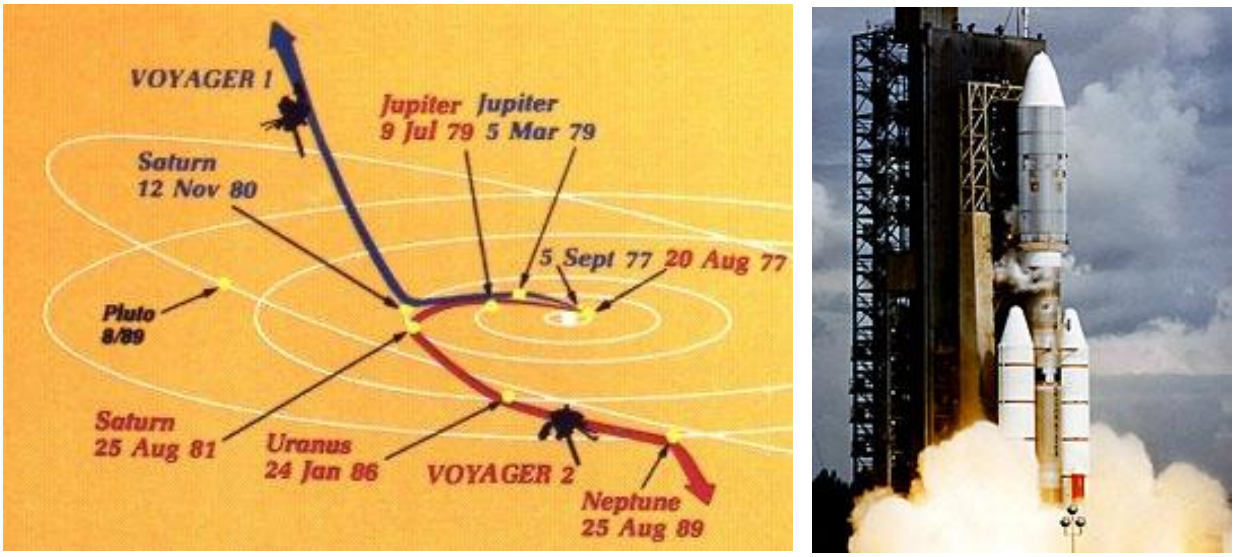
Voyager's Grand Tour

By John Uri
Manager, History Office
NASA Johnson Space Center
https://www.jsc.nasa.gov/history/

Introduction

In the early days of the Space Age, scientists realized that given the right planetary alignments it might be possible to use the gravity of one planet to change the trajectory of a spacecraft and send it on to another planet without expending any fuel. This slingshot or gravity assist trajectory principle was first tested by Mariner 10, which used the gravity of Venus to slingshot its way to Mercury in 1974.

A very rare planetary alignment would occur in the late 1970's allowing a spacecraft to visit all the outer planets (Jupiter, Saturn, Uranus, Neptune and Pluto) using gravity assists at each planet to send it on to the next. This unique alignment would not occur again for another 175 years! The initial ambitious plan, called the Grand Tour, was to send two pairs of spacecraft, one pair to visit Jupiter, Saturn and Pluto, the other to fly by Jupiter, Uranus and Neptune. However, the original plan was scaled back in the budget conscious early 1970's to just two less capable spacecraft visiting only Jupiter and Saturn, and Titan, Saturn's largest moon.

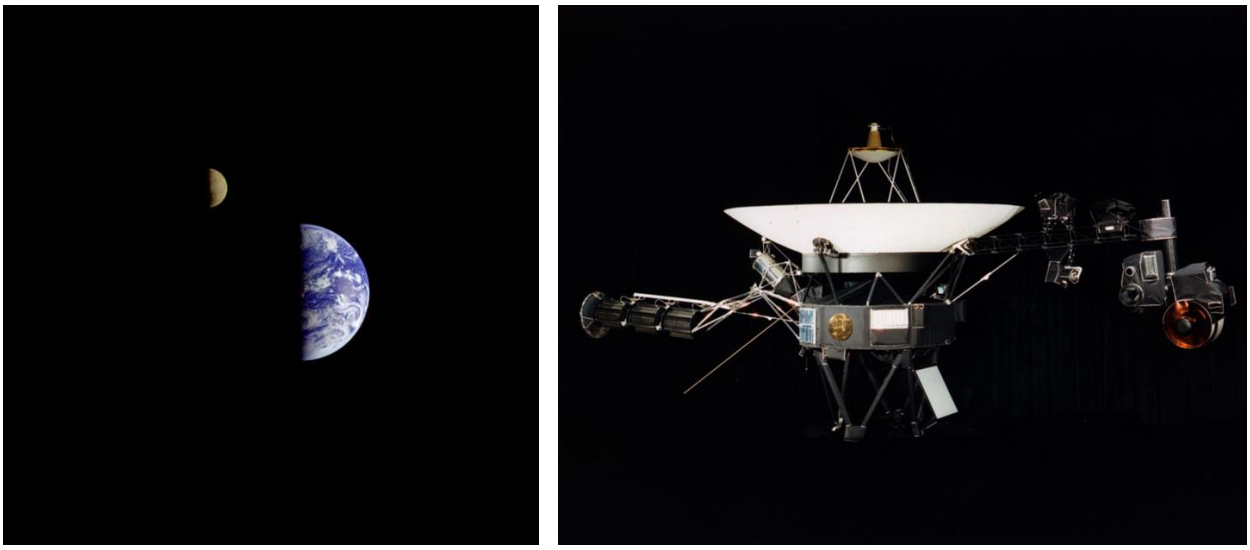


Flight trajectories of Voyager 1 and 2 through the outer solar system (left) and the launch on top of a Titan III-Centaur rocket (right). Images courtesy of NASA.

Taking advantage of this alignment would be two Voyager spacecraft, both beginning their long journeys in 1977. Voyager 2 launched first, on August 20, followed by Voyager 1 on September 5. Both spacecraft would first fly by Jupiter and use that planet's massive gravity to bend their trajectories to then fly by Saturn. Voyager 1 would also be targeted to fly by Saturn's moon Titan, which was known to have a dense atmosphere, a trajectory that would preclude any future planetary flybys. But the option

was kept open, if Voyager 1's Titan flyby was successful, to retarget Voyager 2 to send it on to Uranus and maybe even Neptune – assuming it would survive that long!

Just 13 days after its launch, Voyager 1 scored the first of its many firsts: at a distance of 7.25 million miles, it turned its camera back toward Earth and snapped the first ever photograph of the Earth-Moon system in a single frame, giving a sneak preview of the discoveries that lay ahead.



First photograph of the Earth-Moon system in a single frame (left), taken by Voyager 1 on September 18, 1977. Voyager spacecraft as it would appear in space (right). Images courtesy of NASA.

First stop: Jupiter

On their way to Jupiter, both Voyagers successfully passed through the Asteroid Belt without incident – two Pioneer spacecraft had made the crossing safely in 1973 and 1974 as pathfinders, proving that it was safe to do so. Voyager 1 arrived first, passing 217,000 miles above the giant planet's cloud tops on March 5, 1979. Two months before the close encounter, Voyager 1 began taking photographs of Jupiter and its moons and gathering other scientific data about the planet and its environment, a process that continued for about a month after the fly-by. Voyager 2 followed not too far behind, beginning scientific observations in April 1979 before passing 350,000 miles above Jupiter's cloud tops on July 9, 1979, and finishing observations about a month later.

The 11 instruments aboard each Voyager made amazing discoveries, not to mention the thousands of stunning photographs of Jupiter and its many moons. Among the more notable discoveries were that Jupiter has a faint ring system, its Great Red Spot is a large swirling storm system, the moon Io has active volcanoes, the moon Europa has a geologically young surface made of ice possibly floating on an ocean of liquid water, and that there were three previously undiscovered small moons.

On to Saturn!

Both Voyagers quietly coasted as they headed toward their next target, the ringed planet Saturn. Once again, Voyager 1 was first, beginning observations in August 1980 before making its closest approach 77,000 miles above Saturn's cloud tops on November 12, and finishing studies in December. Significantly, Voyager 1 made a close flyby of Saturn's large moon Titan, larger than our own Moon and with a dense atmosphere, coming within 4,000 miles of its surface near its South Pole. The Titan encounter changed Voyager 1's trajectory so it could not make any further planetary encounters – thus beginning its long journey out of our solar system. Voyager 2 started its examination of Saturn in June 1981, making its closest approach at 63,000 miles on August 25, and finishing observations in September.

The instruments aboard the Voyagers returned a wealth of new information about Saturn and the cameras returned thousands of images of the planet, its rings and satellites. Among significant discoveries, the Voyagers found that Saturn's rings were far more complex than previously believed, Titan may have lakes of liquid hydrocarbons, Saturn has auroras near its poles much like Earth does, and that there were three previously unknown satellites.

Montage of Jupiter and its four largest moons, (left) and of Saturn and several of its moons (right). Images are not to scale. Courtesy of NASA.

Two more stops: Uranus and Neptune

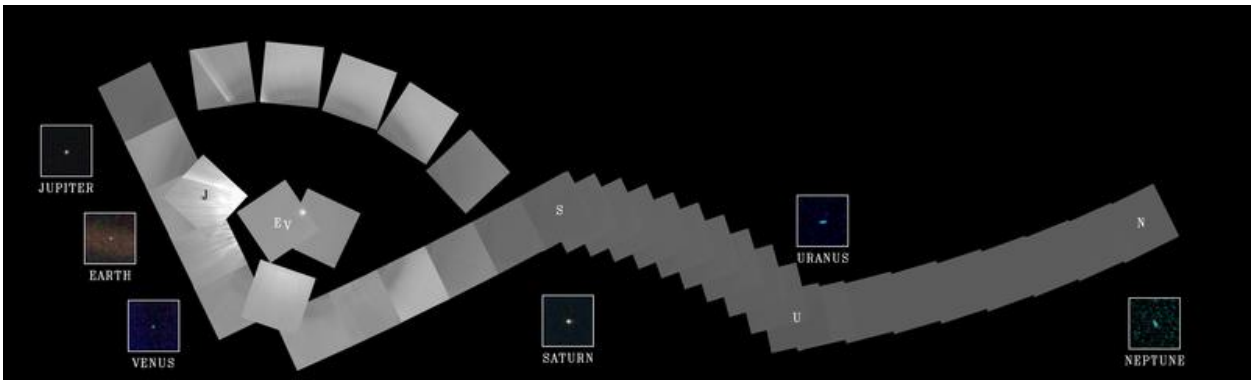
Voyager 2's flyby of Saturn set it up to automatically fly by Uranus after a coast of five and a half years. It began to study the Uranian system in November 1985 and flew within 50,600 miles of its cloud tops on January 24, 1986, before concluding its observations in February. In conducting the first ever robotic reconnaissance of Uranus, Voyager 2 observed the planet's atmosphere, satellites and thin ring system, discovering 11 new moons and a previously unknown magnetic field and returning about 8,000 pictures. And then, it was on to Neptune, arriving there after another coast of three and a half years. Beginning its study in June 1989, Voyager 2 flew within just 3,076 miles to Neptune's cloud tops on August 25, concluding its observations in October. That close pass to Neptune allowed detailed observations of its largest moon Triton. During this first ever close up study of Neptune, Voyager 2 returned about 10,000 photographs of the planet, its satellites and dark rings, discovering 6 new moons, a Great Dark Spot on

the planet as well as a magnetic field, and geysers on the large moon Triton. After exiting the Neptune system, Voyager 2 joined its fellow spacecraft on a journey out of the solar system. But the intrepid Voyagers weren't quite done yet.

Montage of Uranus and several of its larger moons (left) and of Neptune and its largest moon Triton (right). Courtesy of NASA.

Family portrait

On February 14, 1990, more than 12 years after it began its journey and shortly before its cameras were permanently turned off to conserve power, Voyager 1 spun around and pointed them back into the solar system. In a mosaic of 60 images, it was able to capture a "family portrait" of six of the solar system's planets, including a pale blue dot called Earth. It was fitting that these were the last pictures from either Voyager.



Family portrait of six planets taken by Voyager 1 on February 14, 1990, when it was 6 B km from Earth.

Not exactly close encounters

With their planetary encounters over, the spacecraft began the Voyager Interstellar Mission (VIM) in 1989, in which they are going where no man-made spacecraft has gone before, exploring uncharted areas of the outer solar system and eventually crossing the boundary into true interstellar space. Because this part of space is so poorly understood, it took some time to analyze the data that Voyager sent back and determine when that transition took place – it is now believed that Voyager 1 crossed the boundary in August 2012, and Voyager 2 should follow suit in the next few years. Forty years after they were launched, both spacecraft are still operating more than 10 billion miles from their home planet, although most science instruments have been turned off to conserve power. Based on current projections, it is estimated that they can continue to function until about 2025.

In their current paths, neither Voyager will come within less than a light-year from any star in the next tens of thousands of years, long after they will have ceased to communicate with Earth. But, just in case any civilization is able to capture them to determine their origin, each Voyager is equipped with a golden record (think 1970's technology!) with coded information about the spacecraft and its makers. Contained on the record are recordings of sounds from Earth, including music, greetings in multiple languages and even whale songs, as well as photographs of various Earthly activities. Just hope those aliens have turntables! Even a stylus was thoughtfully provided with the record, along with instructions on how to play it.

Each Voyager carries a Golden Record, providing potential finders with information about its creator, the location of and information about the home planet. Courtesy of NASA.

For extra credit:

The Golden Record is available commercially, for streaming, mp3 or Audio CD. A detailed description of the contents are summarized in the 1978 book *Murmurs of Earth: The Voyager Interstellar Record*, by Carl Sagan et al., also available commercially.

A good starting point for more information about the Voyager mission can be found at: https://www.nasa.gov/mission_pages/voyager/index.html

A great article about some of the long-time members of the Voyager ground control team, for some Voyager has been an entire career: https://www.nytimes.com/2017/08/03/magazine/the-loyal-engineers-steering-nasas-voyager-probes-across-the-universe.html?hp&action=click&pgtype=Homepage&clickSource=story-heading&module=photo-spot-region&region=top-news&WT.nav=top-news