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Voyager – a lesson in taking and managing risk

Synopsis

NASA's Voyager Mission has been, and continues to be, an inspiring endeavour that exemplifies the human spirit of discovery and our desire to explore new horizons. The creation and launch of the two Voyager craft in the 1970's involved taking big risks and dealing with many uncertainties in a bold quest to explore the unknown. This article looks at some of the risk management principles from this NASA mission, which is forty years old and counting, and we can apply them to our own activities.

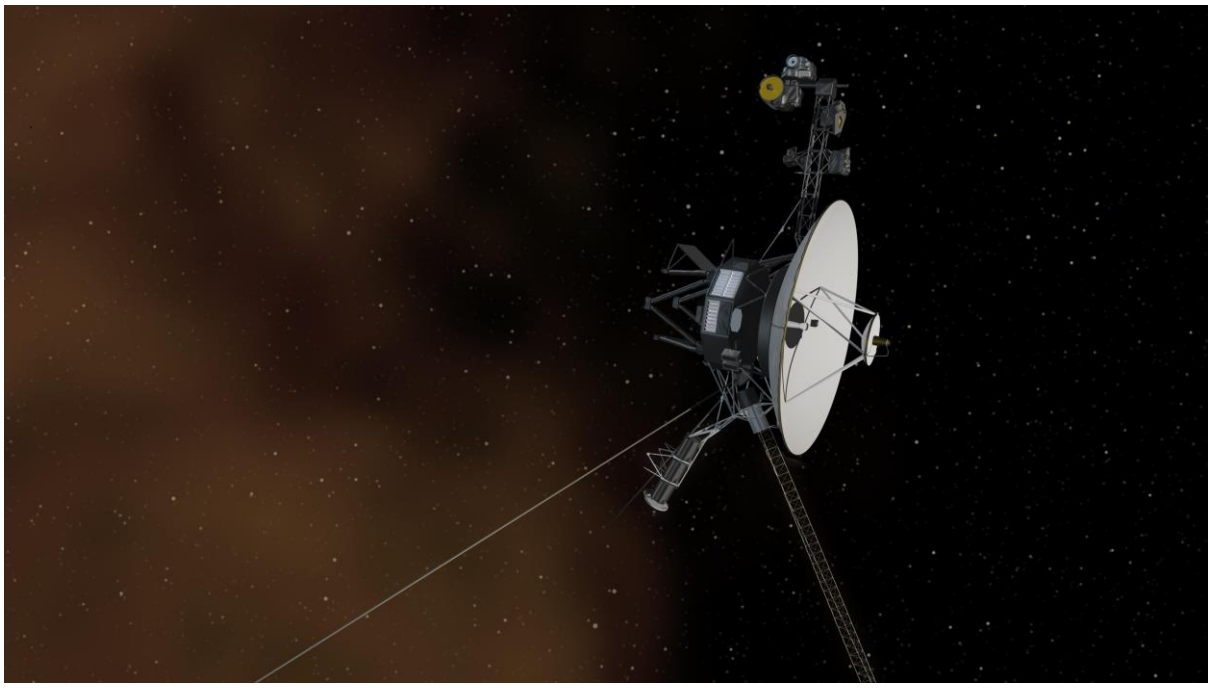


Image credit: NASA/JPL-Caltech

The Mission: setting out on a billion-year journey

The Voyager Mission is one of NASA's best-known space exploration missions. The facts and achievements of the mission – too many to list in this article – are amazing to behold.

On August 20th1977 (four days after the death of Elvis), Voyager 2 departed Cape Canaveral aboard a Titan-Centaur rocket. Voyager 1 was launched on September 5th 1977 (it quickly overtook Voyager 2, per the launch plan). Their mission: to explore the outer Solar System (see my Point 2 below for context). Their achievements so far have been remarkable, more than living up to NASA's hopes and objectives. Both craft have given scientists a wealth of information about the planets and moons of the outer Solar System. Voyager 1 officially reached interstellar space on August 25th 2012, the first human-made object to do so. Voyager 2, which is on a different path to Voyager 1, left the heliosphere on November 5th 2018. Every second, both Voyager craft are reaching farther into space.

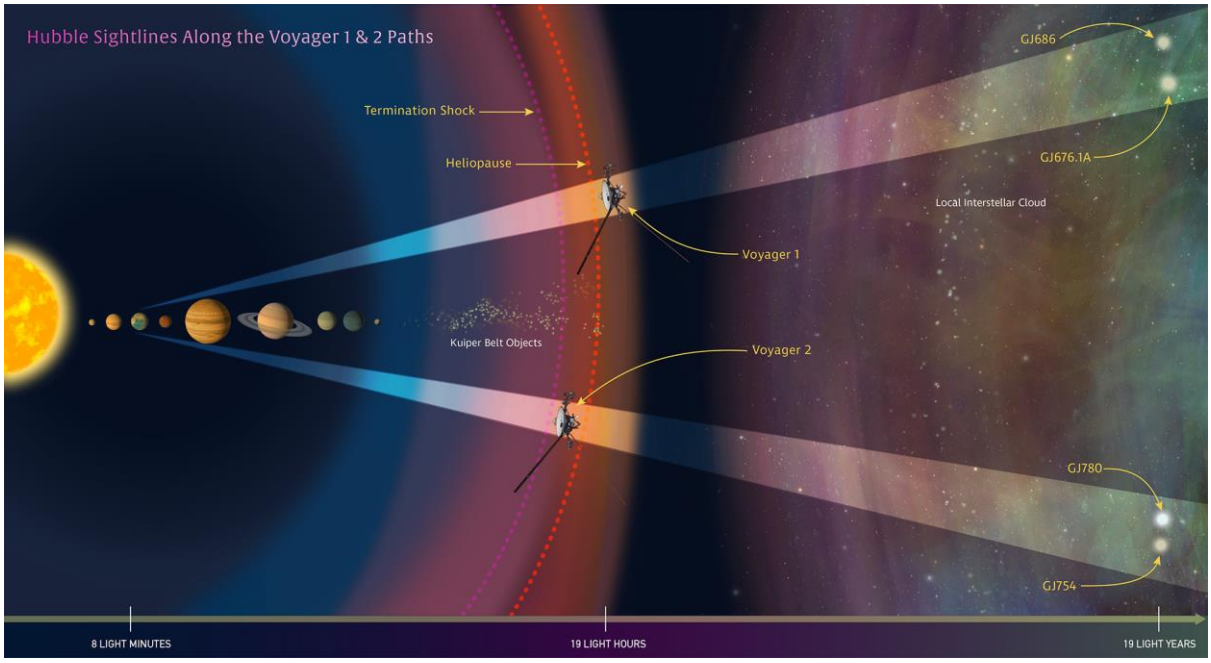


Image credit: NASA/JPL-Caltech

As of December 13th 2018, Voyager 1 is 13,477,882,443 miles (that's 13.48 billion miles, or almost 21.7 billion kilometres) from Earth. Voyager 2 is 11,094,472,456 miles (11.1 billion miles, or 17.8 billion kilometres) from us. To give you a sense of the gigantic distances that these two spacecraft are covering, travelling as they are at about 10 miles (16 kilometres) a second, in the time it took me from first drafting this article to finalising it – two and a half days – these "tin cans" had travelled 2 million miles (that's about 3.2 million kilometres) further away from the Earth. That is the equivalent of making 80 trips around the circumference of our planet.

Embarking on a journey into the unknown

One of aspects of the Voyager Mission that I find enduringly fascinating is how the NASA Voyager team has successfully guided their two spacecraft across the vastness of space for over 40 years. They have successfully navigated huge amounts of uncertainty, overcome obstacles and taken and managed risk in a way that has ensured this inspirational space mission has been an undoubted success.

Here are five points from my own perspective that highlight how the Voyager Mission team has managed risk. On each point I summarise how we can all learn from the Voyager team in our more "down to earth" activities to take and manage risk.

1. How do you deal with "unknowns" and "firsts of a kind"?

We are often faced with challenges on projects and in our operations, sometimes involving "firsts of a kind", or FOAKs. How can we best deal with the risks of FOAKs?

The NASA Voyager team was dealing with a huge number of unknowns and risks with their mission right from Day 1. They did not know (and could not know) what would happen along the journey.

One important piece of information that the Voyager team did know was that they had a specific window of time in which to launch their craft – the autumn (northern hemisphere) of 1977 – if the mission was to be successful. The launch timing had to coincide with a special alignment of the planets Jupiter, Saturn, Uranus and Neptune (something that happens once every 176 years) to allow both spacecraft to get "gravitational kicks forward" from each planetary fly-by.

This "unmissable launch timing" drove the schedule. The Voyager team set themselves up from Day 1 to deal with what they knew would be a dynamic and changing project environment. With a foundation of team spirit and trust in each other to get things done, the team was always thinking about "What if?" scenarios and solutions to overcome risks and issues that were found.

Lesson learned: a "What if?" mindset stands you in good stead. We are often given target deadlines to meet, which we don't always have the chance to influence. Your mindset, and how you manage risk, determines how you tackle a challenge like this.

2. Think about how to over-succeed on your objectives

As the story goes, the NASA team went to the Nixon administration with their original proposal and explained that the last time the outer planets of the Solar System were in an alignment for "a grand tour", President Jefferson was sitting at the President's desk. As articulated in the book, *The Interstellar Age: Inside the Forty Year Voyager Mission*, Nixon's administration and NASA HQ rejected the initial Grand Tour proposal and its costs (in the midst of broader NASA budget trimming) and asked for

a reduced-scope proposal to be re-submitted. The project team took this on board and scaled the mission back to a greatly reduced budget (about US$250 million, equivalent to about US$1.5 billion today) and a focus on fly-bys of Jupiter and Saturn, using two spacecraft. In a low-key way, within their reduced and approved budget, the project team set themselves a “stretch target” to try to extend the mission on to Uranus and Neptune. This would require good risk management foresight for it to succeed.

The use of two spacecraft – Voyagers 1 and 2 – was in itself good risk management, in case one craft malfunctioned before completing its mission or crashed.

Lesson learned: understand and respect your budget holder concerns and use risk management to see insights into opportunities to think through and determine possible stretch targets whilst pragmatically pursuing your main deliverables and objectives.

3. Manage risk in design and think “What if?” in everything you do

The Voyager spacecraft were built at NASA’s Jet Propulsion Laboratory, Caltech in Pasedena, California. The Voyager engineers had to be as sure as they could be that their design and construction would allow the craft to go into deep space. The engineers were constantly thinking about the most improbable things could happen. They were “the original What if? team”.

The team didn’t know what the craft would look like to start with, and how to arrange everything. The design and build process was a “nurturing process” to bring the craft into reality.

The team knew that they couldn’t bring these spacecraft back to repair or service them. Once they were launched, they were out there on their own. Materials and mock-ups had to be rigorously tested, all within the “must not miss” launch timing.

The Voyager craft weigh about 800kg. They are about the size of a small school bus; ten-sided cans that are called “the Bus” in fact, with arms and appendages that have different sensors, power supply and cameras attached to them.

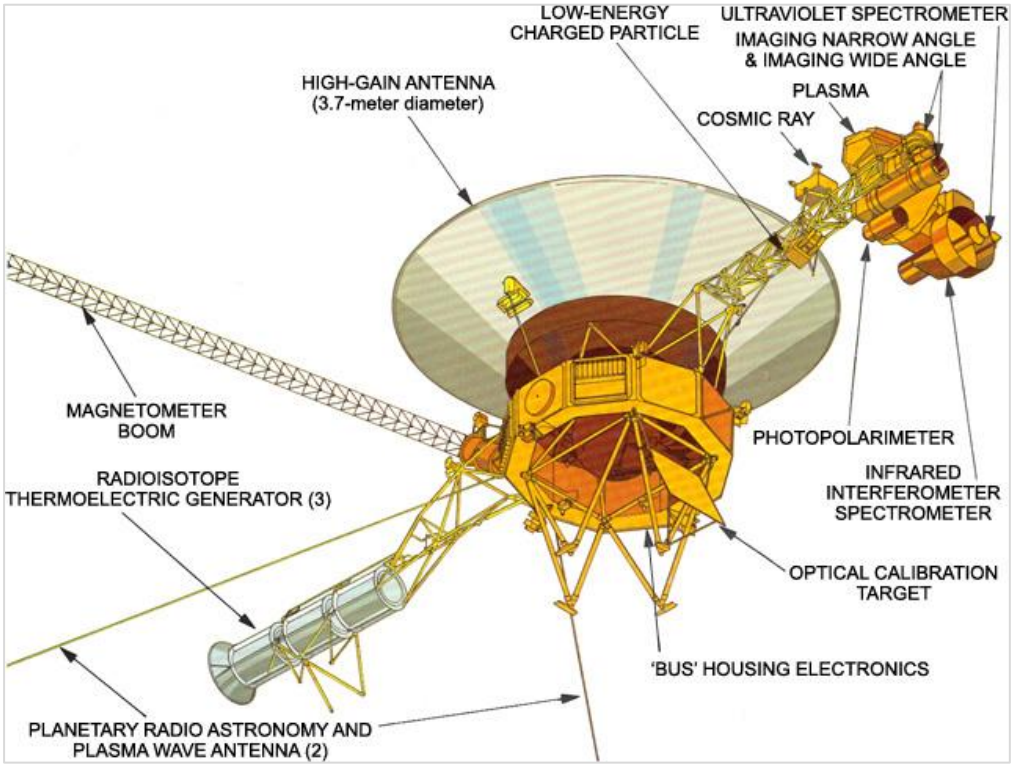


Image credit: NASA/JPL-Caltech

Each Voyager spacecraft has just three computers on board, with a total memory capacity of 69.63 kB. That's about 240,000 times less than the average smartphone you have in your pocket, which is also about 7,500 times faster than their processors. They are using 1970's technology, and it is still working just fine!

Voyager would reveal Jupiter to us in ways we had never seen before. The timing for both Voyager craft to arrive at Jupiter and to have a "gravitational kick" from the Solar System's largest planet was key to the mission continuing past that planet.

Two months before launch, scientists working on the mission predicted that the large magnetic fields around Jupiter would be intense enough to accelerate particles which could generate a massive number of volts (maybe up to 40,000). Cabling on the antennae and appendages of the craft would act as conductors for these charges, which would kill the electrics on the spacecraft. It was good risk management and "What if?" questioning that ensured they would be prepared for this. They had to quickly work out a way to "ground" (or earth) these appendages. The design team went through design reviews quickly, and they had to do some things that were out of the ordinary to find a solution, adapting to the circumstances and tight timeframes. They succeeded.

Lesson learned: good risk management helps us to see insights and act on them quickly to help us succeed in our objectives.

4. Be on guard for unexpected events to happen, and be resilient

I have mentioned several times the “What if?” mindset of the project team. This mindset stood them in very good stead for the events that would occur for the launches of both Voyagers. Every day, the team was wondering if they built the spacecraft well enough.

The spacecraft were folded up in their rockets, ready to unpack themselves when they were in space. The Voyager 2 spacecraft – launched first in August 1977 – began to do unexpected things soon after its launch. It did not follow the intended instructions. It started switching things off as it was being shaken about by the force of the rocket that was propelling it spacewards.
However, the person in charge of the instructions code demonstrated resilience and was able to calm everyone on the team down. They learnt that they had set the limits on the spacecraft too tightly. It needed greater freedom of margins to set itself up.

These problems were resolved for the Voyager 1 launch. However, there was a different problem with the launch of Voyager 1: an incorrect mix of propellant for the Titan part of the rocket meant that the Centaur part of the rocket had to take more of the strain in getting Voyager 1 into space than had been intended. It almost ran out of fuel. It had just 3.5 seconds of thrusting left (before running to fuel depletion) when it gave Voyager 1 the “kick” it needed to be on its way. Just 3.5 seconds later, and the spacecraft may never have been set along its way.

Lesson learned: good resilience is about analysing and responding quickly to problems and demonstrating aspects of a High Reliability Organisation.

5. A “What if?” mindset means you will keep seeing risks early

When Voyager 1 reached Saturn and its moons for its next “fly by” in November 1980 (Voyager 2 was nine months behind by now), it gave NASA and the watching world insights into the planet that we had never seen before.

At this point, the decision to send two spacecraft into space (as a “risk management exercise”) was again shown as very prescient.

The main mission of Voyager 1 was to explore Jupiter and its moons and then Saturn and its largest moon, Titan. After it spent time analysing Saturn and Titan, NASA HQ agreed that Voyager 1 had succeeded with its mission, and that it could embark on an interstellar trajectory that would take it out of the Solar System. Voyager 2 would have gone on that trajectory if Voyager 1 had failed to get that far. Because Voyager 1 succeeded, Voyager 2 was programmed to visit Uranus and Neptune. Thus, the mission was able to retain flexibility and deliver even more success than the plan called for – thanks in part to good risk management.

After reaching and studying Saturn, Voyager 2 had to go behind the planet, where signal would be lost for several hours. When it emerged from the other side, lots of strange signals were being transmitted back to Mission Control. Instruments were

impaired. People initially wondered whether Voyager 2 had crashed into the planet. It turned out that there was a problem with the platform on which the camera sits – it was stuck. It could have put the Voyager 2 mission in jeopardy.

It took a couple of days for the engineering team to diagnose the problem and transmit instructions to Voyager 2 to unjam the platform. They kept pushing it in different directions, back and forth, until it freed up – all of this remotely, 746 million miles / 1.2 billion kilometres away from Earth. The team successfully dealt with this crisis through calculated trial and error.

Lesson learned: taking risks requires us to be flexible and also have good resilience.

6. You know you may need to change course – so be ready for it

Beyond Saturn, the engineers needed to "start again" with Voyager 2 and work out how to take pictures in the depths of the Solar System, where light is weak.

Voyager 2 was re-programmed to adapt to the next phase of its mission, to capture planetary images in the fading amount of light.

After visiting Uranus and Neptune (which, again, heralded fascinating insights), Voyager 2 was programmed to take a trajectory out of the Solar System, having successfully completed its mission. Voyager 2 actually came within a few thousand miles of Neptune's cloud surface as it passed by it, literally skating across it, which allowed it to discover incredible revelations about its moon, Triton. A slight miscalculation and the spacecraft would be no more. And all of this being done remotely, 2.7 billion miles (4.3 billion kilometres) away.

Lesson learned: good risk management means anticipating changes.

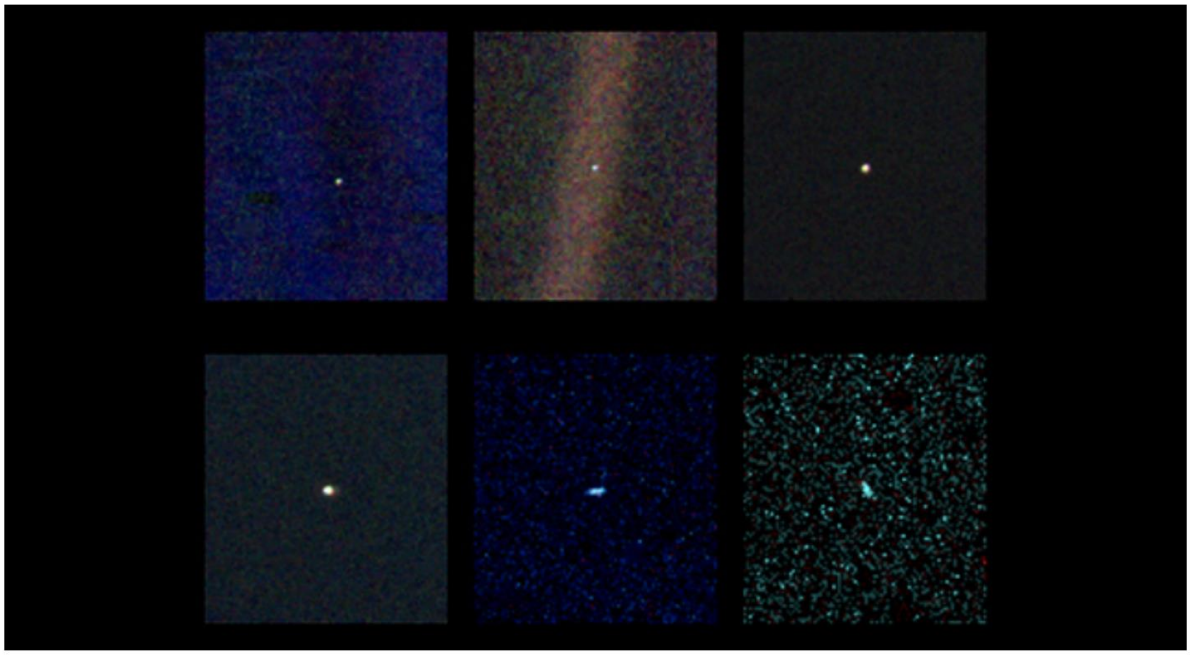
7. Thinking long-term…

The Golden Record is a signature of the two Voyager spacecraft. The foresight of the team to put these "messages in a bottle" inside the craft is a story in itself. There were doubters, about whether it is "a good idea" to "give away our location" to aliens, should they find it. Key to this was that the disc is made of metal and will last a long time – good risk management foresight. To protect the record from dust and particles, it is sheathed in a silver cover. The location of Earth in terms of its direction from different pulsars is engraved. A stylus is included in the package, and a drawing shows how to play the record with the stylus.

Conclusion

In summary, a flexible, Can-Do attitude by the project team and a mindset of “What if?” has played a significant part in why the Voyager spacecraft are still journeying through space, over forty years since being launched from the Earth.

NASA took a risk with the Voyager Mission, and it came off – and how! Remember Voyager 2’s last look-back at the Solar System in October 1989 – what a series of pictures!



This "family portrait" captures Neptune, Uranus, Saturn, Jupiter, Earth and Venus from Voyager 1's unique vantage point. A few key members did not make it in: Mars had little sunlight, Mercury was too close to the sun, and dwarf planet Pluto turned out too dim.

Image credit: NASA/JPL-Caltech

Years after completing “the Grand Tour”, the two Voyager spacecraft, both the size of a small school bus, remember, are flying further away from us. In 2012, Voyager 1 entered interstellar space, 35 years after it was launched. Voyager 2 will do so soon (estimating the exact time when is difficult).

How much fuel do the two spacecraft have left? How much farther will they go? Nearly all of the redundancy built into in the Voyager craft has gone now, either because components and materials have deteriorated over time, or they have been switched off to conserve power. As both spacecraft age, more things could go wrong. Mission Control will decide what else to switch off in due course, and will probably lose contact with them by 2025. Just the thought of still being able to control them, when they are 13.16 and 10.9 billion miles away respectively, and counting, is amazing.

They will keep going after the NASA team loses contact with them. Travelling at 10 miles (16 kilometres) per second on average, Voyager 1 has a date with a star, AC +79 3888 in 40,000 years. Well, it will pass within 1.7 light years of it, which is close in cosmic terms. If all goes well, in 296,000 years Voyager 2 should pass within 4.3 light years of our nearest recognisable stellar neighbours, Sirius, the brightest star in the sky which is 8.6 light years away from the Earth. Both Voyagers should orbit the centre of the Milky Way every 225 million years. There is no wind, water, or weathering in space. It's highly unlikely they will be struck by anything – the vast emptiness of space makes this highly unlikely. They could keep going over billions of years pretty much intact. They may outlive the Sun. When their power sources go dead, and their transmitters stop sending us information, they will truly be messengers for us in outer space.

NASA's approach to risk management

An overview of NASA's use of risk management is described on the NASA website.

You can find out all about the Voyager Mission on NASA's JPL website, a link to which is here.

For a fascinating insight into the Voyager Mission, watch the documentary, *The Farthest*, which is on sale through all major distribution channels.

About the author

Gareth Byatt is an Independent Risk Consultant and owner of Risk Insight Consulting. He is based in Sydney, and has 20 years experience in international risk and project management. Gareth has had the honour of visiting teams at NASA on a few occasions.