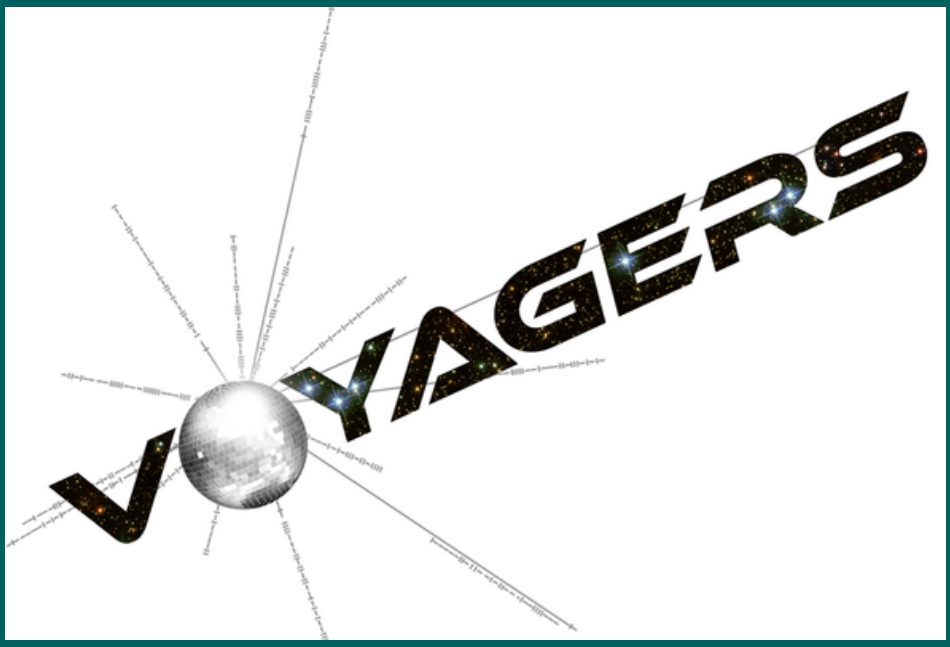

HISTORICAL NOTES AND DISCUSSION GUIDE

MATHEATRE

FISKE PLANETARIUM

CONTENTS

Image credit: Thor Metzinger, Fiske Planetarium

MISSION OVERVIEW

VOYAGER 1 AND VOYAGER 2

In 1965, a grad student named Gary Flandro did some calculations and realized the planets would soon--in 1977--be aligned in an infrequent and particular way. During this alignment in 1977, a spacecraft launched from Earth at that time could use **gravity assist** to boost its **trajectory** on an accelerated course through the solar system, using the gravity of each planet to slingshot along to the next. This series of planetary flybys was dubbed The Grand Tour.

The timing of this discovery was ideal--technology of the space program had reached a point that this mission would be possible in the twelve years until the special alignment. In 1977, **NASA** launched two spacecraft, Voyager 1 and Voyager 2, on a trajectory to Jupiter and Saturn. Funding was not yet in place for the Grand Tour, but as the mission progressed in the years 1977-80, funding was eventually granted for the Grand Tour, giving humankind our very first close-up view of the outer giants Uranus and Neptune. Even with the shortened trajectory thanks to the gravity assists, it still took twelve years to reach Neptune and
its moons.

Image credit: Thor Metzinger, Fiske Planetarium

MISSION OVERVIEW

VOYAGER'S PLACE IN SPACE HISTORY

Just a few years before Voyager, NASA's Pioneer mission had visited Jupiter and Saturn, but Voyager's more advanced technology, and expectations established by data learned from Pioneer, helped the mission's architects plan Voyager's experiments. Voyager's flybys of Jupiter and Saturn yielded many new discoveries of these two planets and their moons, building on the accomplishments of Pioneer and informing later missions such as Juno and Cassini. As of 2021, Voyager is still the only mission to have visited Uranus and Neptune--every photo you've ever seen of these two outer planets came from Voyager!

Each spacecraft--Voyager 1 and Voyager 2--are constructed of approximately 65,000 parts. Data and images from their sensors were recorded on a 8-track tape (ask an older relative if they still remember listening to music on 8-track tapes, before CDs, before cassettes!). The tape would record data, transmit it via radio antenna back to the crew ready to receive and interpret it on Earth, then the tape would rewind and erase the downloaded data to make room for more. The computers on board these craft had about the same amount of power as the keychains we now use to unlock a car from across a parking lot.

Image credit: Thor Metzinger, Fiske Planetarium

MISSION OVERVIEW

REACHING OUT INTO THE COSMOS

Also onboard the spacecraft is The Golden Record. a greeting from Earth, in the event that a future civilization in the far reaches of space might discover one of these spacecraft. The task of trying to communicate with an alien society with no mutual points of reference was a daunting one, but it is known that certain physical laws are constant throughout the entire universe, so our best shot at finding a common language is through science. The record is engraved with scientific landmarks to establish instructions to decode the rest of the record. The record features images of nature and animals, human activities and technologies, recordings of natural and mechanical sounds, greetings in 55 human languages, whale songs, and a global array of music, intended to depict the variety and wonder of life on Earth.

Voyager 1 and 2 were the first human-made objects to traverse the **heliopause** and leave our solar system. More than 40 years after their launch, they are still sending signals to Earth, telling us about conditions outside of the sun's solar winds, but these signals grow weaker every day. Larger and larger radio receivers had to be built just to detect their ever-fainter signals. Eventually we will lose contact completely, and Voyager 1 and 2 will serve as our messengers, carrying the Golden Record into the galaxy on the **miniscule** chance they will encounter another civilization, possibly millions or more years in the future, if ever.

Image credit: NASA

DISCOVERIES

JUPITER SYSTEM

It was previously known that Jupiter emitted a lot of radiation. For this reason, Voyager's crew protected the spacecraft by wrapping their antenna in the same type of aluminum foil you use to protect your leftovers! However, Voyager discovered that Jupiter's magnetic field was far, far larger, than previously thought. Voyager was able to get close-up images of the **striated** weather patterns on Jupiter's surface--known to planetary scientists as "belts" (the darker stripes that spin in a western direction) and "zones" (lighter colored stripes that spin in an eastern direction), furthering the understanding of Jupiter's atmosphere and weather patterns. A big discovery made by Voyager was the previously undetected rings of Jupiter--made of dust particles and much smaller and fainter than the famous rings of Saturn. Some real perspective-shifting discoveries occurred at two of Jupiter's moons--Io and Europa. It was previously believed that most moons were probably very similar to Earth's moon--essentially cold, **inert** rocks. However, Voyager discovered that due to **orbital resonance**, Jupiter's moons build up large amounts of heat in the form of friction. This heat source, known to scientists as "tidal heating," causes dramatic volcanoes to erupt on the surface of Io, and for water beneath the cracked, icy surface of Europa to be warm enough to be in a liquid state.

Image credit: NASA

DISCOVERIES

SATURNIAN SYSTEM

One exception to the incorrect assumption about all moons being stable and inert had been Saturn's moon Titan. Thanks to data from Pioneer and **spectroscopy** from previous studies, it was known that Titan actually has its own atmosphere. There was a lot of anticipation about what Voyager would discover on the surface, due to the fact that this atmosphere was similar to what Earth's atmosphere was like billions of years ago. It was hoped that Titan might give some clues about what Earth was like during that time and how early life emerged. However, due to the presence of large clouds of methane, Titan's surface was completely obstructed from Voyager's view. It wasn't until the Cassini-Huygens mission returned to the Saturnian system, reaching its destination in 2004, that more of these questions were answered.

Saturn itself was known to have a stunningly beautiful set of rings, made of ice particles. Voyager's close up flyby provided much more information about these famous rings, revealing them to have significantly more complex textures--including braids!--thanks in part to gravity provided by a series of previously undiscovered moons, known to scientists as "shepherd moons," orbiting within the rings themselves and providing gravity that not only keeps the ring particles in place, but influence their patterns.

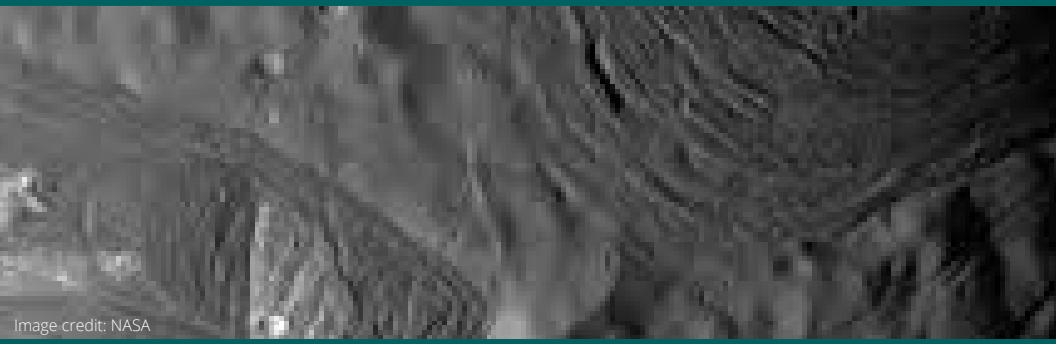

Image credit: NASA

DISCOVERIES

URANIAN SYSTEM

It was known from telescopes and Earth-based spectroscopy that Uranus has a faint set of rings, and spins on a sideways **axis**- rather than spinning upright like a top as it orbits the sun (as other planets do), it rolls sideways like a bowling ball. Besides that, not much was known. Voyager discovered that its **magnetic field** is unlike that of any other planet. Rather than being oriented roughly to the center of the planet, the magnetic field is off center and at a completely different angle. Uranus was also found to have an incredibly long, spinning magnetic tail.

Voyager made many discoveries about the planet's surface, including strange yellow water deep in the mantle (in the form of slushy ice) that is charged with electricity. It was thought at the time that there wasn't much else going on on the surface of Uranus, however Voyager passed over the side of the planet that always experiences winter. There is much more to discover on this large planet, but these discoveries will have to wait until a future mission.

Uranus also has a series of moons, all with their own interesting attributes. The biggest surprise was its smallest moon, Miranda. Voyager revealed that Miranda has the most dramatic landscape of the entire solar system, including cliffs nearly twice as tall as Mount Everest, the highest peak on Earth! Miranda's surface also has a strange composition, suggesting the possibility that it may have broken up and fused back together over time.
Miranda still holds many mysteries.

Image credit: NASA

DISCOVERIES

NEPTUNIAN SYSTEM

From Earth, it's impossible to even see Neptune and its moons as points of light without a telescope. Thus the opportunity to view it up close with Voyager was truly an opportunity for discovery.

Voyager discovered that Neptune's surface has the fastest recorded wind speeds in the solar system, and Neptune has a series of lopsided rings--revealing that all the outer planets are ringed.

Neptune's moon Triton also proved to have a completely unanticipated character. The surface of Triton is geologically active in ways that had been thought impossible in a deeply frozen world so far away from the sun. Geysers erupt nitrogen up to eight kilometers into the atmosphere, which then falls and freezes like snow--revealing new lessons about the behavior of known elements in extreme environments.

Image credit: NASA

DISCOVERIES

EARTH

What can we learn about our own planet from a space mission that leaves us far behind? After all other planned data had been collected from all the planets, as Voyager 1 was on course to find the edge of the solar system, the crew turned its camera back in the direction it had come. All planned photographs had been completed, so there was nothing to lose if the camera was damaged by being pointed toward the sun.

On Valentines Day 1990, more than twelve years after launch, Voyager 1 was programmed to take a series of photos of the entire solar system, as a sort of cosmic family portrait. Earth showed up in the photo as just another tiny point of light, difficult to distinguish from any other. The perspective of seeing our home planet from this vast distance had a profound effect on our idea of our place in the universe. What does this perspective suggest to you?

DISCUSSION QUESTIONS

1. An argument can be made that space exploration is an unwise allocation of resources that could be better used on Earth. But many scientists feel passionately that learning about space and the universe has valuable applications. What do you think we gain from space exploration?

2. When Voyager 1 took a photograph of Jupiter's ring, the crew didn't immediately recognize it and feared the camera had been broken! How does a fear of failure limit or inform the possibility of success?

3. The play "Voyagers" features four scientist characters which are **amalgamations** of different people, meant to represent the team effort that was necessary for the Voyager mission's success. What are some ways a team capitalizes on the contributions of individuals?

4. The two other characters in the play are anthropomorphic representations of the spacecraft themselves. Why do you think humans have a tendency to **anthropomorphize** inanimate objects?

Image credit:
Carla Johns, Fiske Planetarium

DISCUSSION QUESTIONS

5. There is some debate in the play about the value of science fiction, and the play itself uses techniques of science fiction to depict historical events. What is the value of using stories and imagination to relate to history and facts?

6. The music and styles in the play were meant to depict the passage of time between 1977 and 1989. Styles and cultural norms change over time along with advances in technology. What is the value of reflecting on history as we look toward the future?

7. In 1986, shortly before Voyager arrived at the Uranian system, NASA's space shuttle Challenger tragically exploded, costing the lives of all aboard--astronauts Ellison Onizuka, Ronald McNair, Judith Resnick, Dick Scobee, Gregory Jarvis and Michael J. Smith, plus Christa McAuliffe--a schoolteacher who was to be the first civilian to fly into space. The shuttle broke apart 73 seconds after takeoff, witnessed in real time by millions on live TV. Characters in this play struggle with this tragic moment of history defined a generation. Other space endeavors, notably the space shuttle Columbia disaster in 2003, have cost the lives of the explorers on board. In your opinion, is the risk of tragedy worth the reward of discovery? What are the pros and cons of uncrewed spacecraft like Voyager?

Image credit: NASA

DISCUSSION QUESTIONS

8. The Golden Record is an attempt to communicate with a civilization completely unlike our own. What are the challenges of communicating across boundaries (real or merely perceived) of language, culture, generation, class, race, gender among humans from the same planet? How are those challenges amplified when communicating with someone who doesn't even have the same planetary reference?

9. One purpose of the Golden Record was to show Earthlings that regardless of nationality, race, gender, income, etc, we are more alike than we are different. How does the cosmic perspective of viewing our planet from 3.7 billion miles away support or challenge that idea?

10. The Golden Record may never be found. Was it still worth making?

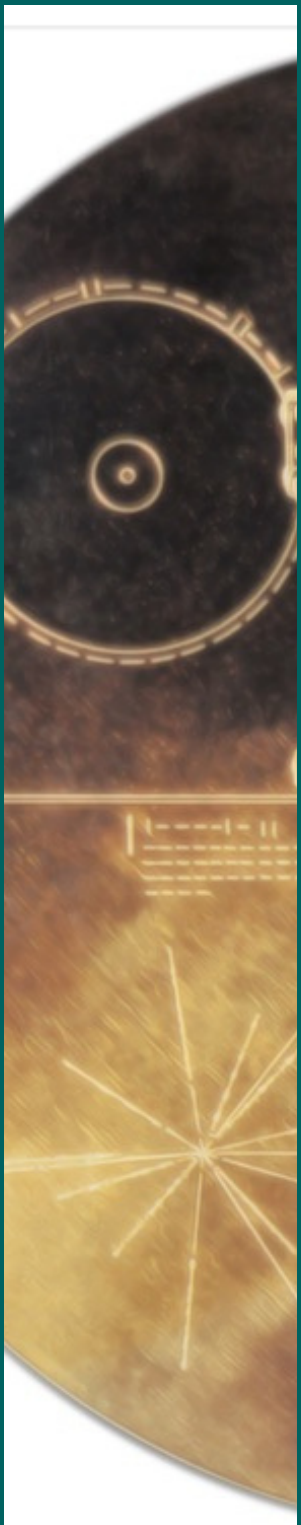

Image credit: NASA

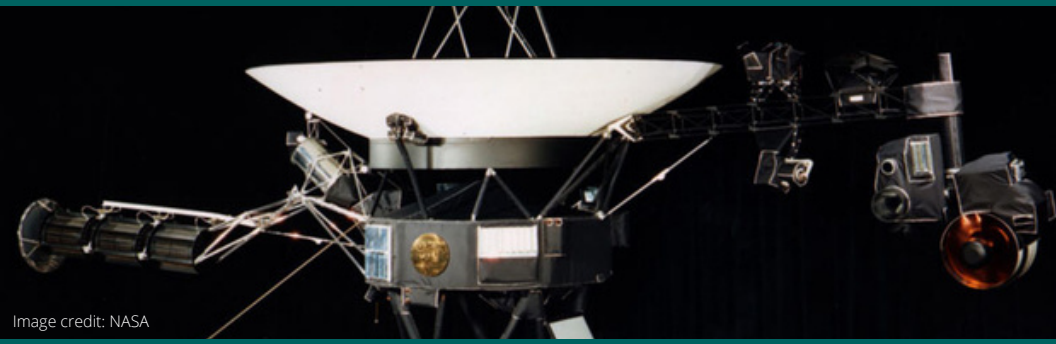

Image credit: NASA

GLOSSARY OF TERMS

gravity assist: the use of a planet or other astronomical object's orbit around the sun (known as relative movement), and its gravity, to alter the path and speed of a spacecraft, often to save fuel and reduce travel time.

NASA: National Aeronautical and Space Administration--an independent agency of the United States Federal Government responsible for the civilian space program, as well as aeronautics and aerospace research. Founded in 1958.

trajectory: the path followed by a projectile flying or an object moving under the action of given forces.

heliopause: the boundary of the heliosphere, which is the region of space influenced by the sun.

striated: layered, or striped. Many things are striated, including geological layers, muscles, lasagna, and in this case the weather patterns on the surface of Jupiter.

miniscule: extremely tiny, barely perceptible.

inert: inactive.

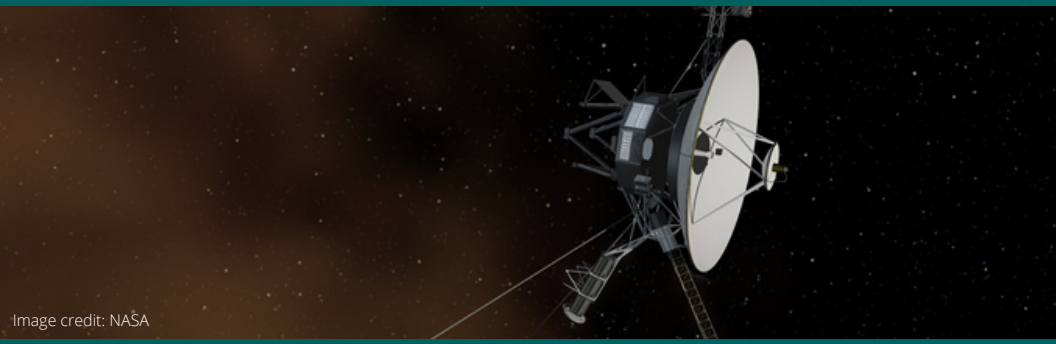

Image credit: NASA

GLOSSARY OF TERMS

orbital resonance: in celestial mechanics, orbital resonance occurs when orbiting bodies (such as a planet's moons) exert regular, periodic gravitational influence on each other. Elliptical, or oval-shaped orbits, mean the distance between a body and its gravitational source varies, causing an effect of pulling the body's liquid to and fro, in a phenomenon called the tide. Tidal heating occurs when this orbital resonance generates heat in the form of friction.

spectroscopy: the study of wavelengths of light that have been emitted, reflected or shone through a solid, liquid or gas. Spectroscopy separates and measures the brightness of the different wavelengths. It can identify chemicals, and determine other information such as temperature.

axis: an imaginary line around which a body rotates.

magnetic field: an electrically charged area that surrounds a planet and protects it from charged particles streaming from the sun, known as solar wind.

amalgamation: a combination of different elements to create a representational depiction.

anthropomorphize: to attribute a human form, characteristics or personality to an object or being that is not human. Sticking googly eyes on something is one example of anthropomorphization.

Image credit: photo by Scott Pakudaitis, graphic design by Jayson Grigsby

RECOMMENDED READING

Voyagers is a condensed telling of an ambitious mission with many, many more stories and discoveries. For more, look the mission up online and check out these books, which were major inspirations of the play's authors.

Bell, Jim: **"The Interstellar Age"**
Sagan, Carl et al: **"Murmurs of Earth"**
Sagan, Carl: **"Pale Blue Dot"**

And a movie: **"The Farthest,"** a documentary about the mission, featuring many scientists who worked on Voyager (and inspired the human characters in the play!).

Matheatre uses live theatre to tell stories that inspire excitement about math and science. For information about other STEM-based live performances and other resources, visit www.matheatre.com.
Matheatre's podcast, History Science Theatre PODCAST, can be found for free on all major podcast platforms.

Voyagers was written by Ricky Coates and Sadie Bowman, with music and lyrics by Sadie Bowman and orchestration by Marc Gutman and Joe McMorrow. *Voyagers* was created in collaboration with Fiske Planetarium, with dome visuals designed by Nickolas Conant and Amanda Wimmer-Flint. Many thanks to John Keller and the entire Fiske team.