# Europa Space Mission

Ishan Odury

As the years pass, technology continues to advance more and more, leading to new, groundbreaking innovations and ideas. However, these innovations come at a cost; they are leading to the fall of this beautiful world. Pollution of the air, water, and soil is rapidly accumulating every year that goes by. This is leading to climate change and the depletion of the ozone layer, which protects society from harmful UV rays (NIEHS, n.d.). In order to combat this issue, society looks toward space colonization, mainly with the interest of exploring and colonizing Europa. In this paper, you will explore Europa in detail and examine the topics related to future space missions to explore Europa.

## Why Europa (Short Explanation):

Europa is one of the largest moons that orbits Jupiter (NASA, n.d.). But why has this moon become the new face of space exploration? Europa has received interest within the past few decades for its potential signs of harboring extraterrestrial life. This was proposed due to Europa's surface being covered in a thick ice shell. Many scientists suspect that under this thick shell lies a vast ocean of liquid water, more than twice the amount of water found on Earth. Data from the Voyager 2 has given images of cracks and grooves that have separated and appeared to produce icy material flowing out of it. This suggests that Europa has been active for a period of time, and underground water is very likely. This hypothesis was proven in the Galileo Europa mission, which was a series of 12 flybys of Europa. The Galileo Europa mission gave evidence that Europa induces its own magnetic field. Scientists suspect that Europa is able to create a magnetic field due to the salt in these oceans. Europa not only has a water source, but also the necessary chemicals needed for building life. These chemicals include carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. Due to the radiation that Jupiter emits, many scientists have concluded that chemical reactions have occurred under these icy surfaces and have allowed for energy to grow. This would allow for life to grow and would allow humans to use this energy in order to colonize Europa in the future. All these reasons have led many space companies, agencies, scientists, engineers, and visionaries to focus their attention on Europa and the exploration of this icy moon (Wikipedia, n.d.). Now that we have learned about Europa and understand why many scientists are eager to explore Europa, it is important that we understand the process of designing a space mission and the work/construction required in order to reach and explore this icy moon.

## Launch Date, Location, and Window:

The first step in designing a space mission is developing and stating a date. The date that I chose is October 10th, 2032. Due to the Europa Clipper being launched to Europa on October 14th. The Europa Clipper was supposed to be sent on October 10, but due to weather issues and, hurricane, the launch was postponed to October 14th (NASA, n.d.). The main factors that contribute to the launch date include gravity assists, fuel, trajectory, and cost. A gravity assist or a gravity assist maneuver is a type of spaceflight flyby that makes use of the relative movement and gravity of a planet or other astronomical object to alter the path and

speed of a spacecraft (Wikipedia, n.d.-a). So the Europa Mission will follow the same gravity assist that the Europa Mission followed. Doing so, the rocket would not need to use as much fuel, due to Mars' gravity to give the rocket a push, increasing its speed. This allowed the engineers of the rocket to equip the rocket with less fuel. This makes the rocket lighter and allows them to add anything else that they need. The trajectory of the rocket would not be direct (shorter time), but rather the trajectory of the rocket would be non-direct(longer time). This was done in order to limit the fuel and allow the rocket to use the gravity assists to propel it to Europa. Cost is the biggest factor when it comes to space exploration and launching rockets. Building a rocket means that everything has to be perfect. In order to be perfect, space companies and organizations such as NASA and SpaceX need to spend lots of time and money on these rockets. But these organizations cannot spend all of their funding on this one mission, as they have many future projects and missions that they are working towards. So, in order to save money, they develop ways to get to the same result while saving money. So the two ways that these companies limited the cost of this mission were by altering the trajectory and using gravity assists (NASA, n.d.). Now that we understand the importance of October 10th, we must figure out what would be the best year to launch the Europa Mission rocket. The best year for the rocket to launch is 2032. Why 2032? Because of the Europa Clipper. The Europa Clipper is a flyby mission, which means that the Clipper will fly around Europa fifty times and take pictures of Europa so that scientists can study them. The Europa Clipper will reach Europa in 2030, so space agencies should launch the Europa Mission rocket soon after that year, 2032. If a rocket is launched in 2032, scientists can utilize the pictures taken by the clipper and create an objective that the Europa Mission rocket can complete. So this is the reason why 2032 is so important for exploration and colonization of space. Although we have a final date, problems may occur. For example, environmental problems, storms, hurricanes, tornadoes, there could be structural problems, coding problems, and more. So if one of these problems occurs, the rocket cannot launch. So in order to combat this problem, the date needs a window in which it can fall. So the window that would allow for a successful launch would be one that is similar to the launch window of the Europa Clipper. This makes the launch window a 28-day time period (Planetary Society, n.d.). However, if this launch window is missed, then the mission will be postponed another year. So in order to have a successful mission, the rocket must be launched within the launch window, without any problems. Now that the date and window have been finalized, but now we need to develop a location for the Europa Mission rocket. The location that would be most optimal for the Europa Mission Rocket would be Florida's Kennedy Space Center. There are many reasons why the Kennedy Space Center is optimal, but these are some of the main ones. Kennedy Space Center is located in Florida, which makes it the closest state to the equator. Spacecrafts that are launched closer to Earth's equator can take advantage of the Earth's rotational speed. So a launch pad that is located near the equator is moving at a speed of 1025 miles per hour relative to the Earth. Another reason why the Kennedy Space Center is the ideal location is due to it is surrounded by water. The Kennedy Space Center, being located around a body of water, allows for safety measures. If the rocket breaks after launch, it will fall into the Atlantic Ocean rather than falling on top of a major city or anywhere else. The final reason is that the Kennedy Space Center has a long history of space launches, which include Apollo, Mercury, and many Space Shuttles. This means that they have the infrastructure, technology, and launch pads necessary for the Europa Mission Rockets to succeed (NASA, n.d.). The Kennedy Space Center launch pad that I would use is the LC-39A.The date, location, and window of the launch have all been finalized. Now that we have

the launch pad, LC-39A, we need a rocket to put on top of that pad. But the question is what type of rocket would best suit this mission. And what are the reasons why this rocket is better than the rest?

**Type of Rocket:**

Before we choose a rocket, we need to understand what factors go into making a good rocket and the details we need to have. The first factor that we have to have is the vehicle requirements. The rocket needs to be able to handle a heavy load. The Europa Clipper weighed about 13,000 pounds at launch. However, the Europa Clipper was not a landed mission; it was a series of flybys. This allows it to be lighter compared to a rocket that is landing on Europa's icy surface. So the rocket that will land on Europa's surface will be a lot heavier than the Europa Clipper. This means that the rocket must be able to handle a heavy load. The next factor we must look at is fueling. The Europa Clipper had 6,000 pounds of fuel propellant before its launch to space. However, the Europa Mission rocket will need a lot more fuel to be able to get to Europa and be able to land successfully. But this extra fuel comes at a cost. If the rocket is equipped with the fuel needed to land the rocket, the rocket will end up being too heavy. This will run the risk of many problems, a major one being a failed launch. So, in order to combat this, the rocket needs to be able to refuel in space. This requires that the rocket has a refueling module and a refueling station in space, post-launch (NASA, n.d.). Next, the rocket needs to have a thermal system. The space mission rocket needs to be able to heat up and cool down the rocket's internal temperature. The rocket will get colder and colder the farther away the rocket gets from the sun. So the thermal systems need to provide heat in order to protect the rockets. But the rocket also needs a strong cooling system. The combustion chamber for the rockets goes through extreme heat and can reach up to 3,500K, the same heat as the surface of the sun. So in order to prevent the engine from melting, a cooling system has to be put into place (Everyday Astronaut, n.d.). The rockets also need to withstand radiation. Radiation can cause many problems, for example, radiation can affect computer systems by interfering with the electronic systems. Radiation can also lead to the degradation of microelectronics, mainly microchips and microcircuit boards. Therefore, the materials that surround the spacecraft need to be resistant to the massive amount of radiation that is emitted from Jupiter (NASA, n.d.). Another major factor that needs to be considered is the communication systems. Communication is very important when it comes to designing the rocket. The rocket needs to be equipped with proper tools to allow astronauts to interact with engineers/companies on Earth. So in case of a problem, astronauts can figure out what the next steps are from ground control. Communication does not only have to be between the astronauts and Earth, but it can also be between the rocket and space agencies. Space agencies need to know if anything goes south with the rocket. So the rocket has to be equipped in order to communicate any problems with the astronauts and the space agencies on Earth. Therefore, the rockets must have a powerful antenna that can still provide a connection even 1.8 billion miles away (NASA, n.d.) After the rocket is launched into space, the next set of problems occurs. Due to Europa's surface being covered in ice, the rocket needs to be equipped with technology to help the rocket land and stay stationary. First, the main module will separate from the command module. Then it will begin a retrograde burn, the rocket orbits a planet in the opposite direction of the planet's rotation and at a much greater distance than usual. Due to Europa's thin atmosphere, the landing module cannot use any parachutes or brakes. Instead, the landing module will use a gravity turn, a

maneuver used in spacecraft when descending from an orbit around a celestial body such as a planet or Europa, in this case (Wikipedia, n.d.-c). Once the gravity turn uses its engineer to control its descent, the landing module will use the landing radar. This radar transmits microwaves to the surface and then measures the waves that the surface reflects toward the spacecraft. Once reaching the surface, the landing module will use thrusters to give a soft landing. Now that the rocket has landed, we need to make it stationary on the icy surface. So I believe that the rocket needs to have a built-in ice drill. This will allow for stability on the icy surface and allow the rocket to be safe from movement. Now that we have all the factors that are necessary for a mission to Europa, what is the best rocket for it? I believe the best rocket to complete this mission is the SpaceX Falcon Heavy. The Falcon Heavy has experience with missions to Europa, as it is the same rocket that sent the Europa Clipper to space. The Falcon Heavy gets its name from the size of the rocket. This will help the mission as it will allow for more technology and supplies to be added onto the rocket: the ice drill. This is why I believe that the best rocket to complete the Europa Mission is the SpaceX Falcon Heavy (Planetary Society, n.d.). The rocket for the mission has been finalized as the SpaceX Falcon Heavy. But now two other components that affect the rocket still need to be determined. These two factors include the fuel type that will power the rocket and the propulsion system. These factors play an important role in ensuring the rocket can complete the mission as efficiently and safely as possible.

**Fuel Type and Propulsion System:**

One of the biggest technical aspects of a rocket mission to Europa is the choice of fuel type and the propulsion system. Due to Europa being nearly 500 million miles from Earth and its location within Jupiter's radiation, it is critical that the spacecraft is engineered with powerful propulsion systems to withstand this radiation. Both these systems must accomplish two main goals. First, these systems must make the rocket escape Earth's gravity, and second, the rocket must survive the long journey throughout space. The choice when choosing fuel and propulsion systems plays an important role in creating the design, limitations, and success in getting to Europa (Science Mission Directorate, n.d.). A challenge that will need to be considered is the type of fuel that will get the rocket to Europa. The mass of the fuel can take up a significant part of the rocket's total weight. As more fuel is added in order to get to Europa, the heavier the rocket will get. This will make it harder for the rocket to get out of Earth's gravity, as well as increase the difficulty of the mission and the cost. To overcome this issue of fuel, the rocket will reach a stop and use the in-space refueling depots. These stations would allow for spacecraft to launch out of Earth's gravity with only a partial fuel load. Then the rocket would dock at the refueling depot and embark on its mission to Europa with a full fuel tank. The benefit of using a partial fuel tank is efficiency and cost. As the spacecraft at launch becomes more cost-effective, while also allows the spacecraft to have flexibility once in space (NASA, n.d.). Although there are many challenges with having a space refueling station, the design, architecture, and ensuring safe fuel transfer into the spacecraft. The benefits are plentiful, as the spacecraft will have a safer mission, and it also allows the spacecraft to change between propulsion during the stop (Science Mission Directorate, n.d.). But what is the actual type of fuel and propulsion that will go into our spacecraft, and will it allow for the success of a mission to Europa? For the past few decades, chemical propulsion systems have been the main system used in space rockets. These chemical propulsion systems are designed to satisfy high-thrust maneuvers (NASA, n.d.).

This chemical propulsion will help the rocket get out of Earth's gravity. For the launch, the Europa mission would rely on a liquid-fuel chemical rocket. This liquid fuel is stored at a low pressure, and then it is vaporized when it is flowed into the low-pressure chamber, allowing for thrust. This thrust is delivered in a high volume over a short period of time, which allows the aircraft to successfully leave Earth's gravity and enter space. Liquid propellant has also become popular for its ability to self-pressurize and its dense storage. Another benefit of liquid fuel is that the fuel is compatible with the SpaceX Falcon Heavy engine (Science Mission Directorate, n.d.). However, once the rocket gets out of this atmosphere, chemical is not the best. This is due to high thrust over a short duration of time. These quick high-thrust engines need tons of fuel, which will drain the fuel supply and cause the rocket to fall short of Europa. So once the aircraft reaches space, the propulsion system changes from force to efficiency, so the electric propulsion systems and nuclear propulsion systems shine. After the rocket is in space, the secondary propulsion system will take over, mainly electric propulsion. The type of electric propulsion that will help this mission succeed is ion propulsion. How ion engines work is that they use electric power, mainly from solar panels, to ionize a gas. Then the resultant ions are accelerated by the electric grids, causing the engines to generate thrust. Compared to the chemical rockets, the thrust produced by electric propulsion is weak. However, these electric ion engines are fuel-efficient and can run for many months and years at a time. An example of how ion propulsion can help a rocket last in space for many years and still have fuel is NASA's Dawn mission. The Dawn mission used ion propulsion to travel between Vesta, an asteroid, and Ceres, a dwarf planet. Due to the use of ion propulsion, the mission was able to last from 2007 to 2018 (NASA, n.d.). So this proves that ion propulsion will allow the rocket to reach long distances after launch without massive fuel consumption. With the gravity assist in place, the rocket can get more speed without using any fuel, making ion propulsion ideal for this Europa Space mission. Ion propulsion is very popular for spacecraft; however, another type is nuclear propulsion. There are two types of nuclear propulsion that we have to take into account: nuclear electric propulsion and nuclear thermal propulsion (NASA, n.d.). Nuclear electric propulsion works by using the heat from the fission reactor to generate electricity, much like nuclear power plants on Earth. That electricity is then used to ionize a gaseous propellant and electromagnetically accelerate it, generating thrust that propels a spacecraft. Nuclear thermal propulsion provides high thrust at twice the propellant efficiency of chemical rockets, freeing up weight and mass for payload and mission-essential supplies aboard the spacecraft. Heat is generated in the fission reactor and directly transferred to a flowing liquid propellant, turning it into a gas, which is then expanded and exhausted through a nozzle to propel a spacecraft. Both of these systems can reduce the travel time to Europa and carry heavy payloads. This is a benefit as this will allow for the attachment of landers, drills, and more technology to study and learn more about Europa. However, although there are many benefits that nuclear propulsion has, there are many concerns. Due to its use of a fission reactor and its still being in development, there are safety risks that need to be addressed. But in the future, nuclear propulsion could be one of the leading options when it comes to deep space exploration missions like Europa. Now that all the options are on the table, what is the best choice in order to ensure the success of a mission to Europa? First, the fuel will be chemical liquid fuel, then the rocket will need to change it to ion gases. The reason that this chemical liquid fuel would be the best is that it allows for a more dense application while limiting the weight. It is also compatible with the rocket, the SpaceX Falcon Heavy. This will be the fluid that gets the rocket into space. The propulsion system that will work with this fuel is chemical propulsion. The chemical

propulsion will react to the chemical fuel, causing a chemical reaction and thrusting the rocket out of Earth's atmosphere and into space. However, once the rocket is in space, the fuel needs to change from liquid chemical to ionic gas (NASA, n.d.-a; Science Mission Directorate, n.d.). The reason for this change is due to the change in propulsion, from it being chemical to electric. Electric ion engines do not create a chemical reaction with the fuel like chemical propulsion. The electric ion propulsion burns that gases to accelerate the rocket, creating thrust and allowing the rocket to get to Europa. So the final choice is liquid chemical fuel in the beginning with the chemical propulsion system. Then, once the rocket is in orbit, the rocket will switch from a chemical propulsion system to an electric ion propulsion system. The fuel that will benefit this system is ion gases. With the use of our space refueling stations, the switch between the two becomes much easier and allows for fewer errors to occur. So, with the help of the outer refueling system, these are the choices of fueling and the propulsion systems that will provide the space mission to Europa with the best chance of success. Now that the fuel and propulsion system is finalized, we need an outer space refueling system that once the rocket gets out of Earth's gravity. So we need to understand what makes a good refueling system and where the optimal place will be.

**Outer Space Refueling:**

Outer space refueling is an idea that hasn't been fully developed yet. There are no refueling stations in space that the rocket could stop at and refuel before. The reason that this type of refueling station has not been created is due to all the difficulties and challenges. The first challenge and the biggest challenge is the design of the refueling station. Due to the station not being built before, there are no templates that the station can follow. This means that there will be tons of trial and error until a suitable station is built. The station will also need to have a docking port for the rocket, a fuel port, and many more. So the design of the station needs to be perfect to incorporate these details. The next problem that will occur is putting it into space. The location of the station is very important. The location needs to be in a location where the spacecraft can easily reach once in space and have limited gravity in order to get the rocket on its correct trajectory. Those are the challenges when it comes to designing the space refueling station, but there are also challenges when it comes to the space mission. The first issue is the trajectory. Due to the rocket needing to be refueled, the rocket will need to go to the refueling station. This will cause the rocket to swerve off its path and lead to a new trajectory being created. So this will lead to new launch dates, trajectory, and time frame. The second challenge that will occur is launching the rocket. Due to the refueling station, the rocket will need to come to a complete stop to refuel and follow its path. However, due to this stop the rocket will need to be launched again. This will require the space refueling station to have launch pads for relaunch. The final challenge that will occur in the space refueling station is fueling. There is no sustainable way for the station to obtain fuel, such as the ion gases needed for electric propulsion. In order to have a supply, there will need to be constant missions to the station for refueling. The only way that the station could have a constant source of fuel is chemical fuel. However, in order to have this supply, the station will need to be near a planet. It needs to be near a planet to extract the water that it contains. Once it extracts this water, the station can extract and break the water into Oxygen and Hydrogen, which are the building blocks of chemical reactions. This lists all the challenges that will arise when designing and building the refueling station and when refueling during the space mission to Europa. However, although

many challenges will occur when designing a space refueling station, the benefits are immense. First, a space refueling station would allow for extended exploration missions into space. Due to there being a refueling station, there will never be a limit on how long a mission can last in space, as long as there is a source of fuel in the station. Due to the refueling station being near a planetary body, the station will extract materials to get elements for chemical fuel. These elements that the station extracts will benefit space exploration. A space refueling station will also help with launches. This is because of the low gravity in space and the less force needed to get out and into space. This will allow for more cost efficiency when designing and building a rocket, as there is no need to pack tons of fuel, as it can refuel in space. This refueling station will also lower costs, and there is no need to create and send new rockets into space for exploration. The old rockets can always refuel and keep sending data while on their exploration, but if there is no longer a need for that mission, they can start a new one. Due to the launch pads, old rockets can go on new missions, which will allow for less space debris and pollution. Now, how would a space refueling station apply to a space exploration mission to Europa? The first way that the Europa rocket will use the space refueling station is to refuel the chemical fuel after launch. Due to Earth's gravity, it burns a lot of fuel to enter space, so I would have the rocket refuel its liquid chemical fuel. This will allow the rocket to launch one more time. Due to this extra chemical fuel, the rocket will be able to launch in case it needs to come back to Earth. The next reason that a space refueling station will be used for this mission is that it will reduce the cost.

The cost will decrease as there is not as much fuel needed for the rocket to complete the mission. This will allow the money to be spent on external technology, like the ice drill and more. Many challenges will occur if a space refueling station is introduced, but the benefits will help advance space exploration and help the mission to Europa succeed. We have gone over everything that goes into setting up a mission to Europa. From the date, location, window, rocket, fuel, propulsion, and refueling. But all these topics get the rocket to Europa, but none of them talk about what the rocket will accomplish after it gets to Europa. So once the rocket lands on Europa, what are the scientific goals and objectives?

**Scientific Goals:**

Humanity has many questions about new potential life sources. This drives the scientific goals that humans hope to obtain once they accomplish a mission to Europa. The main goal is to advance space exploration. Jupiter's moon conceals an ocean under its icy surface. This hidden ocean is so vast that it could contain more water than Earth, which is why it has become one of the key locations of space exploration. In the future, Europa could become the new source of habitability for humans (Pappalardo et al., 2024). The first thing that will need to be addressed is understanding Europa's icy shell and ocean. Realizing the thickness and structure of Europa's surface is important in understanding how the ocean underneath works with the surface. In order to achieve this goal, the mission must include an ice breaker radar, REASON. REASON is a radar that was present on the Europa Clipper, and it is capable of probing deep beneath the surface and detecting layers and bodies of water (NASA, 2025a; Schroeder, 2022). The rocket will also need a Magnetometer and a Plasma Instrument for Magnetic Sounding. These two instruments will allow scientists to measure Europa's magnetic field and understand the plasma environment. Once they accumulate the data, the scientists will be able to hypothesize the depth of the ocean and salinity (NASA, 2025a; Camunda, 2024). The ocean is

not the only place that needs to be sufficient for habitability; the mission must get data on the surface of Europa in order to understand if Europa is truly a viable option for habitability. Once the rocket has landed on the surface and the data has been obtained from the surface, scientists must be able to identify the compounds present. Europa's surface hasn't been explored before, so its surface may harbor salts, compounds, chemicals, and more. So the mission will need to include a mapping imaging spectrometer for Europa. This piece of technology will use infrared spectroscopy to detect all the compounds on the surface, such as salts, organisms, and chemicals, on the surface of Europa (NASA, 2025b). However, this is not the only spectrometer that will be needed for this mission. The mission will also require a MASPEX mass spectrometer to get samples from Europa's atmosphere. Once the MASPEX mass spectrometer obtains the samples, the Surface Dust Analyzer will analyze the composition of the particles in order to develop an idea of what is in Europa's icy ocean, which will allow for a better understanding of Europa (Waite et al., 2024; NASA, 2025a). To understand the active geology in Europa, high-resolution imagery and mapping are required. In order to get this imagery and mapping, high-tech resources are needed for this mission. First, the use of the EuropaImaging System will allow a stereoscopic mapping with the use of different types of cameras. This will allow for the detection of different surface structures and features (JHUAPL, 2025; Turtle et al., 2024). A thermal imager will detect faint heat sources, which will show parts of Europa that have active ongoing activity (NASA, 2025a; Engineering.com, 2015). Now that we have applied all the tools necessary for the mission to succeed and understand Europa's surface and atmosphere, we can shift to the ocean. To get to the ocean, the mission will require a way to drill down through the ice and get to the vast ocean underneath Europa's surface. This is where one of the coolest new technologies will come into play and allow for a path to the ocean underneath the thick icy surface. This technology is the cryobot. The cryobot is a melting probe that was created in order to solve Europa's thick surface. The cryobot penetrates through the surface using thermal power that is supplied by nuclear sources to achieve its mission (NASA, 2023). After the cryobot reaches the subsurface ocean, the cryobot will deploy a hydrobot. This hydrobot is an autonomous vehicle that can explore underwater for any properties or organisms hidden in Europa's ocean (Wired, 2025). However, there are some problems with the technology that may occur. The main problem that will occur is the radiation affecting the electrical components of the rocket. So in order to complete the ambitious mission, the rocket must have a shield. This shield must protect the rocket from radiation, the imaging cameras for mapping and layout, and the power systems (AP News, 2024). If possible, this will allow the mission to report detailed data and have a successful mission. This mission will help demonstrate to the world the engineering capability to explore one of the most challenging places in the entire solar system. With the use of all the technological instruments: the spectrometers, the ice-penetrating radar, the cryobot, the hydrobot, and more, society will be able to advance its scientific knowledge. This is all for the purpose of completing the mission of finding a place that will complete the conditions needed for habitability and allow for the growth of Europa's lifeforms and maybe humans. So we must push to develop our technology so that we can start this mission as soon as possible. However, this is where the next question comes into play. Should this mission be done by humans or robots? How do the benefits that humans bring compare to the benefits that robots bring? Which one will allow this mission to succeed?

**Human Life Support(Human or Robotic):**

There are many factors that go it when considering when discussing how to explore Jupiter's moon, Europa. However, as each of the factors gets answered, one question always arises: should the mission be carried out by humans or robots? Each side offers its distinct advantages, and the choice that is made will either make or break the mission. So, humans or robots? First, let's see the human approach. Human missions bring adaptability and ingenuity that robots do not yet possess. This allows astronauts to make real-time decisions, adapt to unexpected situations, and undertake repairs and improvisations. For example, if the cryobot designed to penetrate through Europa's icy crust malfunctions, humans could repair it on the spot. However, if it were a robotic mission, there would be unavoidable delays that could cause many problems or failure (NASA, 2015). However, many problems occur when sending humans on a mission of this calibre. The main problem that will be faced is human health. A trip to Europa takes 6 years, so the human body must survive many challenges while in space. For instance, a human mission would require oxygen, food, water, and medical care. That is just to live, but there are also challenges from space. No gravity causes many problems to the human body, and the radiation that will be emitted from Jupiter would require advancements in space suits. All these factors would increase the complexity and cost of the mission (Horneck, 2008). Robotic missions, in contrast, offer a more practical and cost-effective alternative compared to a human mission. Robots do not require life support and are not susceptible to the bone and muscle deterioration that humans face in zero gravity. These robots can be built to survive the harsh radiation that is emitted by Jupiter (UCF Pegasus, 2025). Also, robots can operate continuously and tolerate harsh conditions (Li & Liu, 2019). All of these factors prove that robots are better suited for this mission, as there are no health concerns to take into account compared to humans. On top of that, cost and risk favor the robots for the exploration of Jupiter's moon Europa. According to a cost-benefit analysis, robotic missions can deliver significant scientific value at a fraction of human mission costs—Mars probes like the Mars Pathfinder delivered immense scientific returns for only hundreds of millions of dollars, compared to the multibillion-dollar scale of human missions (University of Michigan, 2025). This calls for more of the cost to go into creating and designing the technology that will achieve the data. With the use of robots, the introduction of advanced mission design is possible. For example, an ice pick could penetrate kilometers of ice using its nuclear power, then deploy a hydrobot into the ocean to explore for life. However, if humans were to try this task, it would seem infeasible and lead to less progress for the mission (Supercluster, 2024; Space.com, 2015). This is how robots allow for better results when it comes to the Europa exploration mission, when compared to a human mission. Moreover, both public opinion and expert analysis increasingly recognize that robotic explorers now outperform human missions in several key areas: they are more affordable, safer, and often deliver greater scientific returns (Wired, 2022). All these prove that robots are the better candidate for this type of mission. Although human exploration creates excitement and public interest, the financial, safety constraints make human missions impractical to Europa. Robotic exploration offers a safer and more achievable path. This is why robots will be the ones that will achieve the scientific goal of Europa exploration in the future. Now that we have figured out how to get to Europa with the use of different fuels, propulsion, and locations, we have arrived at Europa. With the help of advanced technologies and robots, we have gotten the data we wanted. But the last question is, will robots and rockets return, or will they stay forever?

**Return or One Way:**

The idea of whether a Europa mission should return to Earth with samples or remain in Europa has profound implications for scientific potential, complexity, and resources. So we must choose the best option for the long run. Many benefits will come with the return of the rocket and the samples. Returning the samples from Europa to Earth would allow for a more precise and detailed analysis compared to the data from the onboard rocket technology. This is because the labs that are available on Earth are equipped with advanced tools, such as mass spectrometers, microscopes, and storage systems, which exceed the spacecraft instruments (National Academies, 2018). If the rocket were to return to Earth with samples of ice and dust, scientists could understand and verify the composition and compounds of the materials, like salts and organisms. These samples would allow for studies and tests that could revolutionize technology, making a return mission very valuable for science (Planetary Science Board, 2018). If the rocket were to return and Europa were found to contain accessible water or rare minerals, future missions to return could be created in order to achieve greater potential and create a greater economic chance of future colonization/extraction of Europa's icy surface. Such a mission would lay the groundwork for a connection between Earth and Europa, making some of Earth's problems have a solution. For example, these materials could help with life, fuel, and industries (Planetary Society, 2025). Although many advantages would come with a return mission to Earth, there are many problems that will occur before any discussion of return is possible. First, to reach Earth, it requires high propulsion, reentry capsules, and precision navigation (ADS, 2002). People may say that it is the same as going to Europa, but the difference is night and day. First, there are no launch pads, refueling stations, or agencies in space. So, in order for a return mission to be feasible, there will need to be a mission to create launch pads, so that the rocket can launch back off Europa's surface and enter orbit. Now, fuel will be difficult as there are no refueling stations, so in order to combat this issue, the rocket will need to take the minerals from Europa and convert them so that they can be used for chemical propulsion. However, this is not the hardest issue. There is a lot of planning that goes into choosing the date, angle, and time for the launch to enter orbit and use the gravity assists to follow the correct path. However, there is nothing in Europa that could provide an accurate simulation that the rocket could follow to obtain gravity assists and get back to Earth. These are all the launch/travel issues that a return mission will cause, but there are also environmental issues that could occur. This mission must also comply with the planetary protection protocols in order to prevent any contamination from the rocket systems (Fries et al., 2015; National Academies, 2018). If we can combat all of these issues, we face the problem of storage. These minerals are from another planet; they face certain conditions that must be kept. This means that very expensive labs and storage facilities must be kept in order to protect these minerals and samples from being destroyed. These are some of the problems that will be faced if we decide to create a return mission. But the biggest issue that will occur is cost. Let's compare the Europa return mission to the Mars sample return mission and see how much money will be needed. The joint NASA-ESA Mars Sample Return, originally projected at over $7 billion, ballooned to $11 billion and faces launch delays pushing return to 2040 (Ars Technica, 2024). Mars is a much easier return mission compared to Europa's greater distance and harder return mission. So if it costs 11 billion to just return the rocket from Mars, how much will need to be spent on the launches, fuel, and storage for a Europa return mission to Earth? Although I would love to see a return mission and observe the minerals from space, it is not a viable option. Due to the return mission causing many problems, the better option would be to stay on Jupiter's moon, Europa. So the rocket must stay on Europa's surface and transmit data from there. The Europa Clipper

will perform 50 flybys and gather high-quality data, images, and geology. With the added data that scientists receive once the rocket lands and finishes its mission, creating future missions based on the results and findings would be easier. This approach would maximize the data under the cost limits. Also, by choosing to remain at Europa to transmit data instead of a return mission, the mission can make even more advancements in habitability. Due to the Europa Clipper, we will get flybys to many regions of Europa and can find a place that can support future exploration by robots. This will allow us to deepen our understanding of Europa's habitability and will lay the groundwork for human space expansion. Even though the rocket is staying still, it does not mean that progress will just stop. We will be building our knowledge step by step, so when humanity needs to establish a permanent presence on Europa's surface, we will be ready. That mission will be safer, more efficient, and allow for the success of the expansion of the human race. So the choice to stay is not a limitation, but rather the path we must follow to grow. One day, we will need to leave Earth and move to another planet. While staying on the surface, we can continue to gather data and prepare a plan to succeed in colonizing Europa. This is why staying on Europa's surface would be the better option compared to trying to create a return mission with added complications for a few samples of Europa. With all of the mission's design, objectives, and decision outlines, we do not look towards the "what if," but the "when" of exploring Europa's icy surface and hidden ocean. Understanding all the goals, challenges, and discoveries will allow us to reflect on the true significance of this mission for science and the future of space exploration.

**Conclusion:**

The mission to Europa represents one of humanity's boldest steps into the outer solar system, combining advanced technology, careful planning, and the pursuit of knowledge. The discoveries made, from the icy shell to probing the subsurface ocean, will deepen our understanding of habitability and the potential for extraterrestrial life. Looking past its immediate contributions to science, this mission to Europa will set the cornerstone of future exploration. With the new technologies developed, tested, and put into place, we will see new missions to other distant planets and worlds. From the single mission to Europa, we will go beyond the unknown. If we find life, this mission could fill the pages of history and could stand as the milestone that changed space exploration. Although it was one single mission, it was the biggest step forward that humanity took in uncovering the secret of our solar system. As we keep reaching for the stars, we will advance. Even though I might not live to see the day, I can't wait for humanity to take the step to leave Earth and start a new chapter for the world.

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