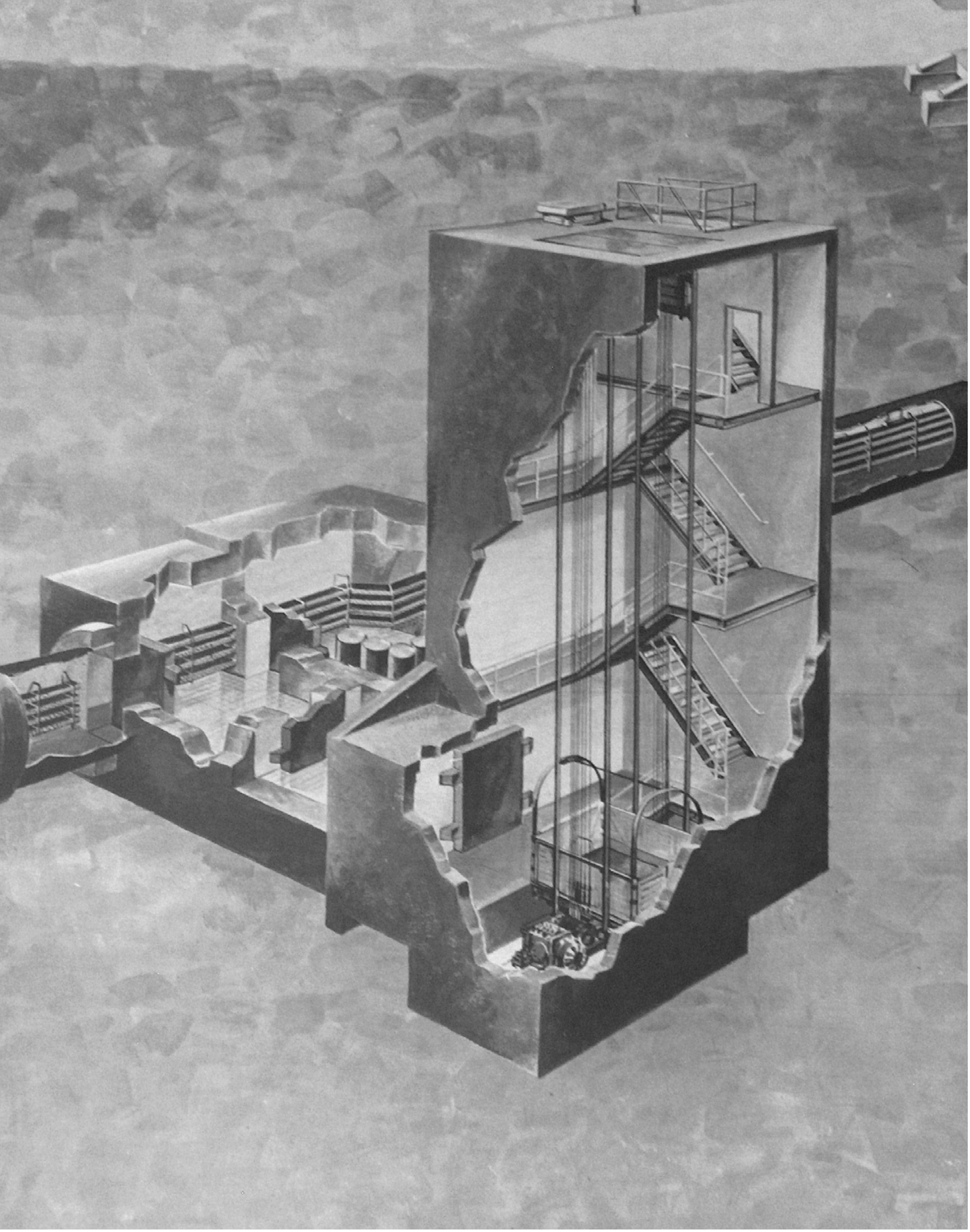
▼ The access portal was the main entrance to the underground complex. Unlike the rest of the complex, the portal was not expected to survive the effects of a nearby nuclear hit. When not in use the elevator was always kept below ground.

▶ The underground portion of the launch complex was composed of four separate structures: the access portal, the blast lock, the control center, and the silo. Two steel tunnels, called cableways, connected the silo to the control center by way of the blast lock, while the blast lock was connected to the outside world via the access portal.

USAF PHOTO, TMM ARCHIVES.



FACILITIES LAYOUT AND EQUIPMENT



TMM ARCHIVES.

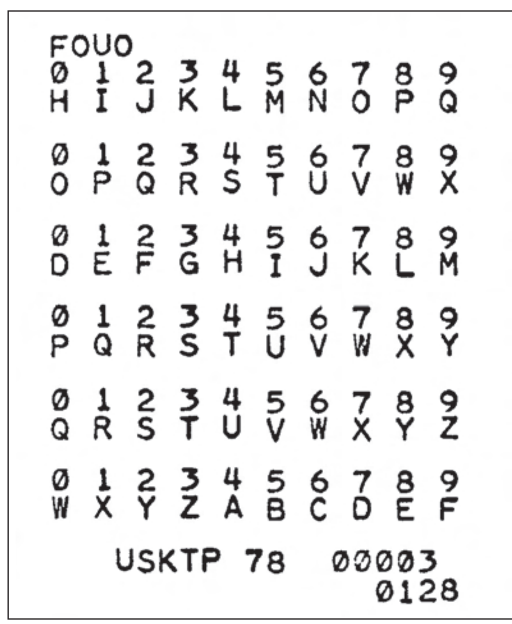
▲ Looking into the entrapment area from the outer portal door. Note TV camera.

the *entrapment area*, which confined those entering until their authorization to enter could be confirmed. The entrapment area consisted of two electrically locked doors, one at each end of a short stairway. When the outer door closed, those inside were trapped between it and the inner door. Both doors had to be buzzed open with a button in the LCC, but both doors could not be unlocked at the same time.

To get through the second door another phone call was made to the LCC and a six-letter code recited. Each code was used only once—everyone (or every group) coming through the entrapment area had a new code, and the code card was burned after use. There is an oft-told legend about having to eat the code card if one did not have matches or a lighter. It is conceivable that this may have happened once or twice as part of a prank, but eating the code was not an approved method of disposal and all

▼ Access portal stairway leading to blast door 6.

▲ Looking up from inner door. Note telephone and VSS speaker at top of stairway, and burn can at right.



FOUO

Ø	1	2	3	4	5	6	7	8	9
H	I	J	K	L	M	N	O	P	Q
Ø	1	2	3	4	5	6	7	8	9
O	P	Q	R	S	T	U	V	W	X
Ø	1	2	3	4	5	6	7	8	9
D	E	F	G	H	I	J	K	L	M
Ø	1	2	3	4	5	6	7	8	9
P	Q	R	S	T	U	V	W	X	Y
Ø	1	2	3	4	5	6	7	8	9
Q	R	S	T	U	V	W	X	Y	Z
Ø	1	2	3	4	5	6	7	8	9
W	X	Y	Z	A	B	C	D	E	F

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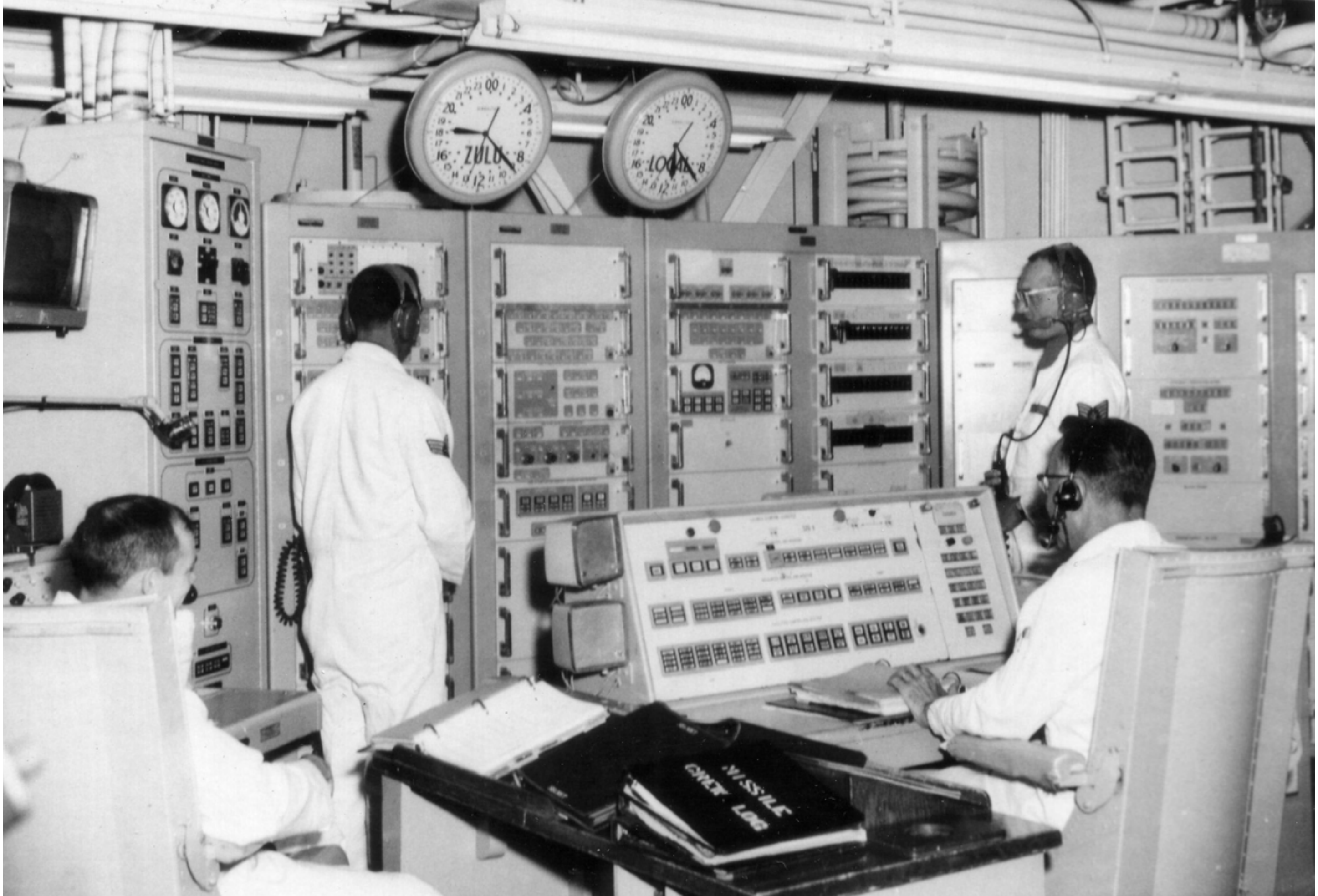
TMM ARCHIVES.

▲ Small code cards, issued by Code Control at the WCP, were essential in gaining access to the underground portion of the complex. "FOUO" means "For official use only." After use the cards were burned in a red-painted coffee can. Forget the stories about having to eat the card if you didn't have any matches, but getting the code wrong meant you were going to have a bad day.



USAF PHOTO, TMM ARCHIVES.

▲ Crew members on alert. Crew members wore white jump suits until about 1967 when "crew's blues" were introduced.

CHAPTER 5

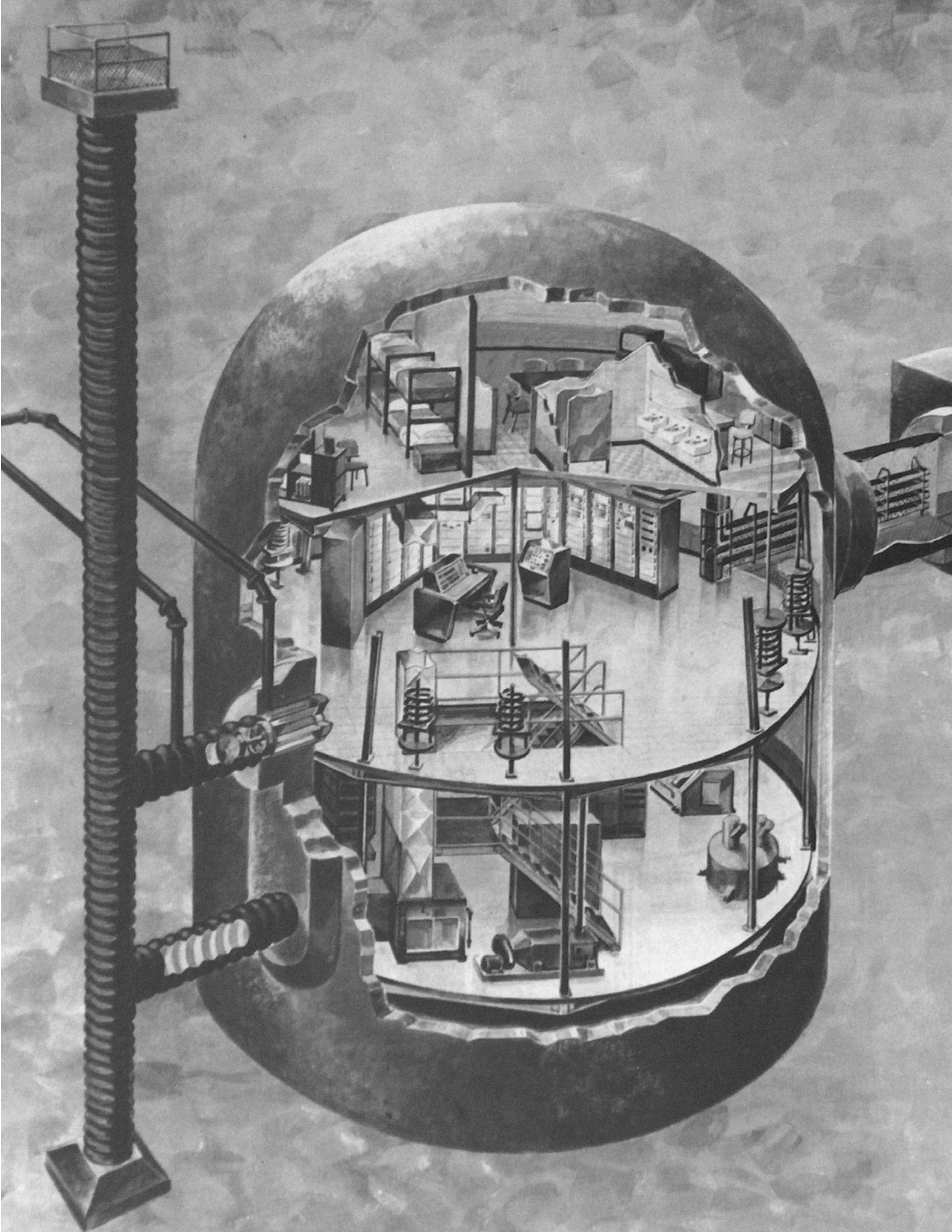
LAUNCH CONTROL CENTER

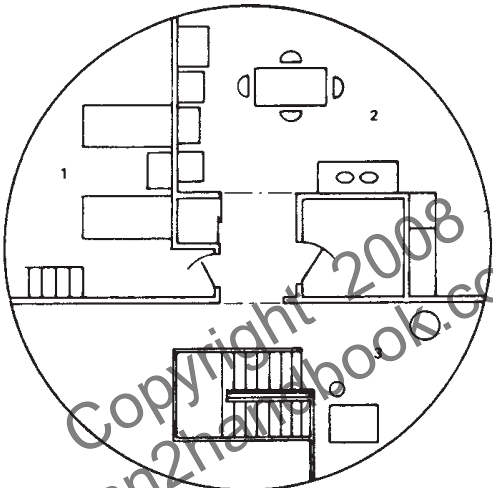
The launch control center (LCC) was a three level structure. Level 1, the topmost level, contained the crew's living quarters, often described as a kind of "Motel 2" because of its austere accommodations. Level 2 was the control center with equipment needed to receive the launch order and launch the missile. The lowest level, level 3, was a support-equipment floor. Levels 1 and 2 were the only designated smoking areas in the underground portion of the complex.

Crew Members

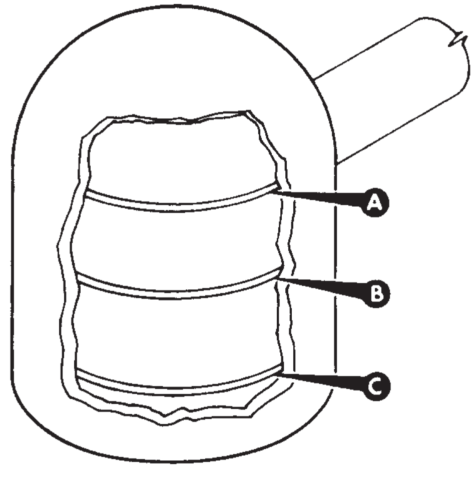
A discussion of the LCC should begin with a review of the missile combat crew members and their responsibilities. Titan II crews consisted of four individuals: the Missile Combat Crew Commander (MCCC, said "M triple C"), the Deputy Missile Combat Crew Commander (DMCCC), the Ballistic Missile Analyst Technician (BMAT) and the Missile Facilities Technician (MFT). In most cases the duties of these four people overlapped. This was essential because, for example, if one crew person became unable to continue his or her duties, someone had to be able to fill in. Just as most systems on the complex had a backup, every duty needed a backup as well. What follows is a brief description of each crewmember's duties and responsibilities.

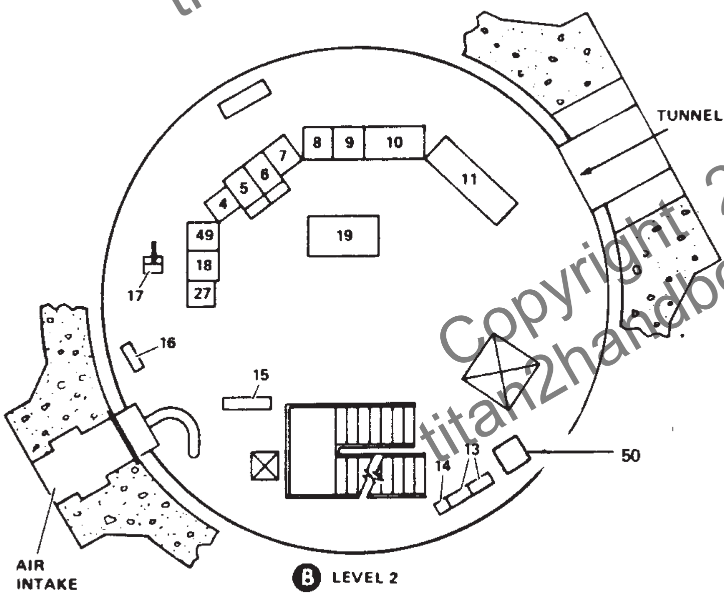
TMM ARCHIVES.



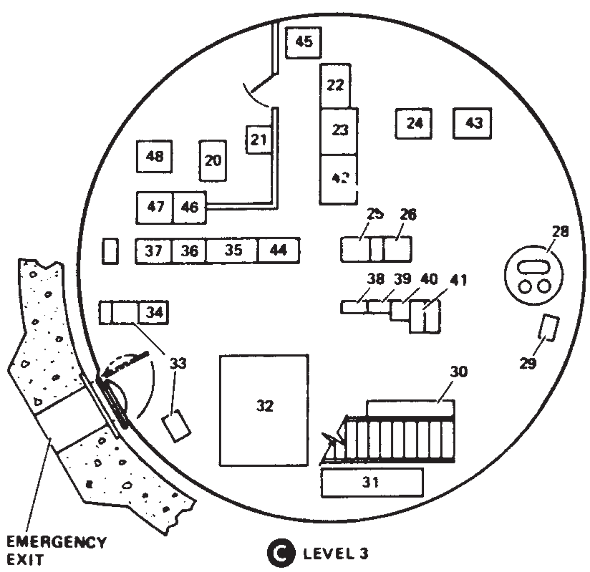


A LEVEL 1





B LEVEL 2



C LEVEL 3

1. SLEEPING QUARTERS
2. KITCHEN AND DINING AREA
3. STAIRWAY AND EQUIPMENT AREA
4. PRIMARY ALERT SYSTEM
5. ALTERNATE LAUNCH OFFICERS CONSOLE
6. VHF AND SSB RADIO
7. FACILITY POWER CONTROL BOARD
8. MISSILE SYSTEMS FAULT LOCATOR
9. CONTROL MONITOR GROUP
10. CONTROL POWER DISTRIBUTION
11. ALIGNMENT-CHECKOUT GROUP
12. (DELETED)
13. LIGHTING PANEL
14. CONTACTOR PANEL
15. HEAT AND VENTILATION CONTROL PANEL
16. DISTRIBUTION PANEL
17. HYDRAULIC HAND PUMP
18. SUBSCRIBER C
19. LAUNCH CONTROL COMPLEX FACILITIES PANEL
20. WIRE PROTECTION AND DISTRIBUTION CABINET
21. TELEPHONE CO. EQPT. CABINET (DMAFB ONLY)
22. MOTOR GENERATOR (DEACTIVATED)
23. BATTERY POWER SUPPLY 1
24. POWER SUPPLY 1
25. VOICE SIGNALING SYSTEM (VSS) CABINET
26. RADIO-TYPE MAINTENANCE NETWORK (RTMN) CABINET
27. HF-UHF RADIO
28. SANITARY LIFT
29. LIGHTING AND CONTROL TRANSFORMER
30. MOTOR CONTROL CENTER
31. AIR FILTER
32. A/C UNIT
33. FACILITY TRANSFORMER
34. CARRIER BAYS
35. COMMUNICATIONS 24-VOLT POWER EQUIPMENT BAY
36. WIRE CONTROL AND TRANSMISSION (WCT) EQUIPMENT BAY (ALOC)
37. WIRE CONTROL AND TRANSMISSION (WCT) EQUIPMENT BAY (LCCFC)
38. TERMINAL EQUIPMENT GROUP
39. MULTIPLEXER RECEIVER GROUP
40. MULTICOUPLER
41. TRANSMITTERS
42. BATTERY POWER SUPPLY 2
43. POWER SUPPLY 2
44. WIRE CONTROL AND TRANSMISSION (WCT) EQUIPMENT BAY (HV/HVPL SWITCHING SELECTIVE SIGNALING CIRCUITS)
45. ELECTRICAL INTERFERENCE FILTER GROUP
46. ELECTRICAL INTERFERENCE FILTER GROUP
47. ELECTRICAL INTERFERENCE FILTER GROUP (ACP ONLY)
48. ELECTRICAL INTERFERENCE FILTER GROUP
49. 487L
50. RTMN TRANSCEIVER BATTERY CHARGERS

TMM ARCHIVES.

▶ The crew's spartan sleeping room. The privacy screen was added when women were allowed as crew members beginning in the late 70s.

▶ A basic kitchen. People who could cook were highly prized as crew members.

▶ This tank contained 124 gallons of potable water for the crew, many of whom refused to drink it. A water heater is partly visible at right

The MCCC, typically a captain or a major, was in charge of the complex. He or she (women were allowed to be crew members starting in the late 70s) authorized and coordinated all activities on the complex. The MCCC also copied, decoded, validated and authenticated all emergency action messages (EAMs). EAMs included everything from simple communication tests, to exercise messages, orders to change targets and the order to launch, among others.

The DMCCC, often a captain or first or second lieutenant, assisted the MCCC in performing his or her duties, and had the additional responsibility of monitoring communications to, from and within the complex. She or he also kept track of the location of all personnel on the facility, and like the MCCC, copied, decoded, validated and authenticated all EAMs.

The BMAT, an enlisted person, was responsible for monitoring the status of the missile and providing the MCCC with information concerning the missile's readiness condition.

The MFT, also an enlisted person, kept track of the status of the entire launch complex, and all the support systems therein, and provided the MCCC with information regarding the readiness of the complex.

The BMAT and the MFT also were trained to copy and decode EAMs.

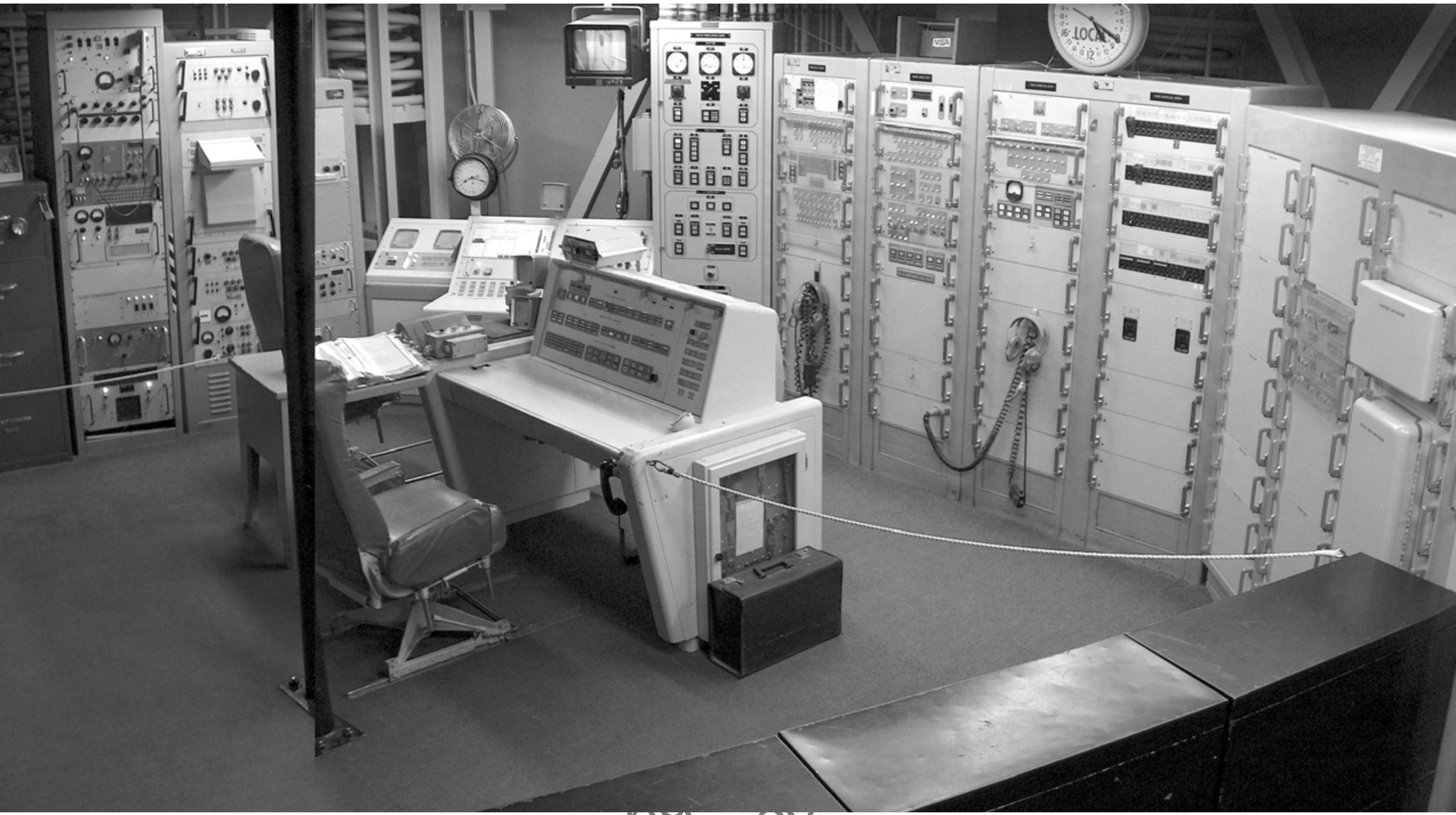
LCC Level 1

Crew members worked a 24-hour shift known officially as an *alert*. Because a crew would be on alert for a full 24 hours, they needed a place to eat, sleep, relax, take a shower and so on. Level 1 of the LCC contained the crew's minimalist quarters. The bedroom contained two sets of bunk beds and a privacy screen for mixed crews. The kitchen was equipped with all the basics: a stove, refrigerator, sink, table and chairs. The restroom was fitted with a toilet, urinal, washbasin and shower. Also on level 1 were a hot water heater, a domestic water storage tank, and an air system exhaust fan.

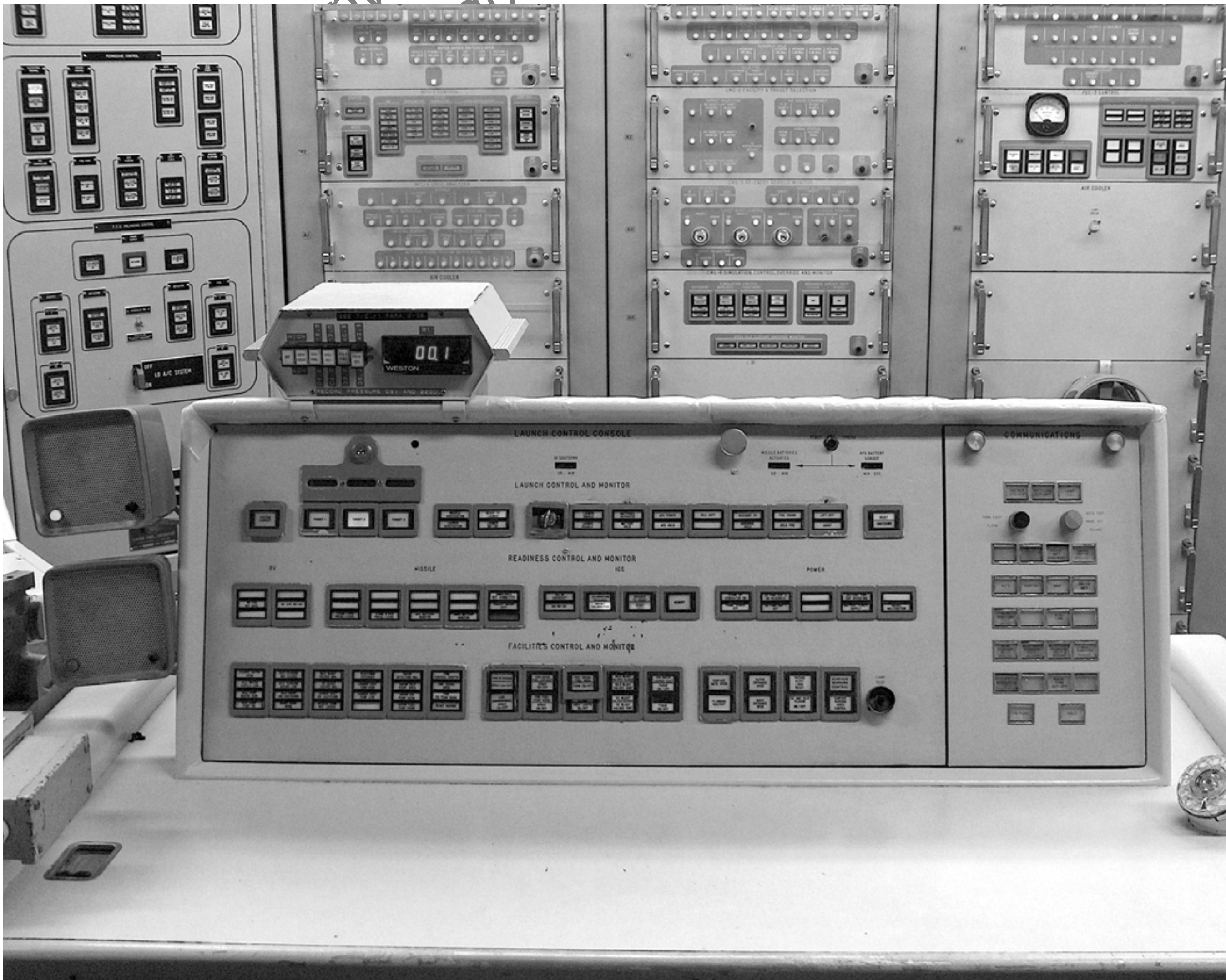
A 250-gallon (950 l) storage tank held 124 gallons (470 l) of potable water. The extra volume permitted pressurization by the utility air compressor system on silo level 7.[1]

LCC Level 2

Level 2 of the LCC was the nerve center of the launch complex and was where the crew spent most of their time. It was here where the order to launch would have arrived, and from here where the crew would have launched the missile. From here the crew could monitor the entire complex and all the activities therein.



▲ The launch control center (LCC). The control complex facilities console (LCCFC) is at center.



▶ The LCCFC. Think of it as the "dash board" of the complex.

◄ A portion of the silo ladderway. This view looks up from level 4 to level 2.

CHAPTER 6

THE SILO

The silo was composed of two elements, essentially two concentric cylinders: the inner cylinder, called the *launch duct*, with an inside diameter of 26.5 feet (8 m), which housed the missile; and the outer cylinder with an inside diameter of 55 feet (17 m). The space between these two cylinders was called the *silo equipment area*—a warren of pipes, cables and machinery needed to keep the missile in a constant state of readiness.

While the launch duct was hollow the silo equipment area surrounding it was divided into nine levels. Each level contained equipment for a specific purpose, and six levels had doors for access to the launch duct. A ladderway provided access to all levels of the silo equipment area while an elevator could access all levels except 1 and 9.

The structure of the silo was dictated by a number of engineering requirements that made it impossible to fully shock-isolate it in the same way the LCC was isolated from its surroundings. By necessity, the launch duct was connected to the silo at the base, and was braced by a concrete floor at level 3. Shock waves impacting the outer silo wall would, therefore, be transmitted to the launch duct. For that reason, all critical equipment in the silo was independently shock isolated—virtually everything was suspended from springs. Even the missile was cradled by an enormous set of shock absorbers.

Because silo shock isolation was impossible in any practical terms, engineers employed what might best be thought of as silo shock *management:* they designed the structures to absorb, damp and minimize shock transmission

USAF PHOTO, TMM ARCHIVES.

to the launch duct to the fullest extent possible. Engineering documents describe several methods of shock mitigation. These included designing the outer silo wall to permit it to flex above level 3; a slip coupling at the interface of the floor and the launch duct wall at level 3 to vertically uncouple the launch duct from the silo at that point; steel floors with gaps and slip joints so that shock energy would be transmitted to the launch duct only at level 3; and a gap between the top of the launch duct and the silo headworks.[1]

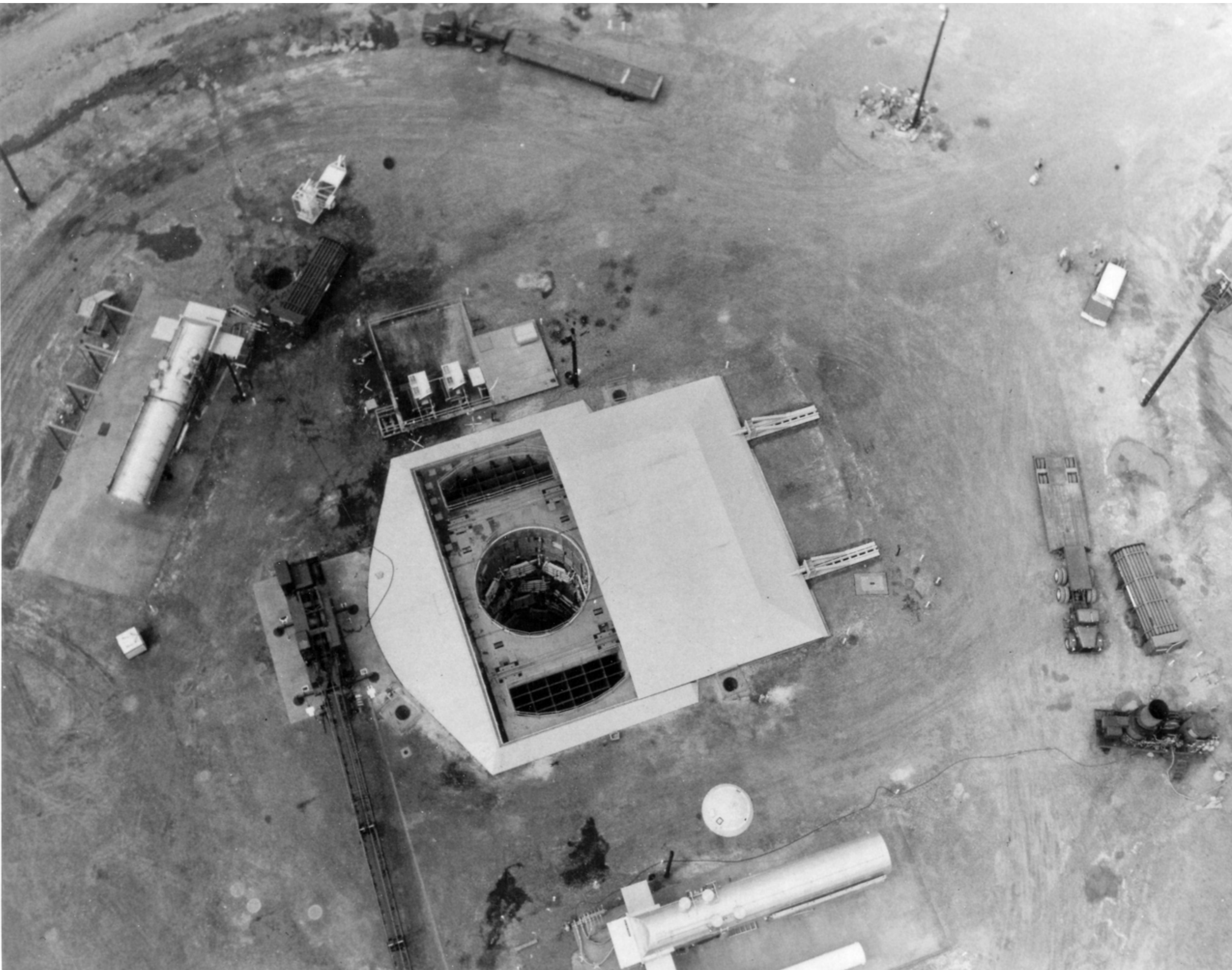
The outer wall of the silo was eight feet (2.4 m) thick from the surface to a depth of about 30 feet (9 m), at which point it tapered abruptly to a thickness of four feet (1.2 m). This taper permitted the silo to flex slightly, while the sheer mass of the eight-foot wall served to absorb lateral shock energy as well as vertical motion applied from above.

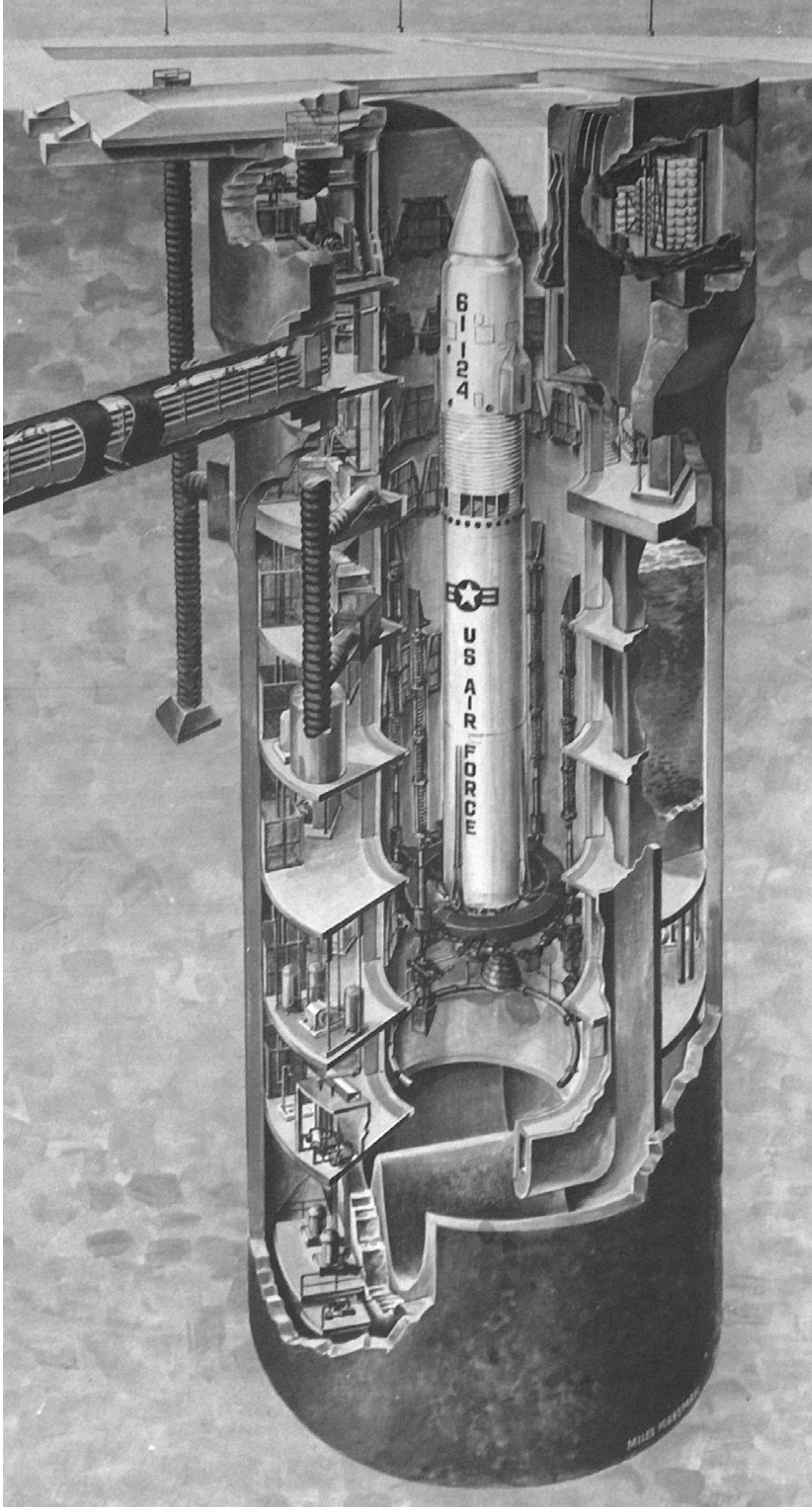
And it's all built for a single use. As one museum docent quipped, "It's a one-shot muzzle-loader." There was never any thought of reloading. The launch duct suffers surprising little damage during launch—nothing that couldn't be repaired in a few weeks. But the Wing had only one spare missile, and in the aftermath of a nuclear exchange, destruction of facilities and infrastructure would likely be so thorough and widespread there would be no means of installing another missile, even if you wanted to.

Launch Duct

The launch duct was a continuous uninterrupted shaft surrounding the missile. At the top was the silo closure door, and at the bottom were two exhaust ducts and the flame deflector plate, usually referred to as the "W" because of its shape. At six levels between the top and bottom (levels 1 through 5, and 7) retractable waffle-like work platforms could be lowered to give maintenance crews direct access to the missile. Levels 1 through 4 and level 7 each had eight platforms while level 5 had only

▼ This aerial photo provides a splendid view of the launch duct and exhaust shafts. Note cooling towers and hardstands.





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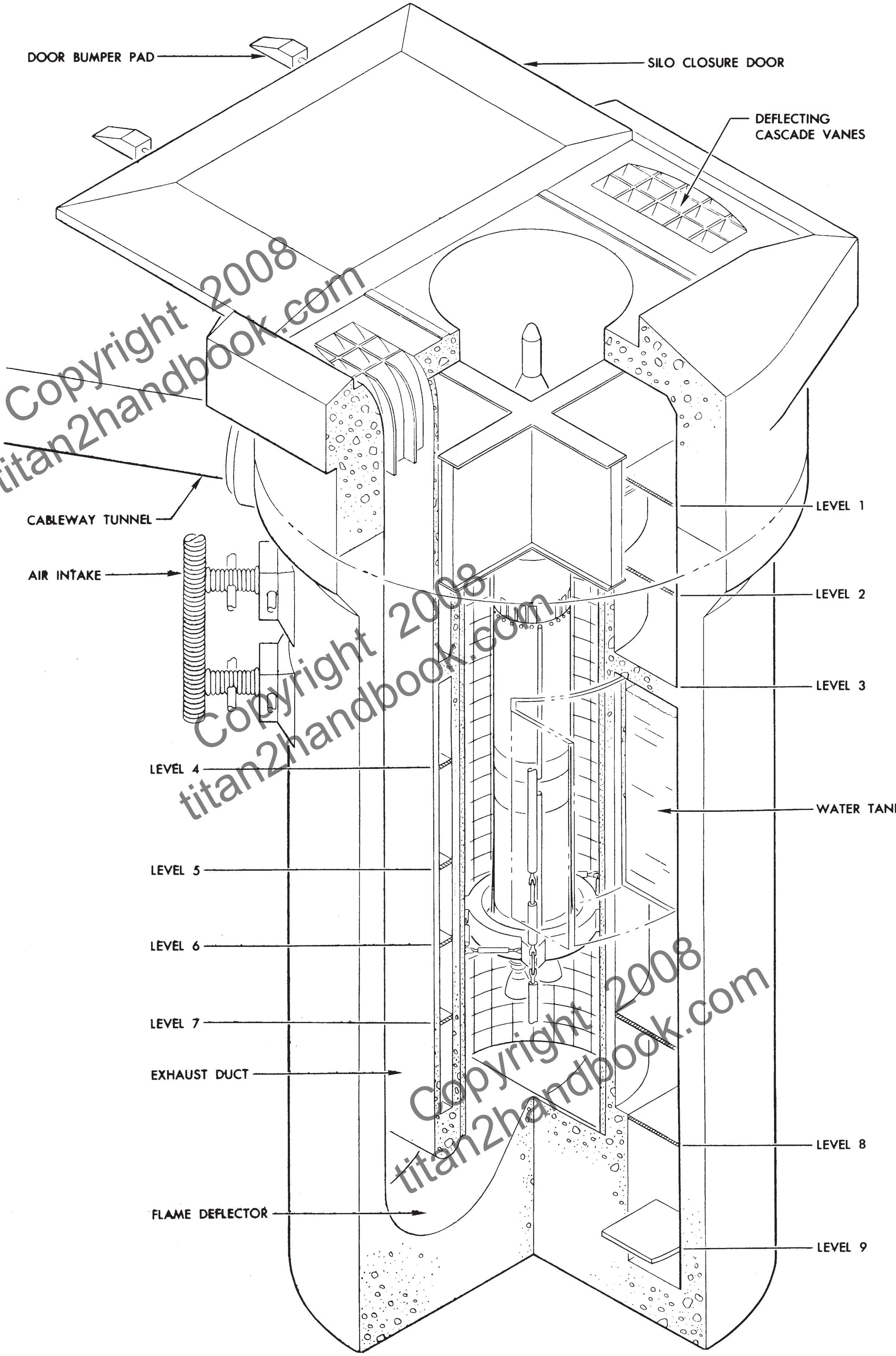
Two views of the silo and launch duct.

◀ At left, a detail from a Martin Company illustration.

▶ At right, a drawing from the Dash One. The Dash One image is rotated about 90 degrees from the Martin drawing and provides an additional perspective of the flame deflector and exhaust shafts. Curiously, the newer Dash One image shows the missile fitted with the older Mark IV reentry vehicle, which was never deployed on Titan II.



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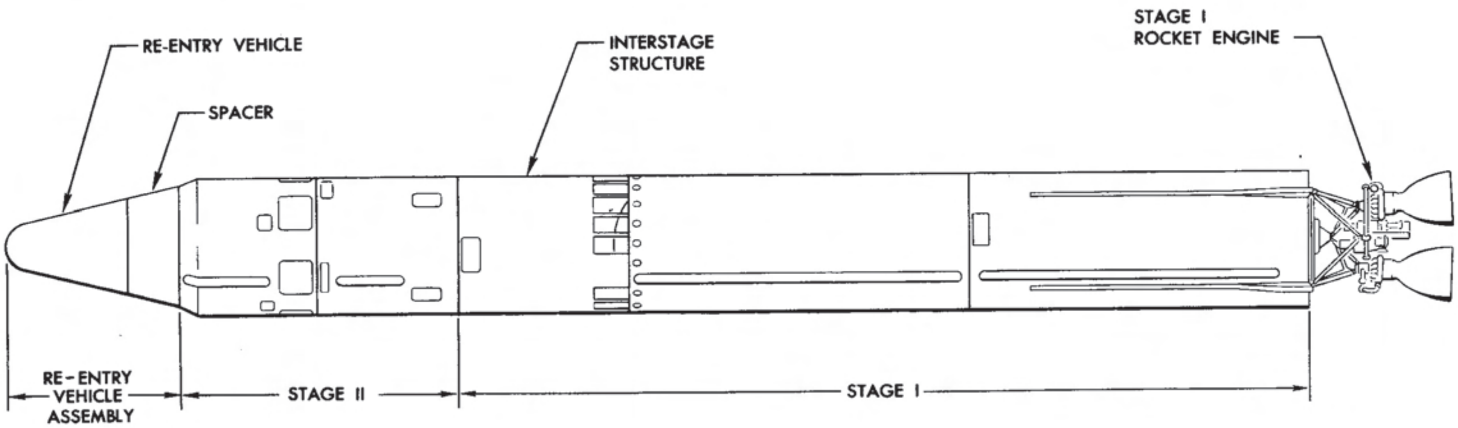

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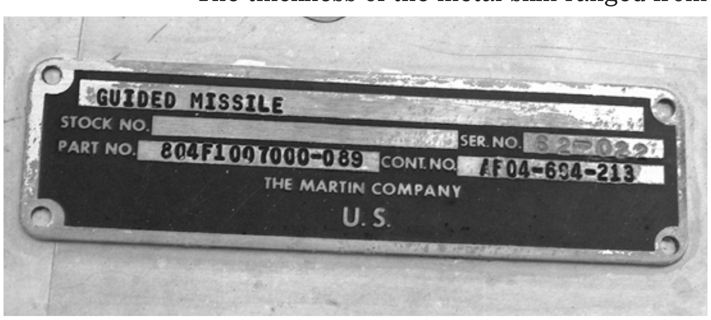
CHAPTER 7

THE MISSILE

Standing 103 feet (33.5 m) tall, with a range of over 6000 miles and topped with the largest thermonuclear bomb ever carried by a U.S. ICBM, Titan II was the blockbuster of the United States' nuclear deterrent. The main body of the missile, often referred to as the *airframe*, was 10 feet (3 m) in diameter and constructed from anodized aluminum, alloy type 2014-T6. The airframe was *semi-monocoque* (MON-a-coke) in design, meaning that the missile was self-supporting, and that its propellant tanks were an integral part of the airframe and not separate internal structures.[1] The thickness of the metal skin ranged from approximately .050 inches (1.27 mm) to .170 inches (4.3 mm) depending on the location. For comparison, a U.S. dime is .053 inches (1.35mm) thick, while a quarter is .068 inches (1.75 mm). Chemical milling was used extensively to reduce the thickness, and hence the weight, of the airframe. Titan II's weight, including the reentery vehicle (RV) and propellant, was nominally 330,000 pounds (150,000 kg)—a number made even more impressive when compared to the weight of the airframe and RV alone: just 23,000 pounds (10,400 kg).[2] Remove the RV and Titan II drops to a featherweight 15,000 pounds (6800 kg). Indeed, the missile was little more than a flying fuel tank. The first stage carried a combined total of about 24,000 gallons (91,000 l) of fuel and oxidizer, while the second stage carried about 5800 gallons (22,000 l).[3,4]

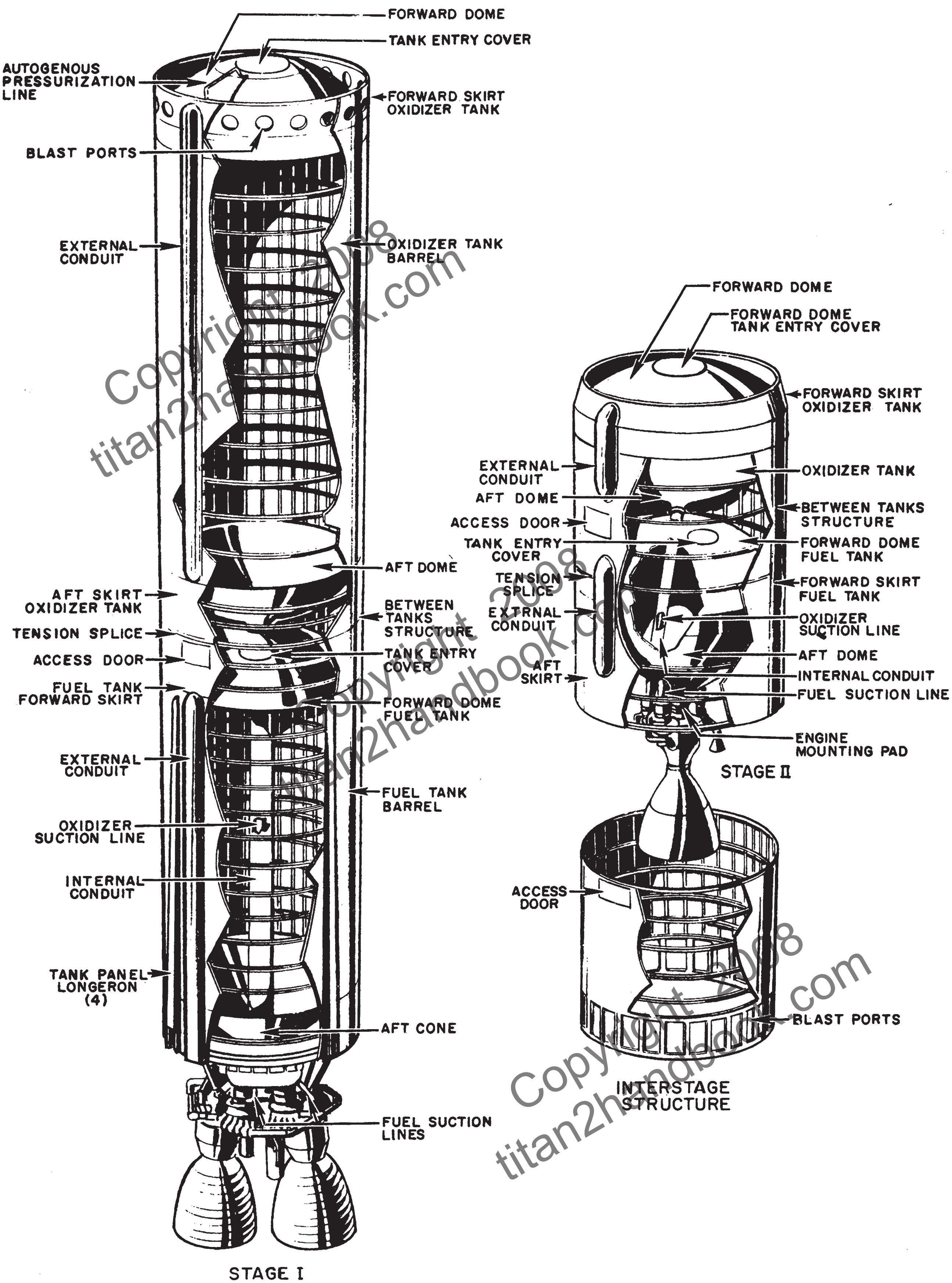


▲ Nameplate on underside of aft skirt.

The missile on display at the Titan Missile Museum, number N-10, was a training missile acquired from Sheppard AFB in Wichita Falls, Texas when the Titan IIs were retired, and was never loaded with propellant. While N-10's first stage is painted with black and white stripes, operational missiles were not so adorned. But all Titan II missiles, including N-10, were festooned with a multitude of labels on the airframe informing maintenance teams of the purpose or function of various panels and connectors.

Propellant—Making the Missile Fly

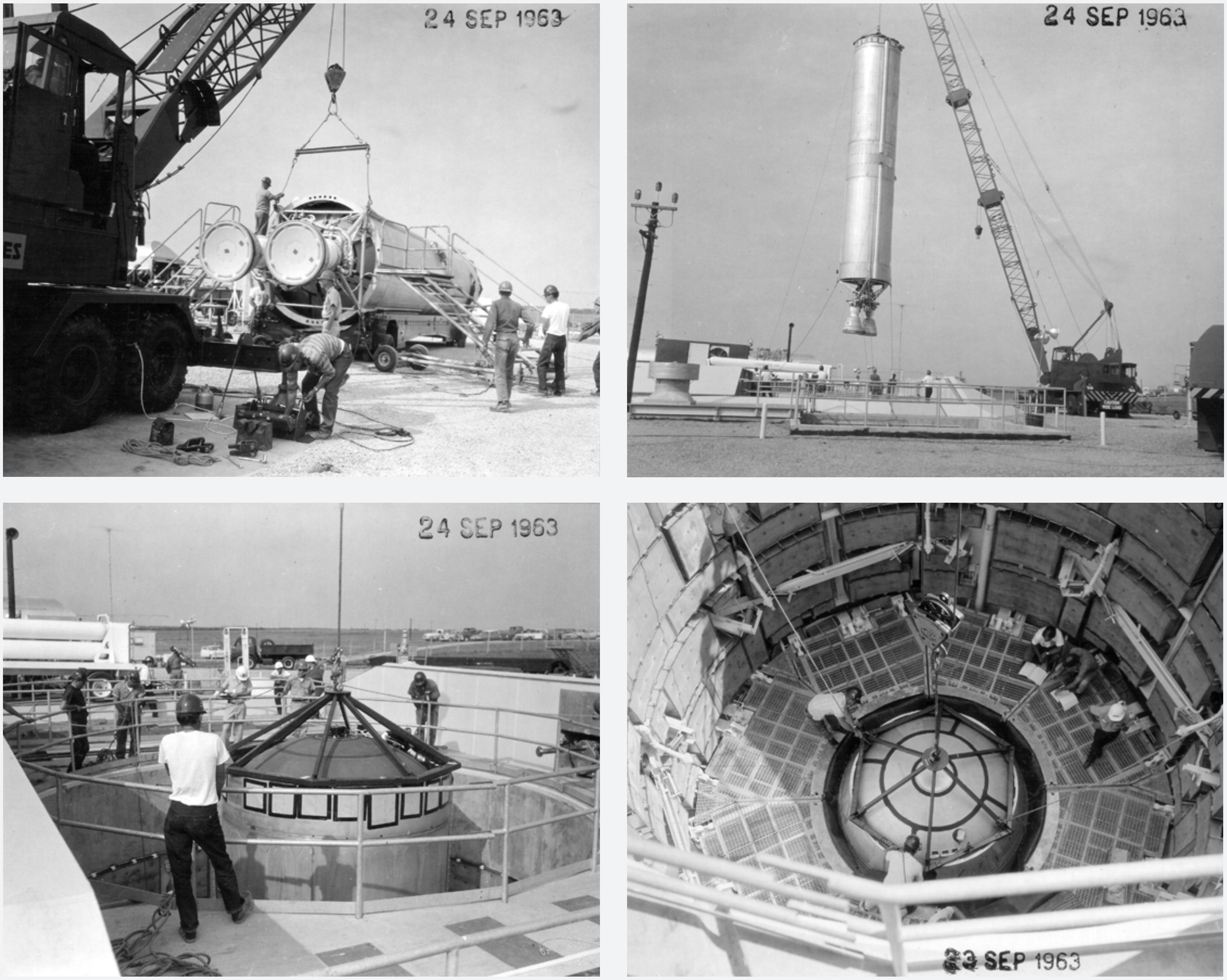
Throwing an 7600-pound (3450 kg) warhead a distance of more than 6000 statute miles (9600 km) requires tremendous energy. In Titan II that energy came from two very dangerous, toxic



MISSILE AIRFRAME CONFIGURATION

Insertion

▼ The missile was transported to the complex by truck and lowered into the silo with a large crane. Stage one was installed first, followed by the stage two. The propellant was then loaded, and finally the RV was installed. This sequence of photos was assembled from two separate installations.



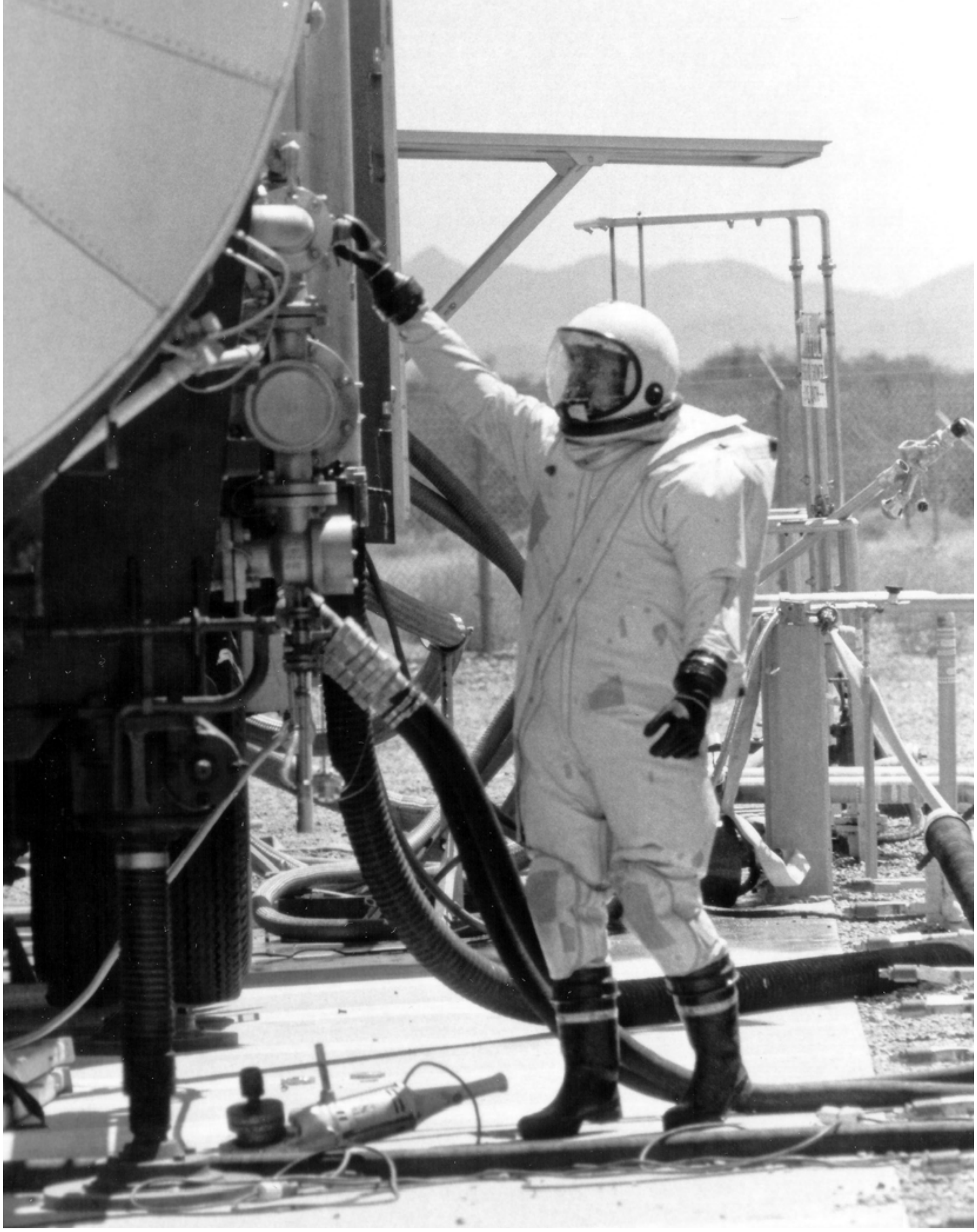
USAF PHOTOS, TMM ARCHIVES.

and volatile chemicals: a fuel and an oxidizer.

In your car the fuel typically used is gasoline, and the oxidizer is oxygen from the air. Gasoline was, in fact, used as a fuel in some early rockets and its chemical cousin, kerosene, was used in Atlas and Titan I. The oxidizer part is a little more complicated. Many rockets and missiles, including Titan II, fly beyond the Earth's atmosphere and therefore cannot depend on oxygen in the air to facilitate combustion. Indeed, most rockets and missiles carry their own supply of oxygen.

Titan II used a rocket fuel called Aerozine 50, a 50/50 blend of the chemicals hydrazine (N_2H_4), and unsymmetrical dimethyl hydrazine $((CH_3)_2N_2H_2)$, and an oxidizer, nitrogen tetroxide, (N_2O_4). Together, these two chemicals were called the *propellant*.

The huge advantage of these chemicals over kerosene and liquid oxygen was that they were stable enough to be stored onboard this missile for years at a time, waiting to go at a moment's notice. While Atlas and Titan I required precious tens of minutes to be loaded, Titan II was always fully loaded and could be launched in just 58 seconds.



◀ The rocket fuel handler's clothing outfit, or RFHCO, worn to protect against the highly toxic vapors of the propellant. The suits were not air-conditioned.

USAF PHOTO, TMM ARCHIVES.

But this huge advantage brought with it two huge disadvantages. First, Aerozine 50 and nitrogen tetroxide are exceedingly toxic and had to be handled with what amounted to moon suits. Those involved with propellant handling wore a special protective suit called a rocket fuel handler's clothing outfit (RFHCO, pronounced REFF-co). The suits were rubberized and were not air conditioned; wearing them in 100° F (38° C) weather was not a pleasant task. Still, it beat the alternative of being poisoned by fuel or oxidizer vapors.

Second, nitrogen tetroxide had to be kept at the correct temperature in order to remain stable. If it got too warm, it would begin to boil inside the tanks of the missile. If it got too cool, it would become jelly-like. The ideal temperature was 60° F (15.5° C), with a tolerance of plus or minus two degrees. Both oxidizer and fuel—along with the entire missile and launch duct—were kept at this critical temperature.

There is a third point regarding the propellant that is an advantage and a disadvantage all rolled up together, and that is that the propellant was *hypergolic*, meaning that the fuel and oxidizer would ignite spontaneously when mixed. The advantage was that there was no complicated ignition system to fail. This disadvantage was that if the fuel and oxidizer mixed accidentally, as from a leak in the missile or some kind of in-silo accident, the results could be catastrophic.

Loading and unloading Titan II's propellant required a great deal of specialized equipment, the most conspicuous of which were the *holding trailers* (large trailer-mounted tanks) and *conditioning trailers* (truck-like heating/cooling units). The process of loading or unloading propellant, together with all of the equipment required to handle the volatile chemicals, was referred to collectively as the propellant transfer system (PTS). Prior to loading the propellant into the missile it was brought to the correct temperature with the conditioning trailers. Once conditioned, the propellant was gravity fed into the missile in the silo. The missile's propellant tanks were then pressurized with nitrogen to prevent any reactions with oxygen or water vapor.

PTS operations were complex, labor intensive, time consuming and dangerous. Whether in the silo or on the surface, spills of fuel or oxidizer represented a potentially life-threatening event, not only for those in the immediate vicinity of the spill, but also for the crew in the control center and anyone downwind of the complex. Aerozine 50 is extremely volatile and in sufficient concentrations will react violently with a wide variety of common substances such as paints, oil, grease and solvents, and even rust. And as mentioned earlier, oxidizer created large volumes of highly toxic and corrosive vapors. Fortunately, propellant spills were an extremely rare occurrence.

The propellant had no "shelf life," so in theory, once loaded it could remain on the missile forever. In practice, however, the chemicals were corrosive enough that gaskets and seals might begin to leak after a number of years. In that case the propellant would need to be off-loaded, then reloaded once repairs were completed.

Stage One

Rocket scientists and engineers are loath to talk about the power of a rocket engine in terms

▼ The LR-87-AJ-5 stage-one rocket engine. It had no throttle control or "off switch" and burned at full power until the propellant ran out. Its thrust was roughly equivalent to that of two Boeing 747s.