SARS

Space Analysis and Reconnaissance Systems

Mission Concept Review

Europa Extraterrestrial Life Survey

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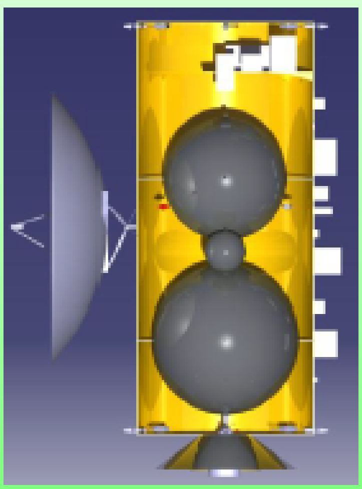

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Summary: The Jovian moon, Europa, is an object of great interest to many science groups, partly because of its possibly habitable environment. The moon is believed to consist of a rocky core with a layer of water above it. The surface is a solid shell of ice surrounding the entire moon. Below this icy shell, many believe that there exists a liquid ocean that may be habitable. This fact makes a mission to this moon very valuable due to its relatively close distance to Earth. SARS aims to study this body by methods described in the following sections.

Required Proposal Summary Information:

- There is no sensitive, confidential, secret, or top secret information present in this report.
- This project does involve non- U.S.collaborators.
- UAHuntsville has partnered with the University of ESTACA in Paris, France.
- All of the information presented in the report is original to the group members of Team SARS and no assistance has been given by outside NASA employees.
- With the worst case scenario, this mission will not have any long lasting impact on the environment.
- With the worst case scenario, this mission will not have any long lasting impact on the historic, archeological, or traditional cultural sites or historic objects.
- This report has no information that would be subject to U.S. export control laws and regulations, including Export Administration Regulations (EAR) and International Traffic in Arms Regulations (ITAR).
- This mission does use radioactive materials which will be contained in (2) ASRGs.
- This proposal will not utilize either the NEXT or AMBR propulsion systems.
- Student Collaboration with high school students is included in this mission.
- This mission does not have any Science Enhancement Options (SEOs).
- The proposer is the University of Alabama in Hunstville.
- This proposal is a reply to the Discovery AO.
- The Atlas V 551 launch vehicle is proposed and will be used for Team SARS mission to Europa.
- The Total Mission Budget is $800M in FY2010 dollars. (See H. Cost and Cost Estimating Methodology)

SPACE ANALYSIS AND RECONNAISSANCE SYSTEM

EUROPA EXTRATERRESTRIAL LIFE SURVEY

INTEGRATED PRODUCT TEAM 2011

MISSION

DEVELOP AN ORBITER AND LANDER TO BE SENT TO THE JOVIAN MOON OF EUROPA.

MAIN SCIENCE OBJECTIVES:

- MAP THE SURFACE OF EUROPA
- SAMPLE ICE ON THE SURFACE AND SEARCH FOR SIGNS OF PAST OR PRESENT LIFE
- INVESTIGATE GEOLOGIC ACTIVITY AND ITS DRIVING PROCESSES

Mission Characteristics	
Launch on Atlas V 551 Launch	Map surface and perform scientific analysis from the orbiter
Utilize a VEEGA Maneuver to reach Europa	Verify the presence of a subsurface ocean below Europa's ice shell
Follow the trajectory designed for the Jupiter Europa Orbiter	Deploy lander to the surface of Europa
Settle into a 100 km polar circular orbit of Europa	Gather ice samples and analyze the composition

Science Mission
Objectives and Goals developed by Principle Investigator at the College of Charleston
Suite of 13 Science Instruments
Focus on finding signs of life on Europa

Partnerships	
The University of Alabama in Huntsville	Mission Design Designed Lander
College of Charleston	Scientific Investigation
ESTACA	Designed Spacecraft
California State University Los Angeles	Designed Ice Coring Drill

ORBITER

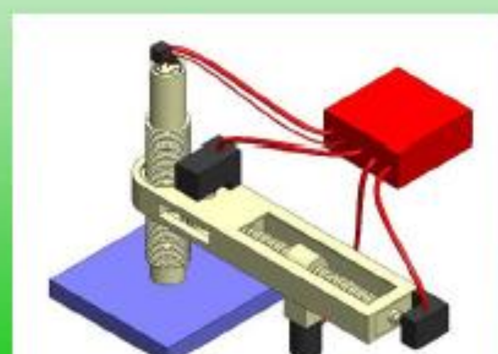
DESIGNED BY STUDENTS AT ESTACA UNIVERSITY IN PARIS, FRANCE
WILL CARRY THE LANDER TO EUROPA
PERFORMS SURFACE MAPPING AND INVESTIGATES POSSIBILITY OF A SUBSURFACE OCEAN

LANDER

DESIGNED BY THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
GATHERS SAMPLES OF EUROPA'S SURFACE TO DETERMINE COMPOSITION
PERFORMS SCIENTIFIC ANALYSIS TO SEARCH FOR SIGNS OF PAST OR PRESENT LIFE

ICE CORING DRILL

DESIGNED BY STUDENTS AT CALIFORNIA STATE UNIVERSITY LOS ANGELES
EXTRACTS SHALLOW ICE SAMPLES FROM BELOW THE SURFACE OF EUROPA
UTILIZES A HOLLOW THREE BLADED CUTTING HEAD TO EXTRACT ICE SAMPLES



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D.1. Scientific Background, Goals, and Objectives

D.1.1. Current Understandings, knowledge, and questions about the Europa-Jupiter system

D.1.1.1Introduction

Today's new frontier has quickly become the emergence of habitable worlds around stars and gaseous planets. According to the extrasolar planet encyclopedia, approximately 539 extrasolar planets have been identified orbiting their respective stars as of Feb 2, 2011[exoplanet.eu]. With such a large number of extrasolar planets found to date, many scientists hypothesize that these exoplanets are more common than previously thought. The greater the number of planets discovered, the greater the chances are to find one that is habitable, even one that may contain life. But investigating planets for habitability and life from such a distance can prove to be nearly impossible. Recent missions to the outer parts of our solar system have brought back surprising results about that planets and moons in our own neighborhood. The Cassini–Huygens mission that arrived at Titan, a moon of Saturn, in 2004 showed an extensive past of fluvial activity, as well as the presence of a thick atmosphere, clouds, and possibly some kind of hydrocarbon cycle, similar to the water cycle on Earth [Mitiri et al. 2006]. Other moons, such as Io, Calisto, and Europa, have shown strong evidence for complex dynamics that could promote the habitability and existence of life on these moons. Many Jovian planets are hypothesized to have large icy moons that formed from the aggregation of materials in the circumplanetary disks that surrounded the gas giants shortly after their formation. And with so many gaseous planets being found around sun-like stars, the possibility exists for an abundance of places to search for life. Perhaps our first step into discovering the new frontier of habitability and life is to investigate our own gaseous bodies and the dynamic moons that are associated with them.

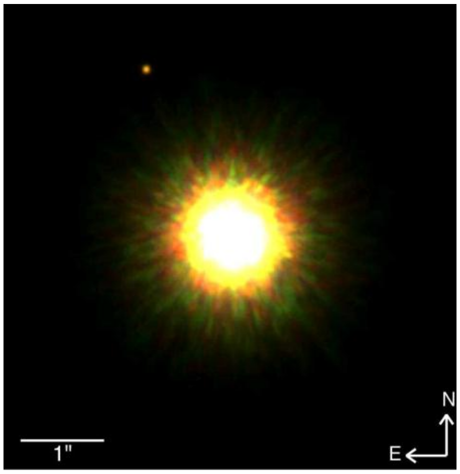


Figure 1: First ever visible light photograph taken of an alien planet, 2008. (Source: Chow, David. (Designer).

According to NASA's 2010 Jupiter-Europa Orbiter report, Europa is being placed in the spotlight as one of the foremost places to look for life in our solar system [Clark et al. 2009]. Our current understanding of Europa includes an abundance of ice and liquid water, possible tectonics, and variable gravitational and magnetic fields. In addition to all of these elements, the large amount of liquid water hypothesized to be below the surface of Europa, has led to some speculation on habitability and the existence of life in the oceans.

Since the 1970s, only limited views of the icy moon have been available for study and analysis. Pioneer 10 and 11 were the first to ever visit the Galilean moons, but only returned fuzzy, dim images leaving their true discovery for further missions. In 1979, two Voyager probes made passes around Europa, sending back images of the icy, rifted surface of the moon. Through the 80s and early 90s many scientists began to paint ideas of an icy world filled with an expansive sub-surface ocean and complex life that inhabit its waters. In 1995 the Galileo mission pushed these ideas one step further, providing detailed images of some of the complex rifting features that dot the surface of the moon. The abundance of lines, breaks, and uneven terrains does appear very indicative of some kind of flow happening below the surface, but still so little is known about the moon's dynamics and anything about its habitability or living inhabitants.

Europa is effectively a small, rocky body with an outer water-rich shell extending upwards of one hundred kilometers, composed of a thin icy cryosphere above an expansive saltwater ocean. This global subsurface ocean is thought to have a volume more than twice that of all of Earth's oceans with temperatures, pressures, and compositions expected to be within the current range of known life on Earth [Clark et al. 2009]. Some of the environments of Europa's relatively young surface, dating to about 60 millions years [Schenk et al. 2004, Zahnle et al. 2008], implies that some geologic processes must still be active today. Europa is much more unique and Earth-like when compared to the other moons of Jupiter and Saturn, because its expansive ocean is in direct contact with the moon's mantle. On Ganymede, Callisto, and Titan, the possible oceans that exists are likely found in the middle between two layers of ice, ordinary ice above the ocean and a high-density ice below the ocean.

D.1.1.2 Habitability

Europa's ocean may contain all of the key factors that create a habitable environment by our current standards – expansive liquid water, a number of essential elements deposited by the solar system and cosmic processes, and a source of energy through tidal processes and radiolytic chemistry. In addition, geologic activity may be able to cycle materials between the surface and the sub-ice environment. All of these ingredients are essential to our current definition of life. If life did indeed exist at one point on Europa, or if it exists today, it may have resulted from one of two origins: either life managed to find its way to the moon through the intense environment of open space, or life was indigenous to the planet and is constrained within its own laws of biology. In either scenario, the most relevant question is whether the conditions below the surface of Europa and the geologic processes that may be ongoing could have been enough to create organic compounds, provide energy, and nurture the beginnings of life. The inferences from Europa's relatively young surface suggest that tidal deformation may be causing heating and powering geologic activity on Europa, perhaps even deep-sea volcanism. The cycling of water through the ocean, icy-crust, and mantle of the moon could be enough to maintain an abundance of reduced and oxidized species within the ocean that are necessary for life.

The breakdown of chemicals on the surface is responsible for a number of other compounds known to be created as by-products: O_2, H_2O_2, CO_2 ,SO_2, SO_4 among other more complex compounds. These important chemicals may be able to reach the interior ocean through subduction, but the mechanism for such dynamics is currently poorly understood. However, if the tidal energies produced by nearby moons and Jupiter is retained within the mantle, a significant amount of subduction and cycling of surface materials could be occurring [Clark et al. 2009].

D.1.1.3 Gravitational and Magnetic Fields

Europa is under the power of a strong gravitational field produced by Jupiter that tugs and deforms the moon (Figure 2). The result of such stress is often a bending and breaking of materials, flows of energy, heating, and mixing of moon materials. These gravitational tides contribute to the amount of thermal energy held by the ice shell and the rocky mantle [Ojakangas and Stevenson 1989] and are likely responsible for some of the surface features caused by near-surface stresses and currents in the hydrosphere [Greeley et al. 2004]. One of the most striking observations of the gravitational fields produced by the moon's orbit around Jupiter is the amplitude of the semi-diurnal tide. If an ocean were not present on Europa, the tidal deformation caused by Jupiter should be enough to provide approximately one meter of change [Moore and Schubert 2000] versus the thirty meter of change that is currently observed [Moore and Schubert 2000]. Therefore a large fluid layer must be present below the icy surface, decoupling surface materials and causing the great number of deformational structures.

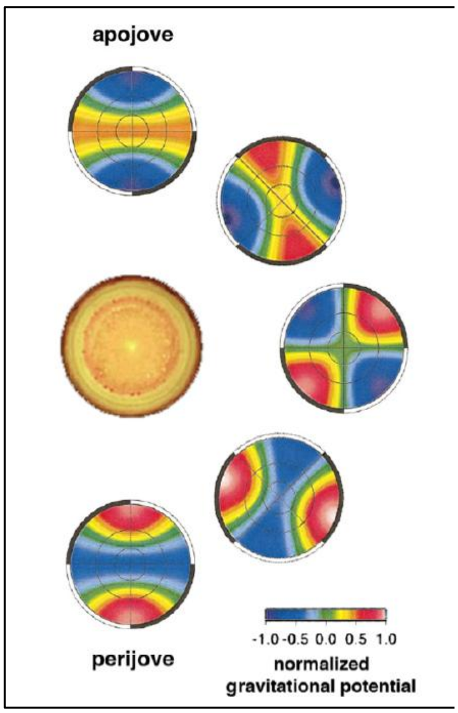


Figure 2: Normalized gravitational Potential exhibited on Europa as it orbits Jupiter [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

Observations of the gravitational field of a body can provide important information about the interior structure and mass distributions. Areas with greater amounts of mass (high density) would exhibit a higher gravitational acceleration. Areas with a lower gravitational acceleration can be interpreted as areas with a smaller amount of mass (low density). On Europa, variations in the moon's gravity field may be indicative of ice thickness, ocean floor topography, or mass anomalies in the mantle. Areas with thinner ice and greater amounts of water should exhibit a greater gravitational acceleration, while areas with thicker ice would exhibit a lesser gravitational acceleration. Although if the ice is isotatically compensated, the variations in the gravity field should be minor. Variations in the gravity field that do not correspond with the ice topography are likely associated with changes in deep interior mass distributions.

Europa is also experiencing a varying magnetic field created by Jupiter. Europa does not create its own magnetic field, suggesting its core is either frozen or fluid but not convecting. However, Europa is able to conduct the rotating magnetic field created by Jupiter through electromagnetic conduction [Khurana et al.1998, Kivelson et al. 2000]. It is this flux in the magnetic field that generates induction currents in the interior and is also indicative of the composition. Since Europa is known to have these induction currents, it is thought the ocean may contain dissolved salts, likely sodium and/or potassium that are allowing for the movement of charges [Clark et al. 2009]. Magnetic sounding at multiple frequencies could be used to place constraints on ice, ocean, mantle, and core thickness and conductivity of surface and sub-surface materials.

D.1.1.4 Ice Shell, Sub-surface Ocean, and Mantle

Current understandings of Europa constrain its structure to a thick icy shell, an expansive sub-surface ocean, and a rocky mantle and core (Figure 3). Understanding the structure and dynamics of the ice shell is key to interpreting the distribution of the sub-surface ocean as well as any ice-ocean exchanges that may be occurring. In terms of habitability, the exchange of materials from the surface to the ocean is essential to the development of life, providing a wide range of highly reactive compounds created through radiolysis or photolysis to the expansive ocean waters. The average thickness of the ice-shell is currently unknown, but best estimates range from a few kilometers to tens of kilometers [Billings and Kattenhorn, 2005]. Thinning and thickening of the ice layer may also be occurring due to thermal processing in the interior. Regardless of processes that are going on in the deep interior, the upper few kilometers of ice are cold and brittle, receiving little to no influence from thermal processes in the interior. The thickness of this stagnant 'lid' is likely a function of the amount of heat production in the interior. If convecting did occur on the surface at some point in the geologic history, impurities may have become permanently trapped in the hard, brittle ice. Beneath this stationary layer is hypothesized to be a warm convecting ice layer, likely free of most impurities as they would drop out during melting [Pappalardo and Barr 2004]. This convection may be responsible for a number of the surface features seen on Europa, such as lenticulae and chaotic structures, ranging from one to hundreds of kilometers across. Figure 4 shows examples of some of the surface features and how they are created from these internal processes. Diapirs, areas of circulating warm ice and water, push towards the surface and cause a melting of the ices above. If warmer pure ice pushes up towards colder impure ice, the impurities may cause the overall melting point to be reduced and the warmer purer ice would effectively melt the dirty ice as the diapir flattens out. In addition, friction and tectonics may be enough to cause local melting of the ice-sheet [Gaidos and Nimmo 2000].

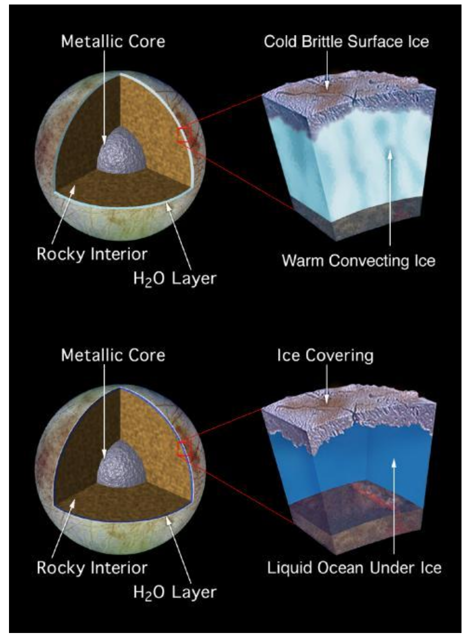


Figure 3: Illustrated depiction of interior structure models for Europa [Source: *Model of Europa's subsurface structure*. (1999). [Web]]

The thickening and thinning of Europa's ice shell is likely due to the evolution and changes in internal heating evolved from the orbit around Jupiter [Hussmann and Spohn 2004]. The lower portion of the ice shell is likely characterized by a slow accretion or ablation of ice [Greenberg et al. 1999]. The differences in the compositions, densities, and temperatures of the ice should be enough to lead to significant structural horizons that should be detectable by sub-surface mapping. In addition, the changes in the formation of the ices, rapidly freezing versus slow accretion should signify the different horizons found through the ice layer.

The unique tectonic dynamics that exist on Europa should produce a number of surface and sub-surface structures. Some of these structures could range from sub-horizontal extensional fractures to near-vertical strike-slip features. Some faults may exhibit some kind of pre-existing structure that may influence the ending structure of the feature. With so many questions about

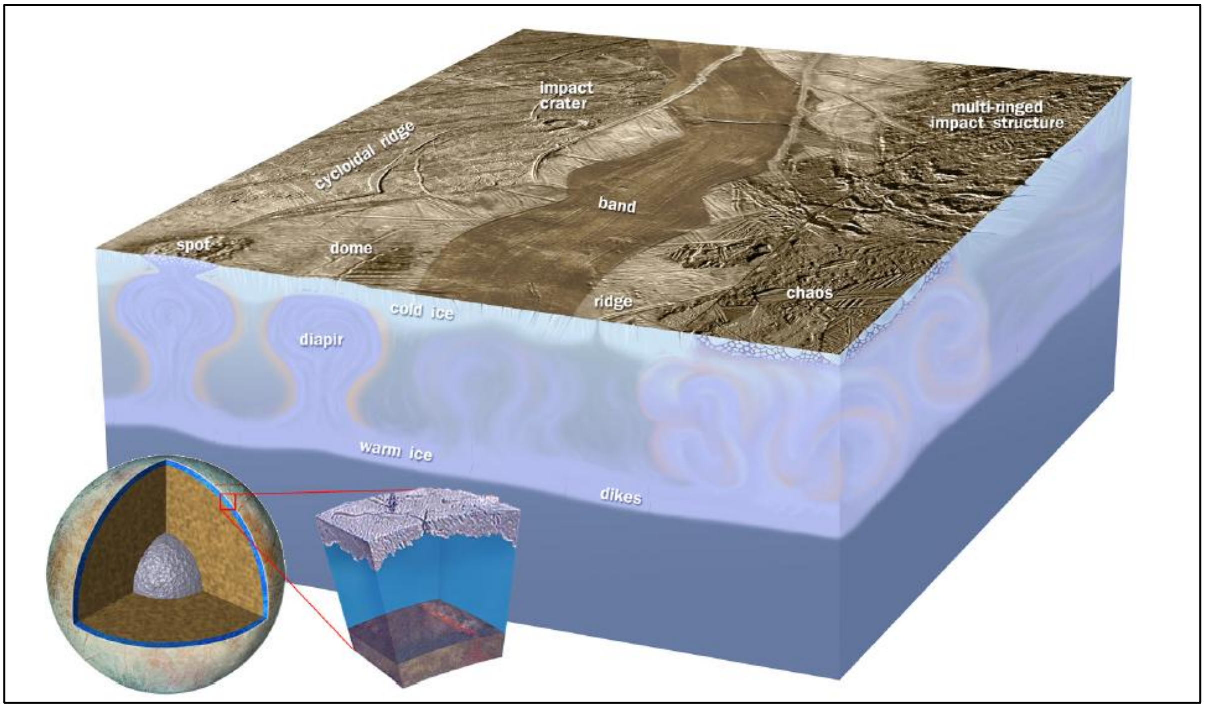


Figure 6: a variety of surface features seen on Europa. (a) Impact crater; (b) pull-apart bands; (c)Lenticulae; (d) pull apart band; (e) chaos terrain (f) dark plains material; (g) cliff; (h)chaos terrain; (i)chaos terrain; (j)ridge complexes; (k)impact features; (l) ridge [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

these tectonic features, constraints can be placed on their formation by studying their depth extent and association with thermal anomalies. In addition, the correlation of subsurface features with surface structures will answer further questions about the origins of these tectonic features. For example, extensional structures observed on Europa, may consists of newly supplied materials brought to the surface from below, if these features are analogous to spreading centers on Earth[Pappalardo and Sullivan 1996]. The origin of this new material could then be traced back to a general origin through sounding the materials of the sub-surface. Impact structures have also shown secondary tectonic structures that may be creating sub-surface features. Near the impact site, radial and circumferential faulting features are present, creating sub-surface structures that may be visible through sounding. One of the mysteries of Europa is the absence of an abundance of impact craters. Probing the sub-surface may reveal ancient impact structures that have had their surface marks erased, placing constraints on the resurfacing processes on Europa.

D.1.1.5 Chemistry and Composition

Understanding and characterizing Europa’s composition is needed to constrain the geologic history, fundamental processes, and habitability of Europa. Composition data from telescopes and the Voyager and Galileo missions have identified Europa as a world composed of mainly water ice, present in crystalline and amorphous forms [Pilcher et al. 1972, Clark and McCord 1980, Hansen and McCord 2003]. Dark, non-icy patches are among the most interesting surface features on Europa. Constraining their composition and origin could provide key clues to understanding the formation of these features and resurfacing processes. This link would provide important information about the nature of the interior, time scales through which materials are cycled, and help identify the habitability of the ocean. Variations in surface materials may also be indicative of their age, allowing for areas of active tectonics to be identified.

Based on the measured spectra from the surface, many non-ice materials are known to exists on Europa: carbon dioxide, sulfur dioxide, hydrogen peroxide, and molecular oxygen [Lane et al. 1981, Noll et al. 1995, Smythe et al. 1998, Carlson 1999, 2001, Carlson et al. 1999a,b, Spencer and Calvin 2002, Hansen and McCord 2008]. In other areas of dark, chaotic terrains distorted absorption spectrum features suggests water bounded in non-ice hydrates. Hydrated materials that have been observed in these disrupted regions are suggested to be magnesium and sodium sulfate minerals that were brought to the surface from sub-surface ocean brines [McCord et al. 1998b, 1999] (Figure 5). Other interpretations suggests these materials may actually be sulfuric acid hydrates created through ocean-derived sulfates present in deposits, by radiolysis of sulfur from IO, or from the processing of in-situ sulfur dioxide [Carlson et al. 1999b, 2002, 2005]. One important objective for this mission is to resolve the discrepancies betweenthe numbers of possible components for the remaining composition of the ice.

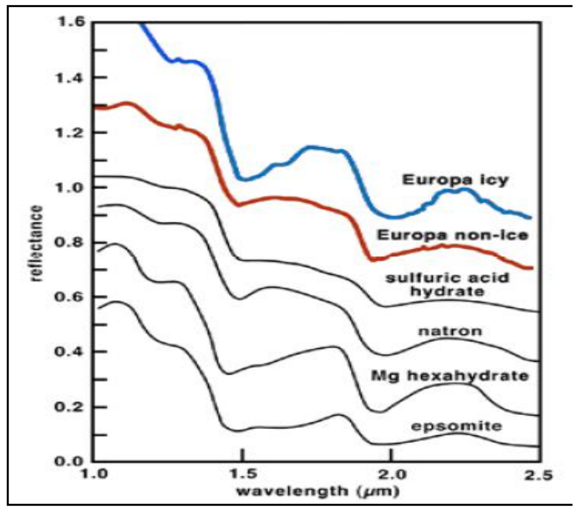


Figure 5: Spectrums derived from Europa's ice and and non-ice materials, compared to candidate spectrums [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

Based on the observations of other satellites near Europa and laboratory experiments with ices, it is thought that a large amount of other compounds can be found on the Moon. Many of these compounds are likely formed from the radiolysis or photolysis of endogenic materials when exposed to intense radiation from cosmic rays or high energy particles trapped in Jupiter's magnetosphere. These highly reactive species combine with other non-ice materials to form a wide array of compounds. Some organic molecular groups like CH and CN have been identified on other nearby icy moons, suggesting Europa may also contain such molecules [McCord et al. 1997, 1998a]. However, organic molecules are not expected to exist closer to the surface in older deposits due to the intense amounts of radiation that would degrade them. If organics are present, they are likely found in areas of lesser radiation and recent deposits. Some other compounds that may be present in the ice include H2S, OCS, O3, HCHO, H2CO3, SO3, MgSO4, H2SO4, H3O+, NaSO4, HCOOH,CH3OH, CH3COOH and other complex species [Moore 1984, Delitsky and Lane 1997, 1998, Hudson and Moore 1998, Moore et al. 2003, Brunetto et al. 2005]. These compounds should be able to be detected using high-resolution spectroscopy, comparing collected spectra to know spectra of elements observed in the lab.

In addition to composition data, isotopic constraints may be able to be placed on some of these compounds. The measurement of isotopic ratios would allow for a greater insight in a number of planetary processes. Ratios of D/H, 13C/12C, 15N/14N, 16O/17O/18O, 34S/32S and 40Ar/36Ar can give insight to geological, chemical, and biological processes that have occurred in the past or are presently occurring on Europa today. Exchange rates between the mantle, ocean, and ice crust are often closely linked to such ratios of radiogenic noble gases. Other endogenic processes occurring on Europa could also lead to measureable isotopic ratios that could provide a time frame of such events. More so, exogenic processes of sputtering and sublimation should also cause some kind of isotopic fractionation.

It is important to identify the source of these secondary compounds. If many of these compounds are proved to be endogenic, then more complex processes could be ongoing but are nearly invisible from the surface. If many of these compounds are found to be exogenic, then the surface of Europa must be experiencing a large number of particles bombarding the surface materials and altering the moon's composition dramatically.

D.1.1.6 Geology

Europa contains an array of complex geology, indicative of the moon's active past and present processes. The relatively young age of the moon's surface is linked to the effects on the moon's structure due to extreme gravitational tides, causing fracturing of the surface and possible mixing of materials between the surface and sub-surface. The surface features identified on Europa can be grouped into three broad categories based on their appearance: linear features, chaotic features, and impact features.

To begin, linear ridges and fractures are some of the most dominant surface features found on Europa. This class of formations includes troughs, scarps, double ridges separated by a

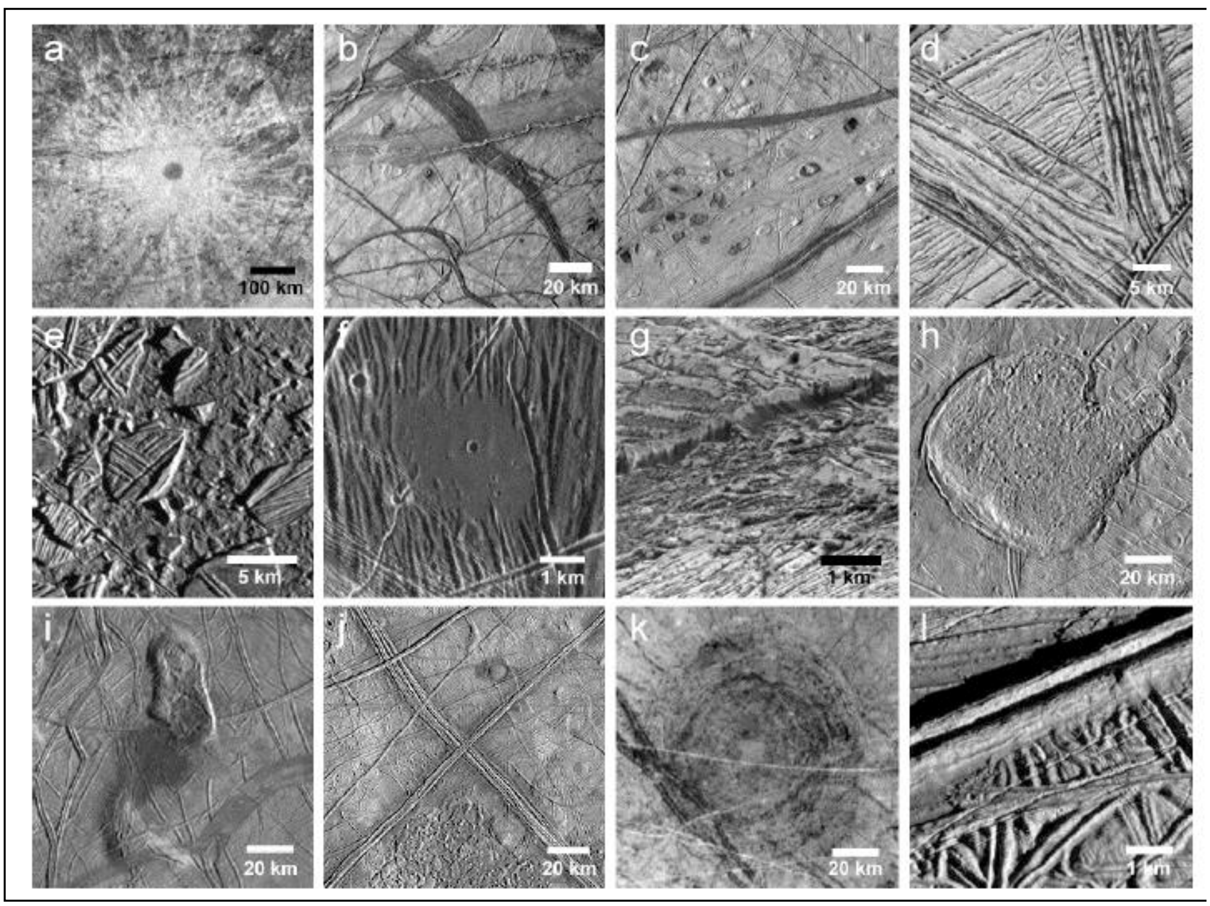


Figure 6: a variety of surface features seen on Europa. (a) Impact crater; (b) pull-apart bands; (c)Lenticulae; (d) pull apart band; (e) chaos terrain (f) dark plains material; (g) cliff; (h)chaos terrain; (i)chaos terrain; (j)ridge complexes; (k)impact features; (l) ridge [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

trough, and intertwined ridge complexes (Figure 6). It is currently unknown whether these features represent the same process in different stages or if they are all completely different processes all together. Ridges are the most identifiable features. They can range from as little as one hundred meters in length to as much as five hundred kilometers. These features can also extend up to a two kilometer width and can be as high as several hundreds of meters. Cycloidal ridges resemble double ridges but form long chains of linked arc-like structures (Figure 6)

Models produced to simulate the formation of these linear features have shown that the fracturing is likely due to some kind of processes within the ice shell itself [Greeley et al. 2004]. Other models suggest that liquid material coming from the sub-surface ocean or warmer ices pushing upwards, eventually squeezing through to form ridges. Other hypothesis state that the ridges may be formed by some kind of frictional heating that causes deformation and possible melting near the areas of greatest shear. Based on these hypotheses, ridges may be representative of areas where an exchange of material between the different layers of Europa is occurring. This would suggest that young ridges would be one of the prime areas to search for evidence for life, due to the abundance of compounds that may be found there. Finally, cycloidal ridges appear to be a direct result of Europa's tidal deformation [Hoppa et al. 1999].

Bands are another type of linear feature, and are likely representative of fracturing and cryospehric separation, similar to sea-floor spreading centers observed on Earth [e.g., Sullivan et al. 1998] (Figure 6). Geometric reconstructions of these features suggest the spreading center model is appropriate, which may include direct contact with the sub-surface ocean [Tufts et al. 2000, Prockter et al. 2002]. Young band deposits appear to be dark while older band deposits are noticeably lighter, suggesting a brightening and possibly a change in composition with time. The small number of contractional features on Europa still poses a serious question in the cycling of materials. A few contractional folds have been identified [Prockter and Pappalardo 2000], and other bands have suggested convergence zones [Sarid et al. 2002], but spreading centers are still disproportionally common. Fractures tend to be fairly narrow, only ranging upwards of a few hundred meters in width, but may extend to more than a thousand kilometers in length. Fractures also tend to cut across most other surface features, suggesting the ice shell is most subject to deformation in the form of fractures. Even today, some of these ridges and fractures could be continually active due to tidal flexing.

Subcircular features, often called lenticulae, other irregular-shaped, and larger disruptive zones make up the second category of surface features on Europa, chaotic terrain (Figure 6). Lenticulae encompasses pits, dark spots, and domes. These are likely areas where compositionally or thermally buoyant ice manages to press upwards through the harder, more brittle ice, usually extending to about ten kilometers across [Pappalardo et al. 1998, 1999]. If the size of these features is accurate, this would imply that the thickness of the ice shell should be at least ten to twenty kilometers during the time of formation [Clark et al. 2009]. Although alternative hypothesis suggests that there is no dominant size of these features, stating that these features are formed either through melting or through convection [Greenberg et al. 1999]. It is important to constrain the size of these features in order to characterize their dynamical formation.

Chaos terrain often refers to broken plates of ice that have been shifted into a new matrix. Plates appear to be connected to a similar origin in localized areas, as if they were once coherent and disaggregated into a secondary matrix. In addition, these areas are sometimes seen rising higher than the surrounding area. Currently one theory suggests that these chaos terrains are formed by the whole or partial melting of a localized area on the ice crust that may occasionally contain patches of brine [Head and Pappalardo 1999. This brine is often represented as areas of dark, reddish material, and is likely derived from the subsurface, perhaps as deep as the ocean layer. Subsurface sounding, mapping, and models of the topography are essential to understanding the complex features of these chaotic terrains.

Impact features are the third and final features that have been identified on the surface of Europa (Figure 6). To date, only twenty-four impact craters measuring ten kilometers or greater have been identified on Europa [Schenk et al. 2004]. This remarkably small number of craters suggests a relatively young surface. The youngest of the 24 craters is Pwyll, measuring twenty four kilometers in diameter, dating to approximately five million years ago [Zahnle et al. 1998]. Identifying crater morphology and local topography could provide an abundance of information about the thickness of the ice sheet and its reaction to such extreme stresses. In addition, ejecta identified from recent events could provide some limited composition measurements of the subsurface ice.

Connecting all of these features is important in studying and interpreting the geologic history of Europa. Unfortunately, only about ten percent of the surface has been imaged in sufficient resolution that is suitable for the construction of such a history. Therefore an emphasis in imaging must be taken to fully understand Europa's geology. However, an attempt at constructing the geologic history in the viable areas has been undertaken. The areas studied have appeared to evolve from ridge and band features to chaotic features, although this sequence is not certain [Greeley et al. 2004]. It is not well understood why such changes have appeared to occur, but one theory suggests that as the ice shell thickens, solid-state convection may be initiated, causing a large upwelling of warm buoyant ice, forming the final chaotic terrain [Clark et al. 2009]. Changes in the color and brightness of surface features are also indicative of their age; features generally appear brighter and less red as they age [Geissler et al. 1998].

Through the data of the global features on Europa and our current understanding of the geology and processes of the moon, a global geologic history based on the cratering models and resurfacing events can be described through a few possible scenarios. (1) The resurfacing of Europa is fairly consistent and appears to be in a steady state. (2) Europa has recently undergone a major resurfacing event. (3) Significant resurfacing events occur episodically. (4) The age of the surface is underestimated. Current thoughts indicated that models following cyclical resurfacing events appear most likely given the dynamical evolution of the Jupiter-moon system [Clark et al. 2009].

D.1.2 Science Goals and Objectives

The goals and objectives for this Europa mission are listed below. These goals and objectives were crafted to apply to one of NASA's strategic goals – to "Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space" [Disocovery AO 2010]. This mission also follows the guidelines provided by the 2010 Discovery Announcement of Opportunity, which states that the program is to "provide frequent flight opportunities for high quality, high value, focused, planetary science investigations that can be accomplished under a not-to-exceed cost cap" [Discovery AO 2010]. The goals and objectives were further determined by NASA's current science needs and areas of interest.

Goals	Objectives
Asses the habitability, hazards, and resources of the outer Solar System and look for the potential for life elsewhere	Search for signatures of past or present life, with a focus on detecting organic compounds, in the surface and sub-surface layers
	Determine the composition and structure of the surface and interior including global ice thickness, investigate a possible magnetic field and its origin, and map moon resources that may be valuable for mining
Increase the knowledge of the history and formation of the outer Solar System	Determine the nature of the geologic activity and the processes that drive it and study the history of this activity

D.2 Science Requirements

D.2.1.Baseline Mission

The baseline mission is defined as the mission created when all science is implemented. For the baseline mission, a total duration of six to eight months will be needed for a sufficient science return. On this timeline, the first fifteen days after arrival at Europa will be used to observe the surface at high resolution in order to choose candidate locations for landing. This state will be primarily observatory, using mostly remote sensing instruments. During those fifteen days, data will be collected and undergo preliminary analysis. An intensive public workshop will be held, inviting scientists and specialists on Europa to choose candidate locations for landing around the North or South pole of the moon and decide upon a final landing spot. The next five to six months of the mission after arrival will consist of a high-power science state where the majority of our instruments will be fully implemented. During this period, the lander will be active on the surface of Europa. The remaining one to two months will be used for a low-power observatory mission, focusing on observing the moon to aide future missions, especially those which will land on the surface.

The following instruments will be implemented during the first and last Observatory Stages of the baseline mission. A High-Resolution Spectroscopic Camera, with imaging & mapping capabilities, will orbit and measure spectra (IR-UV) of the surface to help determine the chemical composition, mapping composition on a global scale. A Gamma Ray / Neutron Spectrometer will measure spectra of the surface and subsurface, determining the geology and composition of the first few meters of the upper cryosphere. A High Resolution Laser Altimeter will provide detailed images of the surface elevation and structure. The next list of instruments will be employed during the Main Science Investigation Stage of the baseline mission. A Gas Chromatograph Mass Spectrometer (GCMS) will provide spectra measurements of in-situ ice samples to help determine chemical composition, searching for chemical signatures that may indicate past or present life. A Drill camera will take photos in the visible spectra of the sub-surface geology of the moon. The Atmospheric Science package will take surface and sub-surface measurements of the internal and external moon temperatures as well as the atmospheric pressure. A Microscopic Imaging Camera will help to determine the texture and grain size of collected samples. A Ground/Ice Penetrating Radar will determine the structure and density of the surface and subsurface layers, and constrain ideas of a liquid water layer existing below Europa's surface. A radio science experiment using two-way tracking of the spacecraft will be employed to measure global distributions in the gravity field of Europa. A Stereo Camera will capture images of the surface from orbit and provide three-dimensional (stereo) output images which can be used to make high-resolution maps of the surface structure. A Magnetometer will measure the magnetic field and its strength at the surface and from orbit, with an emphasis on cyclic changes. A Thermal Radiometer will measure incoming radiation and the albedo of the surface, providing global temperature measurements and some limited composition. A Radio and Plasma Wave Science (RPWS) instrument will measure the electric field and strength, electron density, magnetic field and strength, temperature of the electric and magnetic fields, plasma, interplanetary medium, and planetary magnetospheres from orbit around Europa. The Advanced Seismometer, Gravimeter, Accelerometer instrument (ASGARD) will measure the gravity field and strength in-situ from the surface of Europa, looking for cyclic changes caused by Jupiter and its moons. The instrument will also use its seismometer to measure ground movements at the landing site, searching for areas of active re-surfacing. And finally, the accelerometer in the instrument package will measure variations in the instruments position.

D.2.1.1 Science Traceability Matrix

Goals	Objectives	Measurements	Physical Parameters	Instruments	Environment at Europa
Assess the habitability, hazards, and resources of the outer Solar System and look for the potential for life elsewhere	Search for signatures of past or present life, with a focus on detecting organic compounds, in the surface and sub-surface layers.	Spectra	Regolith Sample	GCMS [a]	Europa Surface [a]: active resurfacing occurring (ice flows, cracks, uneven surface), O_2, H_2O_2, CO_2, SO_2, SO_4, H_2O, sulfuric acid, sulfate salts, solar radiation (high energy electrons), strong gravitational field fluxes (.135g) (~85hr period) , magnetic field fluxes (120 +- 20 nT) (~11.2hr period)
		Spectra (IR-UV)	Surface Geology	Gamma Ray/ Neutron Spec [b]	
		Texture & Grain size	Regolith Sample	Microscopic Imaging Camera [a]	
		Temperature	Surface & Subsurface	Atmospheric Science Package [a]	
Increase the knowledge of the history and formation of the outer Solar System	Determine the composition and structure of the surface and interior including global ice thickness, investigate a possible magnetic field and its origin, and map moon resources that may be valuable for mining.	Internal Structure & Density	Surface & Subsurface Structure	Ground / Ice Penetrating Radar [b]	
		Surface Structure	Surface Geology	Stereo Camera [b]	
		Magnetic Field & Strength	Magnetic Field (surface & orbit)	Magnetometer [a,b]	
		Spectra (IR – UV)	Surface Geology	Hi-Res Spec Cam (imaging & mapping)[b]	
		Spectra	Surface & Subsurface Geology	Gamma Ray/ Neutron Spec [b]	
		Radiation	Surface	Thermal Radiometer [b]	
		Gravity Field & strength	Gravity Field	ASGARD (gravimeter) [a]	
		Spectra	Regolith Sample	GCMS [a]	
		Surface structure	Surface Structure	Hi Res Laser Altimeter [a]	Europa Orbit [b]: solar radiation (high energy electrons, plasma), strong gravitational field fluxes (~85hr period), magnetic field fluxes(120 +-20 nT) (~11.2 hr period)
		Texture & Grain size	Regolith Sample	Microscopic Imaging Camera [a]	
		Internal and External Temperature	Surface & subsurface	Atmospheric Science Package [a]	
		Atmospheric pressure	Surface atmosphere	Atmospheric Science Package [a]	
		Electric Field & strength Electron Density Magnetic Field & Strength Temperature (interplanetary plasma)	Electric & magnetic fields, plasma, interplanetary medium & planetary magnetospheres	RPWS (Radio and Plasma Wave Science instrument) [b]	
		Seismology	Surface Movement	ASGARD (seismometer) [a]	
	Determine the nature of the geologic activity and the processes that drive it and study the history of this activity.	Magnetic field and strength	Magnetic Field	Magnetometer [a,b]	
		Internal density and structure	Gravity Field	Radio Science Experiment [b]	
		Surface Structure	Surface Structure	Hi res Laser Altimeter [b]	
		Temperature	Surface	Atmospheric Science Package [a]	

D.2.2 Threshold Mission

The threshold mission is defined as the mission with the minimum amount of science needed to make the mission justifiable. The threshold mission will have a duration of three to five months, reduced from the baseline mission in order to justify mass and power cutbacks. The first fifteen days of the threshold mission will be maintained as a high resolution observatory stage. During this stage candidate locations for landing will be chosen by a panel of scientists and specialists with the data that has been collected and sent back to Earth. The Main Science Investigation Stage will occur in the following two to three months which is when the lander and orbiter instruments will be collecting the majority of the data required for the mission. The next one to two months of the mission will be another high resolution observatory stage where the observations will be used to plan for future missions to Europa.

The following instruments will be implemented during the lifetime of the threshold mission. A Gas Chromatograph Mass Spectrometer will gather spectra of ice samples, determining composition at the sample site. The Ground / Ice Penetrating Radar will measure the structure and density of the surface and subsurface, looking for evidence of a liquid water layer existing below the surface. The Magnetometer will measure the magnetic field and strength from the surface and orbit, looking for cyclic changes. The High Resolution Spectroscopic Camera will measure the spectra of the surface geology as it orbits, measuring composition on a global scale. The Gamma Ray / Neutron Spectrometer will measure spectra of the surface and subsurface, analyzing the geology and composition of the upper few meters of cryosphere. A radio science experiment will be performed using precise two-way tracking of the orbiter to map the global gravity field of Europa. A Thermal Radiometer will measure incoming radiation and the albedo of the surface, providing global temperature measurements and limited composition. A High Resolution Laser Altimeter will provide detailed images of the surface elevation and structure. A Microscopic Imaging Camera will help to determine the texture and grain size of collected ice samples. A Radio and Plasma Wave Science (RPWS) instrument will measure the electric field and strength, electron density, magnetic field and strength, temperature of the electric and magnetic fields, plasma, interplanetary medium, and planetary magnetospheres from orbit. . The Advanced Seismometer, Gravimeter, Accelerometer instrument (ASGARD) will measure the gravity field and strength in-situ from the surface of Europa, looking for cyclic changes caused by Jupiter and its moons. The instrument will also use its seismometer to measure ground movements at the landing site, searching for areas of active re-surfacing. And finally, the accelerometer in the instrument package will measure variations in the instruments position.

E. Science Implementation

E. 1. Science Instruments

E.1.1 Laser Altimeter

The Heritage Laser Altimeter will be utilized during the orbit stage of the mission to determine surface elevation and structure. This notional laser is a combination of designs from laser altimeters utilized in previous missions. Elements of the Lunar Orbiter Laser Altimeter (LOLA), the Mercury Laser Altimeter(MLA) and the NEAR Laser Rangefinder(NLR) were incorporated into the notional laser design [Clark et al. 2009]. Detailed data taken in high resolution will identify global topographic variations at cross-over areas and interpretations of the moons' morphology.

This will be done with a high powered laser that will scan the surface of Europa with 1 m vertical accuracy and relay the information back to an optical transmitter. The high powered laser functions at a 1064 nm wavelength, sending out pulses at a rate of 28Hz. The laser then separates into five smaller lasers using a diffractive optical element. Each new laser travels to and from the surface and the altimeter detects these beams and measures the distance to travel ratio. These ratios allow surface elevation, slope, and other topographical features to be mapped.

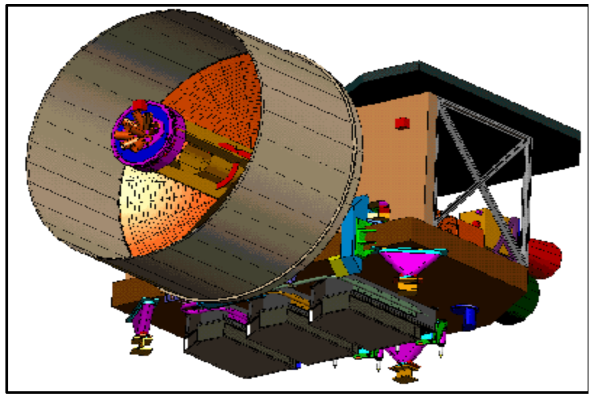


Figure 1: Illustration of Laser Altimeter [Source: Palm, S. (2004, May 10). *The geoscience laser altimeter system.*]

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
5	12	150x150x150	0.046	.029x.029

E.1.2 Gamma Ray Neutron Spectrometer

The purpose of the Gamma Ray Neutron Spectrometer is to capture high resolution data measuring spectra of the surface and subsurface, determining the geology and composition of the first few meters of the upper cryosphere. It will be utilized on the orbiter during the entire 6-8 month mission. The technology behind this instrument involves harnessing cosmic rays from the Sun to bombard the surface of Europa. Due to the lack of atmosphere the rays can easily penetrate to the moons' surface obtaining data at a 2.0 kpbs rate. The cosmic rays then contact an atom, dislodging high energy neutrons or exciting a proton in the nuclei. When these particles return to their normal state of energy, the transition creates and releases gamma rays. Each individual atom in an element gives off a signature energy pattern of gamma rays and the amount of rays detected illustrates the precise abundance of that element in the surface and sub-surface. The Gamma Ray Neutron Spectrometer detects these rays with a high Germanium semi-conductor crystal where electrically charged pulses are received and recorded by the instrument. Neutrons can be observed with materials known as scintillators which give off minute amounts of light when struck by a gamma ray of neutron. The intensity of each light pulse is directly proportional to the energy of the neutron.

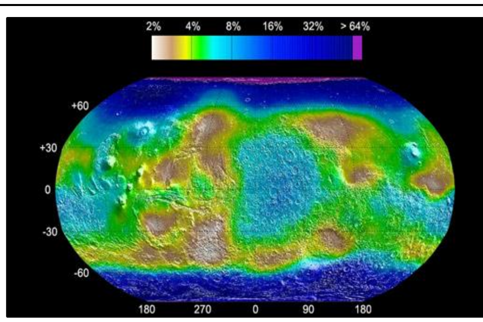


Figure 2: Spectrographic image of water mass on Earth [Source: *Water mass map from neutron spectrometer*. (2008). [Web].]

Determining the composition of Europa is critical to this mission because it is utilized for analyzing the chemical/elemental constituents of the moon. Depending on the spectra detected by the Gamma Ray

Neutron Spectrometer the surface composition can be narrowed down to exact elements and their abundance. Signs of life could easily be indicated by the presence of organic elements, such as carbon and nitrogen, in the surface or sub-surface of the upper cryosphere. Traces of sodium, hydrogen and oxygen would indicate the presence of saline icey substrates which would support the idea of a hydrosphere composed of salt water located below the cryosphere. The instrument employs a 20 degrees x 40 degrees field of view enabling a large percentage of the moon to be mapped in high resolution [NEA].

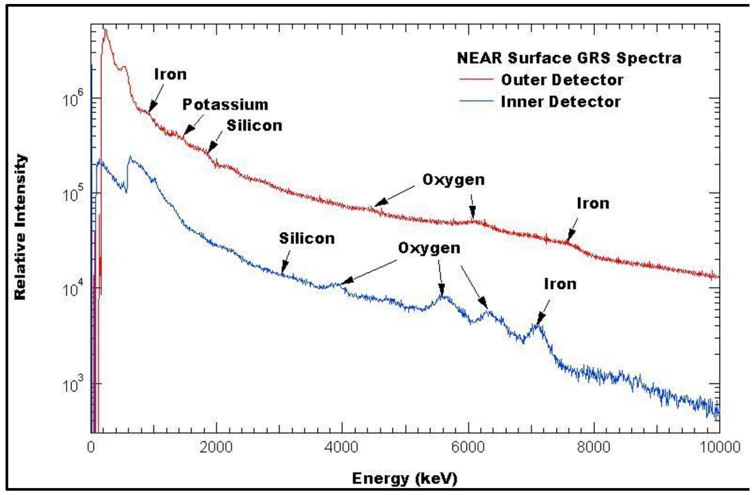


Figure 3: Spectragraph of chemical components [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
4.08	3.6	110x110	2	20x40

E.1.3 High Resolution Spectroscopic Camera

The High-Resolution Spectroscopic Camera will orbit and measure spectra (IR-UV) of the surface to help determine the chemical composition. The Spectroscopic camera will collect images at a size of 640x480 pixels and at a rate of 0.21 kpbs [NEA]. The camera's mapping capabilities will provide global detail of Europa's surface composition utilizing a 10 degrees x10 degrees field of view. The camera will first be employed during the initial observatory stage with a duration lasting fifteen days using 8.4 watts of power. Then the camera will be powered down and reserved for the final part of the mission which is a second observatory stage with a duration of two to three months. Images will be taken within the Near-Infrared to Ultraviolet spectrum (300-3600 nm) with a 1.0 m spatial resolution. Europa has little to no atmosphere so there will nothing inhibiting the view of the surface from the instruments' orbit.

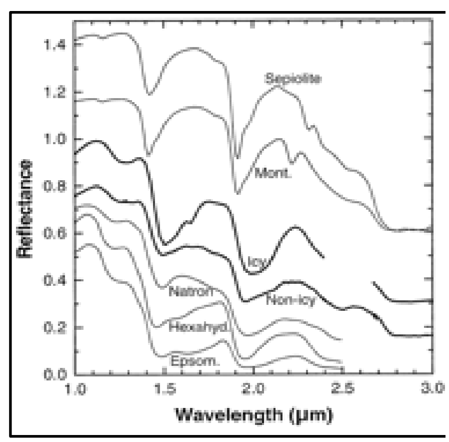


Figure 4: Spectra grade from Europa and Ganymede from pure water ice(top) to least ice-like(bottom) [Source: T. B. McCord, G. B. Hansen, F. P. Fanale, R. W. Carlson, D. L. Matson, T. V. Johnson, W. D. Smythe, J. K. Crowley, P. D. Martin, A. Ocampo, C. A. Hibbitts, J. C. GranahanSalts on europa's surface detected by galileo's near infrared mapping spectrometer. (1998). *Science* , *280*.]

Taking images of spectra is important to the mission because it provides images and maps of the mineralogical components of the surface. Minerals have specific signatures that can indicate past environments. Spectra of wavelengths between 2.4 and 3.6μm are indicative of hydrous minerals, suggesting areas where water once or does exist. Images can be correlated with data from the Laser Altimeter, verifying the chemical components of the surface terrain that will be used for determining the landing site.

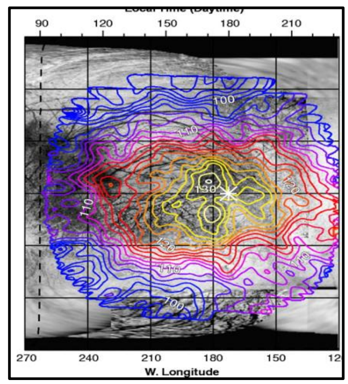


Figure 5: Contours on brightness temperature distribution on Europa during daytime [Source: Spencer, J.R., Tamppari, L.K,. Martin, T.Z., and Travis, L.D., Temperatures on europa from galileo photopolarimeter-radiometer: nighttime

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
2.28	8.4	50x80x200	0.21	10x10

E.1.4 Thermal radiometer

A Thermal radiometer will be employed during the Main Science Investigation Stage which has a duration of 4-6 months. From orbit the radiometer will initially take temperature measurements of the surface and subsurface for the landing sites then continue to measure temperature for the remaining duration of the Main Science Investigation Stage. The measurements will aid in characterizing diurnal heat flow across Europa's surface, illustrating areas of active rifting(see figs characterizing images of day and night temps). The instrument produces these maps with a 3.0 degree x .014 degree field of view and a ground spatial resolution of 10m [NEA]. Incoming radiation of wavelengths between 0.35 and 100 nm will be measured with a temperature range of 0-300K degrees. All day time maps will be taken with an accuracy of 1K and all night time maps will be taken with a 2K accuracy. The instrument utilizes 0.6 watts for power and collects measurements at a rate of 0.3 kpbs, allowing for a quick production of maps.

The radiometer is an important instrument to the mission because it measures temperatures that are used to determine areas of thermal conductivity and insolation. These temperatures can explain active rifts and surface movement occurring on Europa that suggests the possibility of a liquid ocean beneath the cryosphere.

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
1.2	0.6	60x40x40	0.3	3.0x.014

T dditional hardware or

resolution images provided by the stereo camera, greater constraints on the surface structure would aide in providing three-dimensional models of the surface of Europa. In addition, the radio science experiment will also employ the orbiter's telemetry, tracking and command sub-system. Simultaneous dual-frequency downlinks between the X-band and S-band using the High Gain Antenna and tracking from antennas on Earth will allow for the precise measurement of the orbiter's location. Mapping the variations in the orbiter's location around the moon can provide an abundance of information about the local gravity field as well as variations caused by the orbit around Jupiter. The experiment is dependent upon the observation of the phase, amplitude, polarization and propagation times of radio waves sent from the spacecraft and received by antennas on Earth. The transmittance of these radio signals is affected by the mediums through which the waves travel, the gravitational fields of the solar system bodies and that of the spacecraft, and the performances of the systems on the spacecraft and on Earth.

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
N/A	N/A	N.A	53.2	N/A

E.1.6 Radio & Plasma Wave Science Instrument

The Radio and Plasma Wave Science (RPWS) will orbit Europa for the entire 4-6 month duration of the Main Science Investigation Stage. Receiving and measuring data at a rate of 0.9 kpbs, the RPWS can interpret incoming radio signals released from the solar radiation occurring on Europa's surface [cassini orbiter website]. The instrument focuses on the configuration of Europa's Jovian induced magnetic field and its relationship to Europan Kilometric Radiation. The instrument maps the ionosphere and records electrical and magnetic fields that are found in the plasma of the interplanetary medium. The plasma on Europa consists of free electrons and positively charged ions and it is contained by the moon's magnetosphere. The main constituents of the instrument are an electric field sensor, a magnetic search coil assembly and a Langmuir probe. The sensor is made of three detachable antennas which are mounted on top of the instrument. The magnetic search coils are attached to a small platform with extra support for the tall antenna. The probe is mounted on the same platform by a 1 m deployable boom.

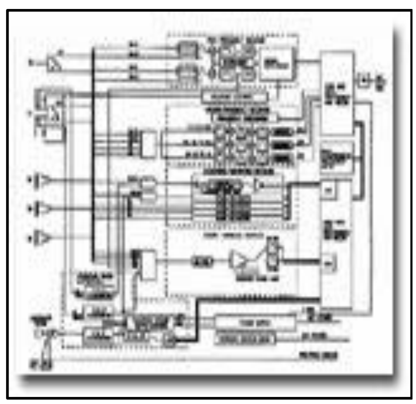


Figure 6: Illustration of elevtric field sensor, magnetic search coil and Langmuir probe [Source: Yu, A. (n.d.). *Cassini solstice mission*. Retrieved from http://saturn.jpl.nasa.gov/]

These three key components enable to instrument to measure electron density, temperature of the electro-magnetic fields and strength of the electro-magnetic fields and that is why it is being utilized for the mission. These measurements can indicate what high energy particles are reaching the surface and how they affectively change the composition.

MASS (kg)	POWER (watts)	DIMENSIONS (mm)	DATA RATE (kpbs)	F.O.V (Degrees)
6.8	7	600x300x300	0.9	360x90

E.1.7 Gas Chromatograph & Mass Spectrometer

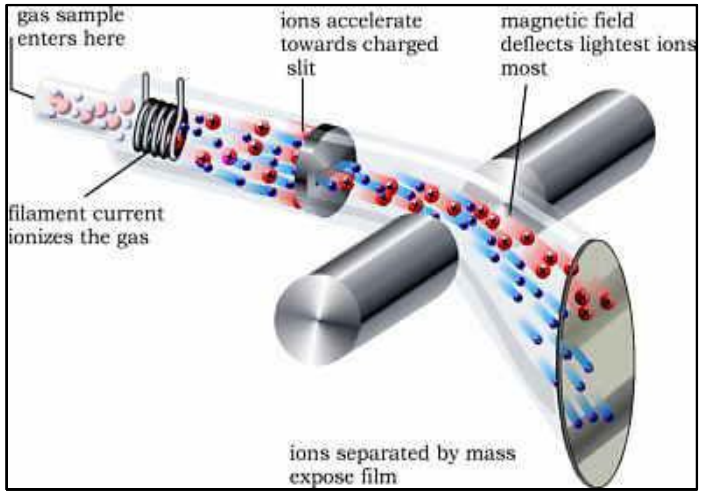


Figure 7: Graphic image of ion and gas transportation [Source: *Mass spectrometry.* (2009).]

The Gas Chromatograph & Mass Spectrometer (GCMS) will provide spectra measurements of in-situ ice samples to help determine chemical composition, searching for chemical signature that are indicative of past or present life [Venus flagship]. It will be employed on the surface of Europa for a duration of two to three weeks during the Main Science Investigation Stage. These two instruments utilize gas chromatography and mass spectrometry to analyze the samples. They are used together because the combination of processes provides a distinct substance identification. Gases can enter through the atmospheric inlet valve and the GC uses a carrier gas to transport the different chemical constituents of a particle. The particle is suspended in the column with the gas stream during the mobile phase and it eventually falls out of the column and into the stationary phase. The time in which this occurs is known as the retention time and each chemical constituent travels at a different retention time depending on its physical and chemical properties. The gases utilized by the GC to measure retention time can also be produced during pyrolysis.

The MS measures the mass to charge ratio of charged particles. The sample taken enters the MS and is first vaporized then ionized. This ion source is created when a metal filament has voltage applied to it. The ions are separated according to their mass to charge ratio and these are detected by utilizing electro-magnetic fields. The separated ions move from the analyzer to the detector and the relative abundance of each ion is recorded into specific signals that can be processed into mass spectra. The spectra can be compared to known ion spectra to determine the chemical element composition of each original sample.

The GCMS is necessary for landing sites because it provides highly accurate compositional data that can only be retrieved by taking samples on the surface. It can identify a variety of volatiles such as oxygen, hydrogen, sulfur dioxide, magnesium sulfide and carbon dioxide and it is the interpretation of these chemicals that help indicate the presence of water and life.

MASS (kg)	POWER (watts)	DIMENSIONS (mm)	DATA RATE (kpbs)	F.O.V (Degrees)
11	40	480x275x270	2	N/A

E.1.8 Microscopic Imaging Camera (MIC)

A Microscopic Imaging Camera will help determine the compositional and morphological information on Europa. Because the images will be taken at a microscopic scale, grain size of collected ice samples can be captured. Grain sizes can then be analyzed to determine the texture of the in-situ samples. The camera requires less than 1.0 watts of power and will be utilized during the lander portion of the mission which has a duration of 2-3 weeks. Fine-scale features of reflectance and texture can be observed from the images at a size of 1024x1024 pixels [NEA]. The MIC uses a single broad-band filter, so the imaging produced is monochromatic. While the instrument is being employed stereoscopic images and mosaics are be taken by moving the camera between successive frames. When taken at various distances from the target images can be used to create a 3-D view of the sample. The object-to-image distance is 100 mm and the focal length of the MIC takes measurements at 20 mm with a working distance of 63 mm. Data is collected at a rate of 0.85 kpbs and with a pixel-to-pixel accuracy of ≤5%.

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
0.1	<1	19x40x96	0.85	N/A

E.1.9 Advanced Seismometer, Gravimeter, Accelerometer for Rough Deployment (ASGARD)

The ASGARD instrument combines a Seismometer, a Gravimeter, and an Accelerometer to revolutionize the way in which geophysical data is collected [ASGARD]. Using only 0.3 watts of power to function, the ASGARD will be employed for 2-3 weeks during the landing part of the mission. Technologies involved in the instrument design include the MEMS seismic sensor, impact-hardened electronics and low power electronics. The Seismometer will produce seismographs that measure ground movements at the landing site with an accuracy of 10-8 m/s2/!Hz. It will be employed on the surface of Europa, searching for areas of active re-surfacing. Seismic activity on Europa will be accurately located and characterized by a network of four active seismic sensors that function simultaneously. The

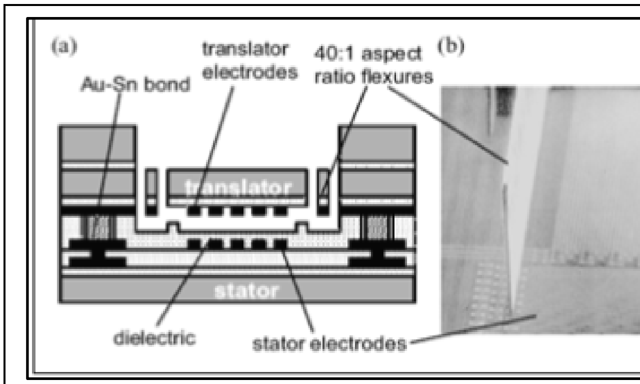


Figure 8: Illustration of ASGARD components [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

seismometer utilizes an internal vacuum system to reduce Brownian noise and low noise electronics. The gravimeter has an accuracy of 10^2 Gal and will measure the gravity field and strength from orbit looking for cyclic changes caused by Jupiter and its moons. The Accelerometer has an accuracy of +- 10 cm/sec and takes specific weight measurements(weight per unit of mass) over a 0-1000m/sec range. It is unique in this design because it uses in-plan overlap of electrodes for sensing and actuation.This instrument was chosen for the mission because not only is it cost and power efficient, it is extremely accurate in the data it collects.

MASS (kg)	POWER (watts)	DIMENSIONS (mm)	DATA RATE (kpbs)	F.O.V (Degrees)
0.1	0.3	200x250x200	1.2	N/A

E.1.10 Magnetometer

The Magnetometer will measure the magnitude and direction of Europa's magnetic field. Two will be employed during the entire 4-6 month duration of the Main Science Investigation Stage at the surface and from orbit. The magnetometers will take magnetic strength measurements with an emphasis on cyclic changes at a rate of 0.086 kpbs. The reason two magnetometers will be utilized during the mission is to discriminate the small magnetic field produced by the landing and orbiting stages.

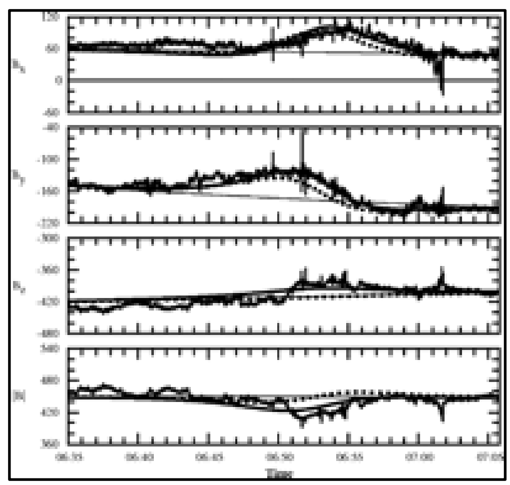


Figure 9. Three components and field magnitude of background field without Europa's perturbations [Source: Kivelson, M. G., K. K. Khurana, C. T. Russell, M. Volwerk, R. J. Walker, and C. Zimmer (2000), Galileo magnetometer measurements: A stronger case for a subsurface ocean at Europa, *Science* 289:1340–1343.]

The type of magnetometer utilized in this mission is known as Fluxgate [NEA]. They consist of a tiny magnetically susceptible core that has two wires coiled around it (Primary and Secondary wire). The secondary coil surrounds the primary coil and these wrap around a permeable core. Alternating currents are applied, inducing the core into plus and minus saturation. When the magnetometer reads an external magnetic field half of the core is aided in flux and the other half is opposed in flux creating a signal dependent on magnitude and polarity.

Europa's varying magnetic field is induced by Jupiter and it suggests subsurface conduction. Areas where subsurface convection is present may indicate a liquid ocean beneath the cryosphere. A magnetometer is necessary in order to measure the magnitude of the magnetic field and interpret possible regions that are indicative of subsurface convection.

MASS (kg)	POWER (watts)	DIMENSIONS (mm)	DATA RATE (kpbs)	F.O.V (Degrees)
1.6	1.65	100x50x100	0.086	N/A

E.1.11 Atmospheric Science Instrument (ASI)

The Atmospheric Science Instrument will take surface and sub-surface measurements of the internal and external moon temperatures. It will also characterize main atmospheric properties, including pressure, wind speed and wind direction, if present on Europa. It will be employed during the landing portion of the Main Science Investigation Stage for a duration of 2-3 weeks, collecting data at a rate of 0.25 kpbs [Venus flagship]. The ASI is composed of sensors that analyze basic variables (density, temperature, pressure and wind) of the atmospheric structure. The measurements collected during the landing portion of the mission will be processed to determine how volatiles impact the rate at which temperatures increase and decrease.

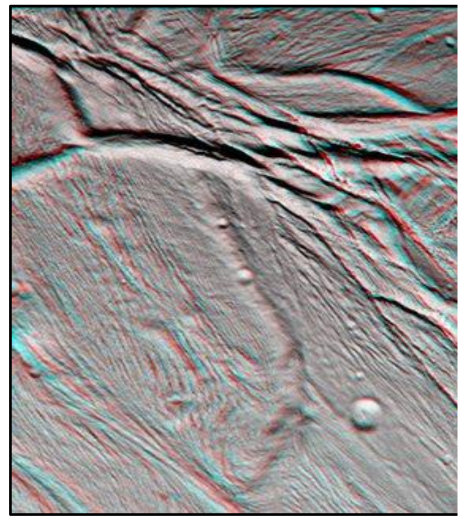


Figure 10: Stereo Image of Saturn's moon's surface [Source: *Icy saturn moon's 'tiger stripes' more extensive than thought*. (2010). [Web].]

The ASI is an important part of the mission because its data can be correlated with measurements from the Thermal Radiometer to provide accurate and detailed recordings of the temperature fluctuations on Europa. This package of instruments provides a fast and efficient way to collect atmospheric data that is indicative of viable environments for life to exist. Even if there is no atmosphere the ASI still measures the temperature oscillations internally and externally, which when combined with data taken, can indicate where a liquid ocean could occur.

MASS (kg)	POWER (watts)	DIMENSIONS (mm)	DATA RATE (kpbs)	F.O.V (Degrees)
2	3.2	100x100x100	0.25	N/A

E.1.12 Stereo Camera (SC)

The Stereo Camera will capture images of the surface from orbit and provide three-dimensional (stereo) output images which can be used to make high-detail maps of the surface structure. The SC will be utilized during the orbiting period of the Main Science Investigation and during the final observatory stage, with a total duration of 6-8 months. The camera is capable of performing at a low power stage(5.3 watts) as well as a high power stage(43.3 watts). When the camera performs at high power it functions as a high-resolution camera and is capable of obtaining near-simultaneous imaging data of targeted sites. The SC is a scanning instrument that has nine mounted CCD line detectors found parallel to the focal bed and captures images in four colors and five phase angles at a rate of 8.72 kpbs. The camera has a 30 degree x 30 degree field of view [MARS EXPRESS]. Images have a ground spatial resolution of 100 m and are seen within the UV-NIR wavelength range. These images combined with the images taken from other camera instruments utilized throughout the mission will provide global high-resolution images. Pictures taken at high spatial and vertical resolution will aid in characterizing morphological and topographical features of the moon.

The Stereo camera is useful to the mission because it maps large areas of the moon at high-resolution, providing detailed information on the geographical surface features. Details of surface features help determine what and where tectonic processes occur on Europa. Images that show surface flexing and rifting suggest the possibility of a subsurface ocean as the cause for the movement. The images can be combined with correlating data from other mapping instruments to provide further interpretations of the geologic processes occurring on Europa.

MASS (kg)	POWER (watts)	DIMENSIONS (mm)	DATA RATE (kpbs)	F.O.V (Degrees)
20.4	5.3(low) 43.3(high)	515x300x260	8.72	30x30

E.1.14 Ground/Ice Penetrating Radar (GIPR)

The radar will be utilized during the orbiting portion of the Main Science Investigation Stage for a duration of 4-6 months. The GIPR is a dual-frequency sounder utilizing a 5MHz x 1 MHz bandwidth and a 50MHz x 10 MHz bandwidth [Clark et al. 2009]. The technology exercised in this instrument is similar to the Mars Advanced Radar for Subsurface and Ionosphere Sounding(MARSIS) on the Mars Express mission. The high frequency radio waves are transmitted to the surface as a series of pulses, providing a high spatial resolution for observing the subsurface up to 3 km deep. The low frequency band is specifically designed to investigate an ice/ocean interface. These low pulses search for the transition between brittle (colder) and malleable(warmer) ice layers that reaching depths of 30 km and are indicative of diapirs. The low frequency band also eliminates potential risks posed by unknown attenuation and thermal/compositional boundaries. Low bands have to compete with the Jupiter noise in the radar band when being transmitted across the Jovian side of the moon so an increase in power is necessary. However, this noise does not affect the

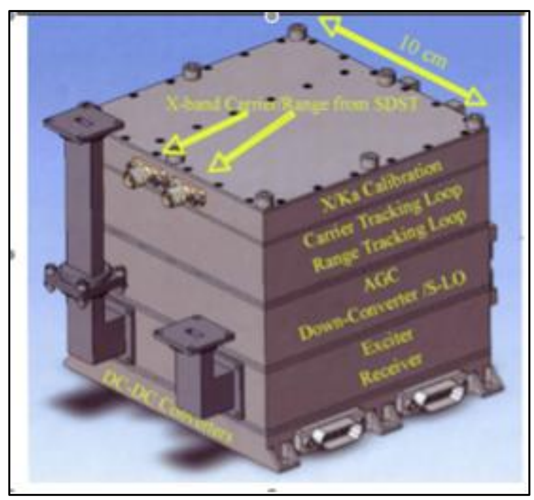


Figure 11: Illustration of Ground Penetrating Radar [Source: M., Clark, K., Greeley, R., Jones, Lebreton, J. P., Magner, T., Pappalardo, R., and Sommerer, J. NASA and ESA, (2009). Jupiter europa orbiter mission study 2008: (NMO710851)NASA.].

radars' capabilities on the anti-Jovian portion of Europa. When these pulses contact the surface of the moon they are reflected back to a receiving antenna that records the variations between contact reflections. As the conductivity of the radar increases the depth at which the pulses can penetrate increases. The data is recorded at a rate of 140 kpbs and with a 5.7 degree field of view.

This instrument utilizes the most power (45 watts) during the mission but because it can provide interior composition and mapping on a global scale the power consumption is overlooked. It is essential to completing the science portion of the mission because it records changes in material densities that occur laterally and vertically. Ice has a specific density range and when the radar detects materials that do not fall into this range it can suggest a subsurface ocean. The GIPR also supplies global mapping of the cryosphere, including detailed isopach maps showing variations in ice thickness which can be indicative of diapirs.

MASS (kg)	POWER (watts)	DIMENSIONS(mm)	DATA RATE (kpbs)	F.O.V (Degrees)
26	45	400x400x250	140	5.7

E.2 Data Sufficiency

Each instrument planned to be used during the mission's lifetime should be capable of providing a sufficient amount of data and level of resolution to answer the stated science objectives. These qualities and quantities of data can be found in section E.1 (i.e. accuracies, resolutions, data rates, etc.). A time period of six to eight months is suggested for the majority of these instruments, with resolutions high enough to discern the needed parameters, in order to take complete and accurate measurements of Europa. Other instruments will only require a duration of three to five months.

E.3 Data Plan

Data from the landing component of the mission will be transmitted to the orbiter's telecom system, and then relayed to Earth for analysis. The data collected from the orbiter's instruments will also be relayed to Earth in the same fashion. The data received from the initial observation stage of the mission (during the first fifteen days after arrival at Europa) will be compiled and analyzed with a focus on producing maps of surface and sub-surface composition as well as surface structure. These maps and the following analysis will be used with all previous data of Europa to determine the best location for a landing site prior to the deployment of the landing component. Data taken from the subsequent stages will be used in a similar fashion, with a focus on producing global maps of ice thickness, composition, and geologic structure. Data suggesting the existence of a sub-surface ocean as well as any biologic activity will be analyzed with the highest detail and care. The outputs provided by the analysis of the data should be easy to understand and detailed enough to assist in further investigations of Europa. Approximately one year after the initial package of data is received from the mission, a report outlining the preliminary findings will be published. In order to assist in analyzing this data, a collection of scientists from varying fields will be hired, including post docs, graduate students, and undergraduate students (section I), over a period of years.

E.4 Science

The science team for the Europa mission consists of the Principal Investigators (PI), Jordan Adams, and the Co-Investigator (Co-I), Caitlyn Mayer. Resumes for each team member can be found in section J.3. The Principal Investigator is responsible for managing all science team responsibilities and investigating all goals and objectives outlined by the Discovery Announcement of Opportunity (AO) that are pertinent to a Europa mission. The Co-Investigator is responsible for aiding in the management of all science tasks as well as the research and production of final products. Funding for all science team members will be provided by their respective institutions.

E.5 Plan for Science Enhancement Options (SEO)

There is currently no Science Enhancement Option planned for this mission to Europa.

F. Mission Implementation

F.1 General Requirements and Mission Traceability

F.1.1 Mission Traceability Matrix

Mission Requirements	Mission Design Requirements	Spacecraft Requirements	Ground System Requirements	Operations Requirements
Search for signatures of past or present life, with a focus on detecting organic compounds, in the surface and sub-surface layers. **Determine the composition and structure of the surface and interior including global ice thickness, investigate a possible magnetic field and its origin, and map moon resources that may be valuable for mining.** **Determine the nature of the geologic activity and the processes that drive it and study the history of this activity.**	Rocket Type: Atlas V 551 Launch Date: No Later Than December 31st, 2017 Mission Length: 9+ Years Orbit Altitude: 100-200 km Geographic Coverage: Orbiter will map the surface of Europa with a camera, and send that data back to Earth. The lander will provide detailed information about the surface in the small area it lands in. Orbit Local Time: 2.1 hours Type of Orbit: Circular Polar Orbit of Europa	Spinning	Passes per day: 11 Full Passes	General spacecraft maneuver requirements and frequency: Venus Earth Earth Gravity Assist (VEEGA) 30 month orbit of Jupiter to decrease spacecraft velocity Descent from 200 km orbit of Europa to 100 km descent Break orbit of Europa and crash into Jupiter
		Orbiter Volume: 14.4 m^3	Spacecraft Antenna Size: 3 meters diameter	
		Lander Volume = 1.299 m^3	Lander Antenna Size: 0.02 meter diameter 0.152 meter height	
		Orbiter Power: 1 ASRG: 160 Watts 2 Rechargeable Lithium Batteries	Transmit Frequency: Ka Band	
		Lander Power: 1 ASRG: 160 Watts 1 Lithium Ion Battery	Power available for orbiter communication: 100 Watts	
		Radiation Shielding: Tantalum	Power available for lander communications: 10 Watts	
		Orbiter Data Rate: 28 Mbit/s	Number of orbiter data dumps per day: 3 (Assumed)	Special maneuvers requirements: Release lander onto specified location on Europa
		Temperature Range for Spacecraft Systems: 28°C - 40°C	Number of lander data dumps per day: 5 (Assumed)	
		Lander Data Rate: 165 kbit/s	Spacecraft data destination: Mission Operations Center Science data destination: Mission Operations Center	Rationale for maneuvers: VEEGA maneuver requires much less propellant than any other path to Europa Lower C3 which allows for higher payload mass
		Orbiter Mass Wet = 2769 kg Dry = 903 kg	Real time data transmission requirements: None	Ephemeris requirements: Mapping of the surface of Europa, as well as a myriad of scientific measurements
		Lander Mass Wet = 937 kg Dry = 456 kg	Deep Space Network Location: White Sands Complex	

F.2. Mission Concept Description

The spacecraft will utilize a Venus Earth Earth Gravity Assist (VEEGA) to reach the Jovian system. This trajectory was chosen due to its low requirement for propellant in comparison to other trajectories. The craft will travel for close to six years before arriving in the Jovian system.

After arriving in a 100 kilometer orbit around Europa, the orbiter will begin mapping areas around the poles for a suitable landing location for the lander. Once a suitable landing location has been chosen by a panel of scientists that have reviewed the mapping data, the orbiter will be issued drop coordinates to release the lander upon arriving next to that particular location.

Upon landing, the lander will deploy its drill and array of scientific instruments. The results of these tests will be sent to the orbiter, which will still be in a 100 kilometer orbit around Europa. It will be able to communicate with the lander every 2.1 hours, ensuring for ease of data transfer between the two elements. The orbiter will have begun heavy use of its own instruments during this time. All collected data will be compressed, and sent back to Earth via the Deep Space Network (DSN).

Following the completion of all testing on Europa, the orbiter will travel towards Jupiter, performing the science enhancement option en route. Upon arriving at Jupiter, the lander will hurtle into Jupiter until it is crushed under the immense gravity. This is to help prevent contamination of possible life inhabited areas.

Figure 18 below depicts the orbiter deployed around Europa.

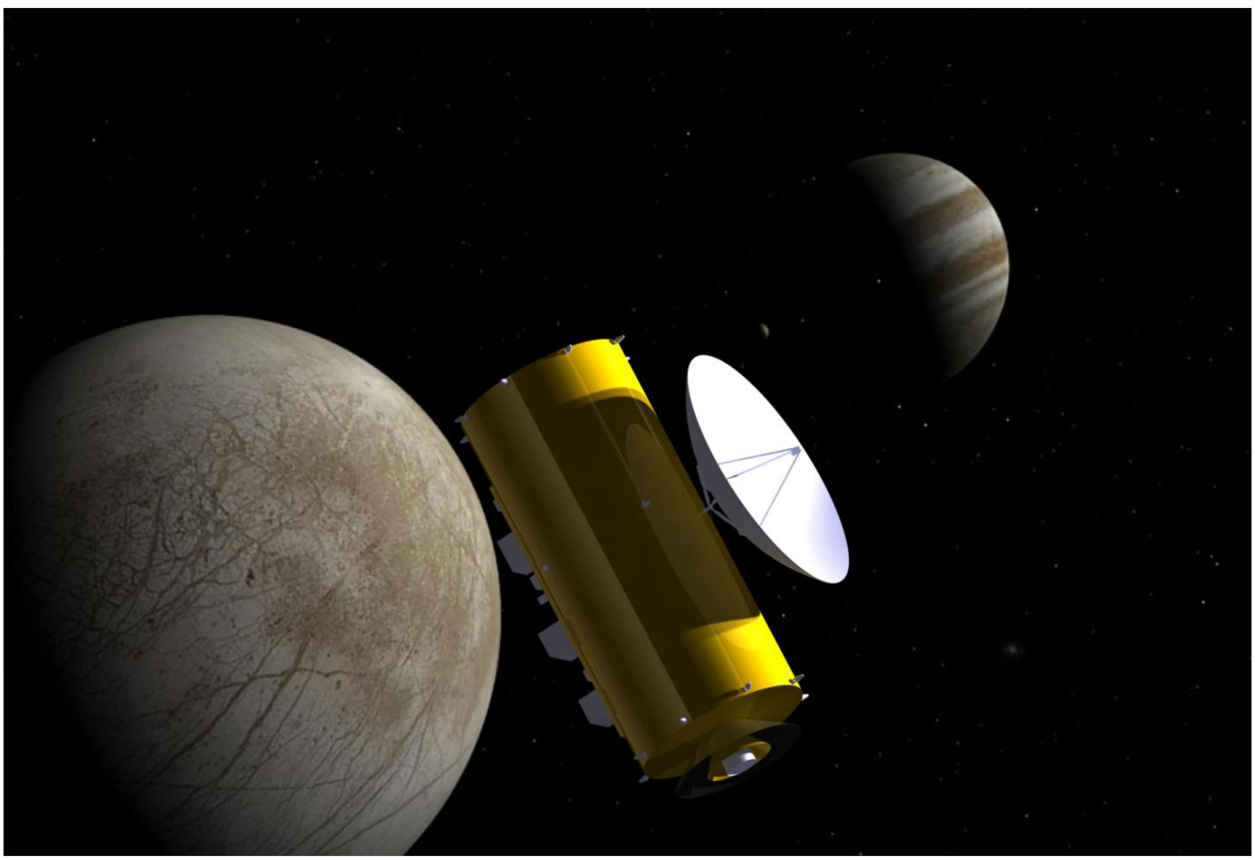


Figure 18 – Orbiter in Space

F.2.1. Mission Design

F.2.1.1. Con-ops Figure

Figure 19 below is a representation of the SARS mission concept of operations.

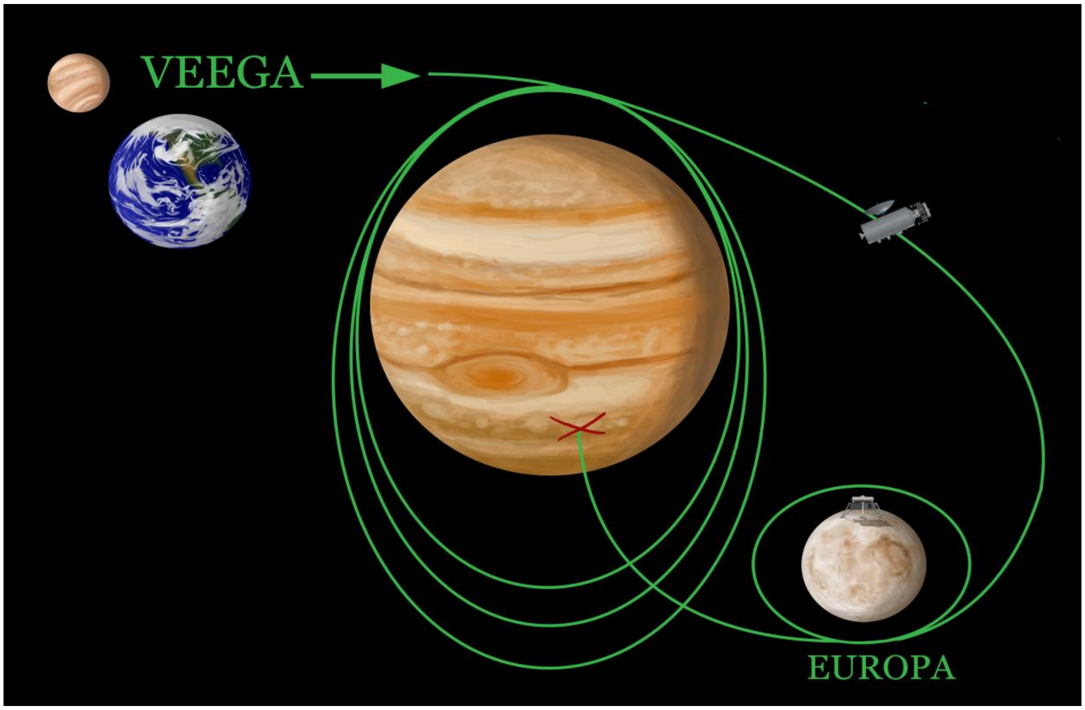


Figure 19 - ConOps

F.2.1.2. Mission Duration

The mission will take approximately nine to ten years. The travel to Europa will take approximately eight years and four months. The science mission is planned to last six to eight months

F.2.1.3. Trajectory

The SARS orbiter will follow the trajectory created for the Jupiter Europa Orbiter (JEO). A Venus Earth Earth Gravity Assist (VEEGA) will be utilized to reach Europa from Earth. It will take approximately six years until the spacecraft reaches Jupiter and performs its Jupiter Orbit Insertion (JOI). The SARS spacecraft will orbit Jupiter for a period of thirty months to decrease its velocity before entering orbit around Europa. The SARS spacecraft will then perform its Europa Orbit Insertion (EOI) burn and settle into a polar circular orbit at a height of 200 kilometers. The orbiter will stay in this orbit for twenty-eight days before descending to a 100 kilometer orbit. Once the science mission has been completed, the spacecraft will break orbit from Europa and begin a course for Jupiter to be disposed of (Not JEO). Figure 20, which was taken from the JEO report, depicts the trajectory that will be used.

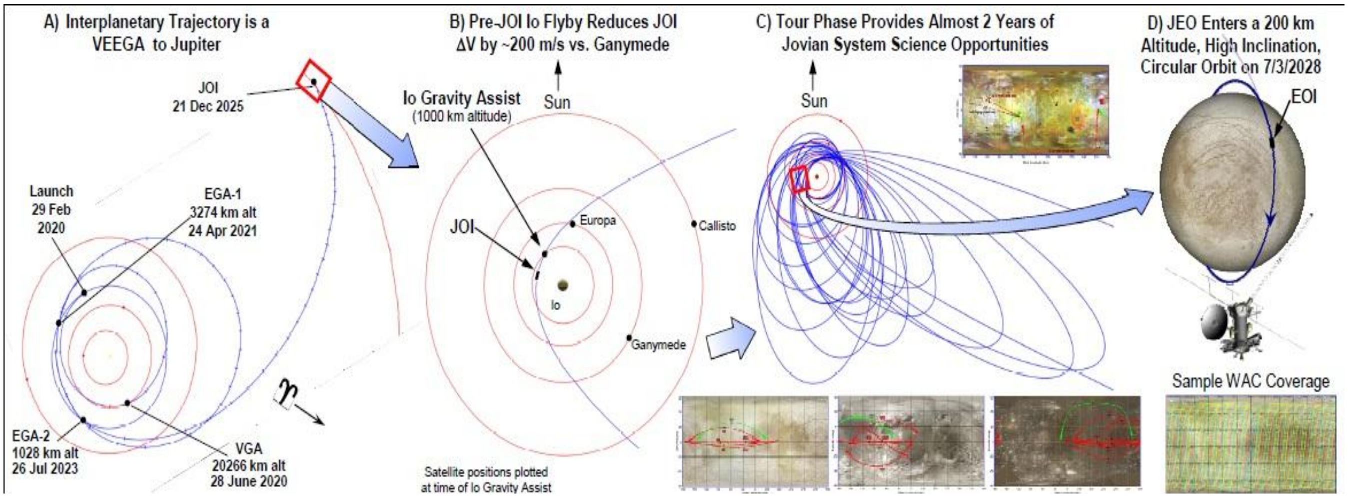


Figure 20 – VEEGA Maneuver

F.2.1.4. Orbit Information

The spacecraft will be orbiting Europa in a polar circular orbit at an altitude of 100 kilometers. The polar circular orbit was chosen to allow for maximum communication time between the lander and orbiter elements, and the altitude was chosen to allow for maximum effectiveness of scientific instruments, particularly the mapping camera. At 100 kilometers, the orbit will have a duration of 2.1 hours.

F.2.1.5. Critical Mission Events

The mission can be divided up into 9 primary events. These “critical events” are as follows:

1. Perform VEEGA to reach Jupiter
2. Slow velocity in Jovian orbit
3. Enter Europa orbit
4. Map surface for landing site
5. Drop lander on chosen landing site
6. Perform scientific analysis with orbiter and lander
7. Relay data to Earth
8. Dispose of orbiter

For the mission to be completed, all of these events must be successfully accomplished.

F.2.1.6. Data Transmission

The antenna design by ESTACA is capable of transmitting data at a rate of 28 mb/s.

F.2.2. Launch Vehicle Compatibility

The SARS mission will utilize the Atlas V 551 launch vehicle (LV) to propel the spacecraft on its trajectory to Europa. SARS was given the option to select any launch vehicle from the Atlas V family, except for the Atlas V Heavy Launch Vehicle (HLV). The 551 was chosen because it has the highest performance of the available launch vehicles, and the SARS mission consists of several large elements all necessary to


Figure 21: Atlas V 551 Launch Vehicle
http://www.asdnews.com/news/

accomplish the objectives and goals of the mission. The SARS spacecraft will interface with the Atlas V 551 by use of the C-22 launch vehicle adapter (LVA). The C-22 is one of many standard adapters available form United Launch Alliance (ULA) for use with the Atlas V family of launch vehicles. The Atlas V 551 launch vehicle is shown in Figure 21.

F.2.2.1 Payload Fairing (PLF)

The Atlas V 551 comes equipped with a 5 meter outside diameter payload fairing. The short variation of the 5 meter fairing has an available internal diameter of about 4.5 meters and has a height of about 10.2 meters. This provides plenty of space to house the SARS spacecraft in preparation for and during launch. Figure 22 below shows the SARS spacecraft packaged inside of the PLF.

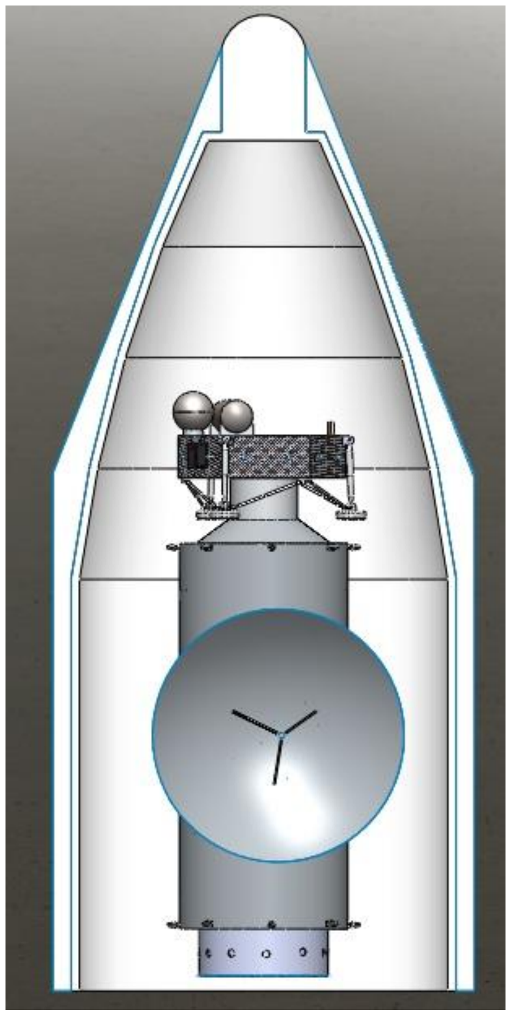


Figure 22 – Elements in Payload Fairing

F.2.2.2 Mass Constraints

The total mass allowed for the mission is 5500 kilograms. This was obtained using the Performance Query Tool from the NASA Launch Services website. Choosing the Atlas V launch vehicle family and a characteristic velocity (C3) of 7.6 km^2/s^2, the total launchable mass for the mission determined. In its current configuration, the SARS mission has a total mass of 4883 kilograms, including element margins. The SARS mission is well within the constraints of the Atlas V 551 launch vehicle.

F.2.2.3 Other Launch Vehicle Families

The SARS mission to Europa must be compatible with three families of launch vehicles. These three families are the Atlas V, the Delta IV, and the Falcon 9. Due to uncertainty about which launch vehicles will be available at the time the mission is to launch, the elements of the SARS mission must be easily adaptable to the three different LV's. This is fairly simple to ensure with the Atlas V and Delta IV LV's because of their greater performance and lift capacity as compared to the Falcon 9. The SARS mission is quite large and either of these launch vehicles could easily lift the elements of this mission into space and toward Europa.

The SARS mission is not, however, compatible with the Falcon 9 launch vehicles or any of the smaller Atlas V models. To make these viable options major changes must be made to the SARS mission. An alternate mission compatible with these launch vehicles is detailed at the end of this report in Appendix A.X.

F.2.3. Flight System Capabilities

F.2.3.1. Orbiter

The orbiter is responsible for getting SARS to Europa. Our mission was to choose the engines which will allow us to accomplish this objective. Since there are numerous possible engine configurations, it was necessary to classify these different engines and choose the proper location and quantity of each. Control is needed in all three directions of space, which is one of the reasons why there are so many varieties of engines available on the current market. Based on the parameters of weight, specific impulse, valve power, and thrust, three engines were selected for use. The first engine that was chosen was an Aerojet MR-111C (1.0-lbf). The second was an Aerojet MR-107K (50-lbf). It was determined that sixteen MR-111C engines and four MR-107K engines are needed for this mission. The MR-107K was the most efficient engine that would allow the spacecraft to rotate while the MR-111C was the most efficient engine that would maneuver the craft in the directions not provided by the main engine. The following two CAD drawings show a basic sketch of how they will be arranged on the outside of the orbiter to allow for rotation and translation.

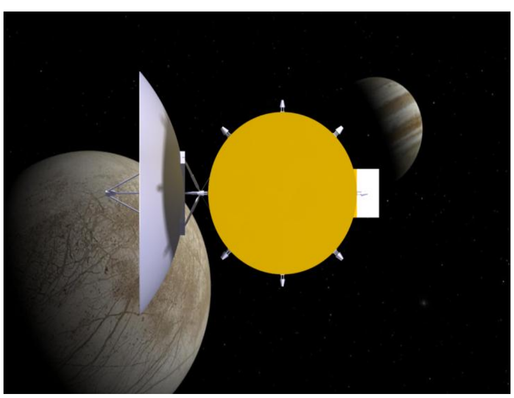


Figure 23: Eight (8) MR-111C engines located at either end of the orbiter.

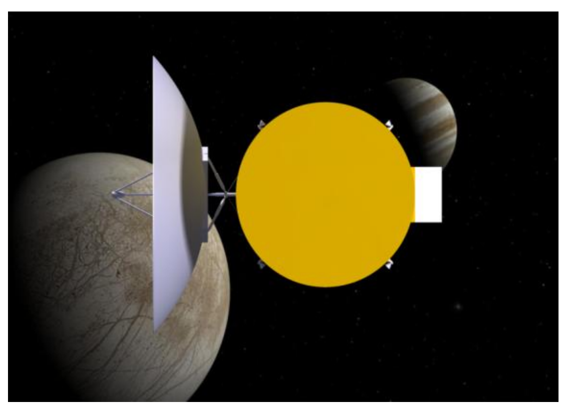


Figure 24: Four (4) MR-107K engines located at orbiter's center of gravity.

The orbiter will use the HiPAT DM engine as its main engine. This is the engine that will be used for the duration of the travel upon separation from the Atlas V-551 to Europa.
The propellant tanks are designed to be constructed with titanium because of its lightweight and high strength. Since the engines need both Hydrazine and NTO (Nitrogen Tetroxide) for fuel, different tanks had to be designed for each. By the calculations given in Appendix J.15, the spherical hydrazine tank has a mass of 114.32kg and a radius of 0.823m, while the spherical NTO tank has a mass of 68.89kg and a radius of 0.692m.

In a long mission where the demand for power is not continuous, regulating power that is used by the different subsystems is very challenging. Solar panels were considered, but due to the mass constraints and poor efficiency, it was determined that solar panels would not be a good option for power. The orbiter does have an ASRG with an 850°C high end operating temperature which provides approximately 160W of power. After reviewing the power demand of the instruments that are on the orbiter, it was determined that the 160W would not be enough to meet the demand if all the instruments were running. It was determined that two VES 180 rechargeable lithium batteries, which produce 175 W/hrs each, will be needed in case all of the instruments were running at the same time. Two batteries were chosen because one would supply the equipment along with the generator while the other would serve for backup in case of failure.

For any mission, the communication subsystem is a vital part because data has to be transmitted to and from Earth. The orbiter features a single antenna which can receive and transmit data from both the lander and Earth instead of integrating an antenna for just the lander transmissions and another solely for transmission back to Earth.

Antenna design is quite complicated because of its integration on the satellite. It could not be placed on top of the orbiter because the lander is connected there. Consequently, the antenna had to be put on the cylindrical face of the satellite. This meant that the antenna size would be limited by the Atlas V payload fairing envelope. Placing the antenna in this position caused an imbalance on the orbiter. In order to mitigate the unbalance, the other instruments were placed on the opposite side of the cylindrical hull to counteract the moment caused by the weight of the antenna. The calculations for the antenna are in section J.15. The antenna's structure consists of a 10mm thick sandwich structure of carbon fiber and Kevlar honeycomb. The antenna has a diameter of 3m and a depth of 0.5m. By basic calculations the mass of the antenna was determined to be 131 kg. The receptor weight had to be added to the weight of the antenna to obtain a total mass for the telecommunication subsystem. A Wideband Ka-band antenna from Octane Wireless was selected and has a mass of 227 g. The mounting brackets for the antenna system had to be taken into account, and it was assumed that the supports would be 10% of the mass of the antenna. Using known data and the assumption that the supporting structure would be 10% of the antenna mass, the total system mass was estimated to be 144 kg.

UAHuntsville assigned ESTACA the task of choosing the interface between the lander and orbiter. ESTACA chose the vehicle adapter's dimensions and determined what material and thickness should be used. The C22 LV adapter was chosen to connect between the Atlas V551 and the orbiter. The table below shows the details of the adapter.

Table 17: Launch Vehicle Adapter Summary	
Material	Integrally Machined Aluminum Construction
Mass	15kg
Thickness	2.81mm
Height	384.8 mm

Diameters	1,595.6 mm and 553.7mm

While there are 8 science instruments on the orbiter, other equipment is needed to make the sure that the mission is completed as planned. The most important system that is needed is navigation. It determines the position, acceleration, speed, and altitude of the spacecraft. There are many possible systems which measure some of these items, but two instruments were chosen to cover all four of the requirements. It was determined that an EADS Astrium Astrix3M2 would work well for this mission. It implements three gyroscopes which measure the acceleration and speed of the spacecraft. It was decided that the central axis of the orbiter would be the best location for this system. The second instrument chosen was a star tracker, which is an optical device that measures the position of stars using a camera. By comparing the measured position and the entire star field database of the star tracker, this system can determine the altitude of the orbiter. A SED36 star tracker was determined to fulfill the requirements and chosen to be included on the obiter. It is the most accurate star tracker developed by the CNES. The design is derived from the already flight proven SED26.

With any space mission there is only a limited window in which data can be transmitted from the obiter back to earth. The CORECI (Compression Recording Ciphering Unit) integrates the compression and recording for satellites. This unit stores the videos and images that are recorded by the science instruments and holds them until they can be transmitted back to earth. A solid state recorder is also needed to store and hold the data collected by the other instruments. Of the solid state recorders needed to fulfill the requirements, it was determined that the CORECI 2X which has 4Tbits of memory would fulfill the requirements of the mission.

There are a total of 17 instruments/tools that are being placed on the orbiter. The instruments can be broken down into two types: those that are on the outside of the orbiter and those on the inside of the orbiter. The star sensor and science instruments are on the exterior face of the orbiter, while the inertial reference system, energy generators, and data storage equipment are placed inside the orbiter. The measurement instruments were placed on the opposite side of the orbiter in order to keep its center of gravity on the axis of the cylinder since the antenna is so heavy.

For the framework structure of the orbiter, it was determined that a sandwich structure of carbon fiber and aluminum honeycomb would be capable of supporting the loads placed upon it. In order to protect the instruments on the inside of the orbiter from radiations and solar winds, a thickness of 20mm was chosen. The structure is cylindrical with a radius 1m and a length of 4.6m. Using some basic calculations, the total mass of the orbiter structure is 309kg which also includes 71.37kg to aid the structure for the stresses and loads placed upon it during take-off.

The total mass of the orbiter is the addition of the total structure mass and the total instrument mass. To account for hydraulic plumbing and electrical cabling, 10% of the combined structure and instrument mass was added. As a result, the dry mass of the orbiter is 904kg with the propellant mass being 2769kg. Combining these two numbers gives the orbiter a total mass of 3673kg.

F.2.3.2. Lander

F.2.3.2.1. Deployed Spacecraft Figure

The SARS lander is depicted in Figure 25 below.

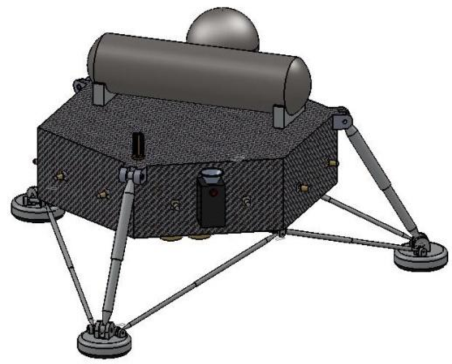


Figure 25: Deployed SARS Lander

F.2.3.2.2. Subsystem Design

F.2.3.2.2.1 Structure

The SARS Lander is primarily based on the Mars Polar Lander launched by NASA in 1999. The SARS Lander is a three-legged lander and measures 3.5 meters wide and just over 1 meter tall from the ground to the top of the science deck when the legs are fully deployed and has a mass of approximately 170 kg. The deployable legs support the science deck, a hexagonal shaped aluminum frame wrapped in composite exterior panels which houses the on-board systems. The polygon shape was chosen to minimize the lander's mass and dimensions. Through careful planning and equipment placement the spacecraft can easily be balanced about its center of gravity.

The lander is supported by three deployable leg assemblies which are radially spaced about the science deck. Each of the leg assemblies consist of a main leg which is connected to the lander and two supporting legs which are connected to the lander at one end and to the main leg at the other. The legs assemblies are extendable and are intended to deploy upon separation from the orbiting spacecraft. Prior to deployment the legs are stowed using spring-loaded mechanisms in a manner such that they do not extend past the bottom of the science deck. Upon landing the legs experience large compressive forces. In order to limit the effect of the landing force, the lander portion of the main leg assembly should be formed from a crushable material, such as aluminum honeycomb. At the end of each leg assembly is a circular footpad which contacts the planet's surface. The bottom of the footpad should be slightly spherical in shape in order to improve the stability of the lander on the planet's surface.

The main bus is separated into different compartments which serve to house the flight computer and science equipment. The various components must be arranged properly to maintain symmetry about the geometrical center of the polygon shape. In order to minimize cabling mass, the subsystem positions should be chosen in a complimentary manner.

F.2.3.2.2.2 Propulsion

After a suitable landing site has been chosen, the SARS lander will rely on a monopropellant propulsion system to achieve a soft landing on the surface of Europa. A monopropellant system was chosen because of the many advantages it offers over an alternative design. These advantages include cost, weight, and simplicity, mostly due to the fact that an oxidizer system is not necessary when using monopropellants. Monopropellant propulsion systems also have the ability to pulse, which will be necessary as the SARS lander is approaching the surface of Europa. Of the three monopropellants used on flight vehicles, hydrazine has the most desirable properties, including a high specific impulse, and will be used for this mission. Because hydrazine is highly toxic, it is possible that the first ice sample taken from the Europan surface will be contaminated. Therefore, this sample will be discarded.

A pressure fed system has been chosen because of the pulsing ability it offers. A pressure fed system also requires less pressure in the propellant tank. Therefore, the tank walls will feel less stress and can be thinner, making the tank assembly weigh less than one of an alternative configuration. The design also includes a barrel propellant tank, spherical pressurant tank, the temperature and pressure sensors, and the tank and line heaters necessary for operation. Helium has been chosen as the pressurant because of its low mass.

Dual Aerojet MR-80B rocket engines have been selected to provide the required thrust for the SARS lander. Each MR-80B provides up to 3100 N of thrust and 231 s of specific impulse. A mass value of 7.94 kg per engine is acceptable. The Aerojet MR-80B has been tested, is flight ready, and meets all of the requirements for completion of the mission. Figure 26 to the right depicts the AeroJet MR-80B Rocket that will be utilized on the SARS lander.

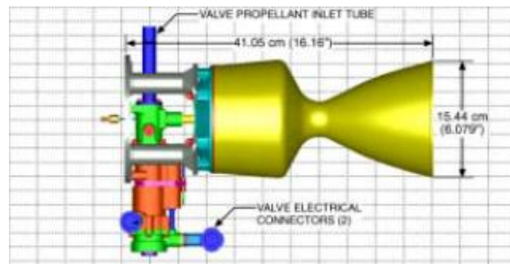


Figure 26: AeroJet MR-80B Rocket

F.2.3.2.2.3 Attitude Control System (ACS)

Once the lander separates from the orbiter, it will begin its descent toward the surface of Europa. To accomplish a safe soft landing the lander’s attitude control system (ACS) must steady and orient the lander so that it lands upright. The ACS is a very important system in assuring the success of the proposed surface science mission. The ACS must be able to cancel the lander’s horizontal velocity after separation so that the lander can descend vertically toward the surface. It must also be able to hold the lander in the proper position to ensure that the lander does not impact the surface at an odd orientation, which would cause catastrophic damage.

The components of the attitude control system include star trackers, a sun sensor, a radar altimeter, an inertial measurement unit (IMU) and several hydrazine thrusters. The star trackers will determine the orientation of the lander by matching the pattern of the stars at Europa to preprogrammed star maps. The sun sensor will also help to orient the lander during its descent by pointing a specific side of the lander toward the general direction of the sun. Once the desired orientation has been reached, the lander’s main propulsion system will be activated and begin to slow the lander’s descent. From this point until the lander has reached the surface, the radar altimeter will determine the distance the lander is from the surface and send this information to the lander’s on-board computer to ensure that the propulsion system throttles at the proper times to ensure a safe landing. The hydrazine thrusters will fire based on the information gathered by the star trackers and sun sensors to help maintain the lander’s orientation. The IMU will also orient the lander by centering the momentum of the lander around its center of gravity.

F.2.3.2.2.4 Command and Data System

The SARS lander will use two components for its Command and Data System (CDS) system. Team SARS will employ a SEAKR GEN-1 command and data handling subsystem and an AMPEX DSR400B solid state data recorder in order to facilitate the command and data handling and storage. The GEN-1 will perform all of the functions necessary for the lander's command, control, and power management. The system is based on the 3u compact PCI standard providing a high level of system capability in a small enclosure. The avionics system provides a common platform for both Command and Data Handling functions as well as electrical power distribution and management for most landers. The GEN-1 will be run by the RAD 750 SBC and will come with Guidance Navigation Interface (GNIF), Digital I/O, Controller, Analog Acquisition, Power Supply Connector, and Power Distribution Switches. Figure 27 shows a basic layout of the Gen-1 system.

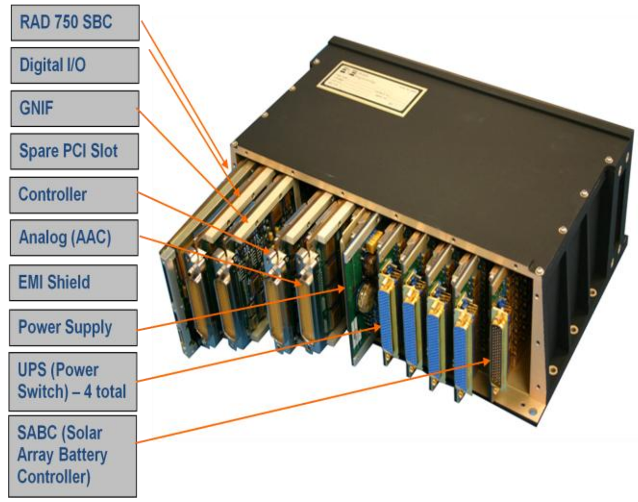


Figure 27 – SEAKR GEN-1

For data storage the AMPEX DSR400B has a sealed non-volatile, solid state memory cartridge that enables the solid state recorder to operate in the extreme environments and severe vibration and shock conditions encountered by most landers. The DSR400B can store either 72 GB or 1 TB depending on what option is needed. At the time of this writing, the exact parameters have not been defined, but future research will dictate which option should be utlized. A basic picture of the AMPEX DSR400B is displayed in Figure 28. The price of this system depends on which option is chosen. The 72 GB has a price of $27,000, while the 1 TB is $97,500.

Figure 28 – AMPEX DSR400B

F.2.3.2.2.5 Telecommunications

Data will be collected by the lander and transmitted to the orbiter. The Deep Space Network will then be used for communication between the orbiter and Earth. A diagram of this process is shown in Figure 29.

The lander will use the Ka-band and residual carrier BPSK modulation to transmit data to the orbiter. The USO (Ultra-Stable Oscillator) will oscillate the frequency to BPSK. There is approximately a 20 minute window every 2.1 hours that can be used for transmission between the orbiter and the lander; therefore, the lander will use a store and forward architecture which will allow storage of all collected data and the transmission of the data in the window allowed for communication to the orbiter.

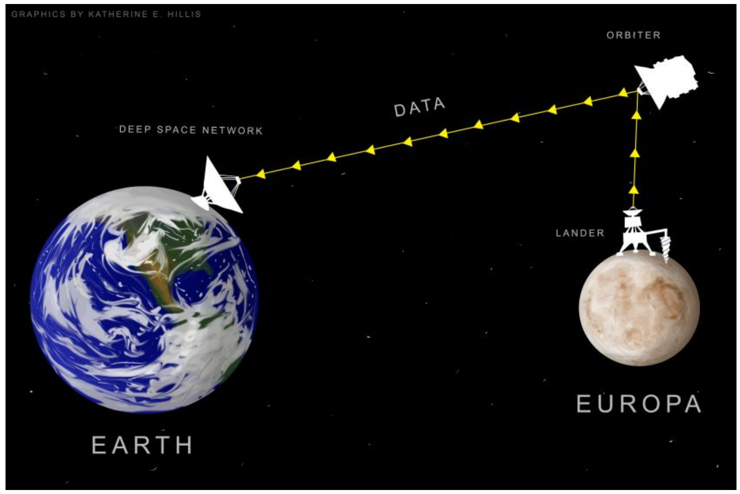


Figure 29: Lander Data Transmission

The Data System will compress the collected science data by 33% before it is transmitted to the orbiter. This compression is the standard for data collection missions. This compression will also allow the satellite dish attached to the lander to be much smaller because less data will have to be communicated to the lander and eventually to Earth. Communicating less data to Earth will cost the project less money because it will lessen the use of the Deep Space Network. The data rate needed after compression is 165.2 kbit/second. This data rate assumes a 2 minute window for the lander and orbiter to initiate communications and a 20 minute window for communication every 2.1 hours. The calculation also assumes the orbiter will pass directly over the lander. This assumption is valid because it is planned that the orbiter will have a polar orbit and the lander will be at one of the poles. This calculation also encompasses a margin for missed passes which multiplies the stored data by a factor of 5. This will ensure all data can be communicated without error.

The most significant concern when landing on Europa is the impact with the planet followed by the vibration of the landing. To allow the Telecommunications equipment to survive landing it will be cross-strapped. This will protect it from both the shock of impact and the vibration of the landing approach.

Ideally a heritage system would have been found for telecommunication; however, since no data was found the telecommunication system had to be sized using known equations and assumptions. Based on these assumptions (presented in the lander data transmission section) the telecommunication system will weigh in total about 3.1 kg and use approximately 10 W of energy. The diameter of the antenna will be approximately 0.02 meters and will have approximately 0.152 meters height.

F.2.3.2.2.6 Power

One primary power source was considered for the EELS mission, the ASRG, or Advanced Stirling Radioisotope Generator. The ASRG is a power system that uses Stirling power conversion technology. The Stirling cycle is used for the higher conversion efficiency as compared to that of radioisotope thermoelectric generators, or RTGs, which obtain their power from radioactive decay. The ASRG is currently in development by the United States Department of Energy and NASA. Finally, the ASRG has been proposed for the EJSM, Europa Jupiter Science Mission, and the TSSM, Titan Saturn System Mission.

Two ASRG units will be required to power the baseline EELS project. The ASRG has two levels of operation, one at 650 ^{O}C and one at. 850 ^{O}C. The ASRG used on the EELS mission will be the 850 ^{o}C system, which outputs approximately 160 Watts. Regardless of the operating temperature of the system, the ASRG has a power degradation of 0.8 % per year. With this in mind, approximately 8.5 years after launch, when the spacecraft will initially enter Europa's orbit, each ASRG will have approximate 149.12 Watts of power output. Furthermore, the ASRG has a relatively low mass of approximately 19 kg, meaning it will have a low impact on the overall mass requirements of the spacecraft. The Payload Power Profile show below gives the CBE (Current Best Estimate) values as provided by the subsystem engineers. When given subsystem power profiles, a completed power profile for the entire spacecraft will be created. The lander profile is in figure 30 to the right.

Europa Lander Power Profile (Watts)	Launch	Transit to Europa	Trigger Values for Landing	Lander: Main Science Investigation [2 - 3 Weeks]
Payload				
Magnetometer	0	0	0	29.3
Advanced Gravimeter	0	0	0	0.3
Atmospheric Science Package	0	0	0	3.2
Drill Camera	0	0	0	1.0
GCMS	0	0	0	40.0
Microscopic Camera	0	0	0	1.0
Subsystem				
Telecom	0	0	0	10
Thermal	0	0	0	0
Propulsion	0	0	336	0
ACS	0	0	0	76
CDS	0	0	0	77
Totals	0	0	336	237.8
* Required to trigger values on motors during landing				

Figure 30: Lander Power Profile

In order to complete the EELs mission, a secondary power source is required to trigger values on motors during landing. For this reason, one eight-cell Lithium-ion battery will be used for transient demands for power. The lithium-ion battery depth of discharge is limited to no more than 40%. The battery is charged when excess ASRG power is available.

The total power output of the two ASRG units upon initially entering Europa's orbit is approximately 298.24 Watts. One ASRG will be assigned to the orbiter, and the other will be assigned to the lander for the respective system's science. The orbiter main science mission will require a power output of approximately 75.15 Watts, while the lander main science mission will require approximately 47.15 Watts. With approximately 149.12 Watts of power output on both the lander and orbiter, the ASRG will produce more than enough power for both science missions.

F.2.3.2.2.7 Thermal

During the mission to Europa, there are two huge obstacles the thermal control system encounters: radiation and extreme cold temperatures at the pole of Europa. Since Europa lies within Jupiter's harsh radiation bands, radiation is a constant threat to the mission. In order to protect all of the equipment on the lander from the radiation, shielding along with radiation hardening the payload instruments will be employed. A Radiation/Louver system will be utilized in order to keep the equipment on the lander within operating temperature ranges

Based on the assumption that each instrument on the lander will be radiation hardened to have a Total Ionizing Dose (TID) tolerance of 300 krad and a Displacement Damage Dose (DDD) tolerance of 7.2E8 MeV/g (Si), and using a radiation design factor of 2, Tantalum (WCu) will be used as the shielding material at a thickness of 0.35cm (~138 mil). At a 0.35 cm thickness, Tantalum shields to have a TID of 150 krad and a DDD of 3.6E8 MeV/g (Si) behind the shield. Shielding the entire lander creates an excessive amount of mass and is unnecessary, so each payload instrument set, CDS components, and the antenna will be shielded in separate, tight boxes composed of Tantalum. According to the areas required for all equipment needing to be shielded and the shielding thickness required, the total mass for radiation shielding is 81.13 kg.

Direct solar energy and Planetary IR energy for Europa were considered to be about the same as Jupiter due its close proximity to Jupiter; direct solar is 51 W/ m^2 and planetary IR is 13.6 W/ m^2. View factors for the lander, F_1 and F_2, were both determined to be ¼ because the lander will be on the surface and on the pole of Europa. With the area of the lander and the IR emissivity of the lander material taken into account along with the solar properties of Europa, an equation for the equilibrium temperature was used to determine the maximum and minimum internal temperatures of the lander.

According to the operating temperature ranges of the payload instruments, the internal temperature of the lander needs to be between 0˚C and 40˚C. Considering the mechanical efficiency to be about 32%, the maximum internal power dissipation from all systems on the lander is determined to be about 736 W and the minimum dissipation is about 340 W. With the internal power dissipation and thermal properties experienced on the surface of Europa, the minimum internal temperature is roughly 101˚C and the maximum temperature is about 233˚C. Because the maximum and minimum internal temperatures are higher than the maximum operating temperature, a radiator/louver system is used to dissipate the excess heat.

In order to dissipate the amount of heat needed to maintain the temperature of the lander, the radiator needs to release 779.89 W and requires an area of 1.79 m^2. At this area, using 0.305 m x 0.267 m aluminum louvers, 22 louvers are needed with a total mass of 7.77 kg. The louvers will use a bi-metallic actuator set to open at 40˚C and close at 27˚C. A 5056 Aluminum honeycomb radiator will be used in conjunction with the louvers and has a mass of 1.53 kg. The total mass of the entire thermal control system will be 90.42 kg and the system will require no power.

F.2.3.2.3. Mass Breakdown Table

Table 18 shows the mass breakdown of the SARS payload.

Table 18 – Mass Breakdown Table

Total Payload Mass: 5500 kg
Contingency 516 kg
Lander Margin 270 kg
Lander Dry Mass 456 kg

Lander Propellant Mass 484 kg
Spacecraft Margin 100 kg
Spacecraft Dry Mass 903 kg
Spacecraft Propellant Mass 2769 kg

F.2.3.2.4. Power Profile Figure

The lander power profile is presented in the table below.

Table 19 – Power Profile Figure

	Landing	Mission				Disposal
		Navigation Control	Temperature Below X	Preparation for Drill	During Transmission	
Telecom	Off	Off	Off	Off	On	Off
Thermal	Off	Off	On	Off	Off	Off
Drill	Off	Off	Off	On	Off	Off
CDS	On	On	On	On	On	Off
Payload	Off	Off	Off	Off	Off	Off
Propulsion	On	Off	Off	Off	Off	Off

ACS	On	On	Off	Off	Off	Off

F.2.4. Additional Mission Elements

To accomplish the penetration and extraction of the ice surface the design includes an ice coring drill and a robotic arm to deliver and support the drill.

The drill head itself is a scaled down version of the current ice coring drill used on earth to investigate arctic ice. It includes a three blade system that breaks up the ice while a hollow section in the middle surrounds the ice sample. An internal threading is included in the hollow area of the drill to grip onto the ice sample and extract it after drilling is complete. The drill itself is not a full meter long and so will require multiple extractions at the same site to reach the required one meter depth.

The Ice grip is a device that is also a scaled down version of a device currently used in core drilling. It consists of three leaf spring blades and an internal spring that pulls the base platform upward. This pushes the leaf spring blades out creating an expansion against the tube of ice previously drilled. The blades then bite into the tube to prevent rotating providing a stable platform for the drill head to rotate from.

The robotic arm consists of three major components: a delivery tube, a ball screw, and a rotating base. The delivery tube has an external threading that acts as an acme screw to raise and lower it from the landing vehicle to the ice surface. It contains the drilling system internally and has groves to accommodate the blades of the ice grip and prevent rotation while still inside the delivery tube. The ball screw system provides linear translation to extend the delivery tube containing the drill away from the landing vehicle. Finally the rotating base allows the system to rotate back towards the landing vehicle and deliver the sample to the analysis equipment

The proposed solution will use brushless DC (BLDC) motors to operate the robotic arm and drill, since BLDCs are considered optimal for space application, taking into consideration of the environmental factors of Europa. BLDCs are ideal alternatives to steppers, because brushes can be unreliable in vacuum; elimination of brushes, commutators and sliding contracts in BLDCs improves life and reliability as there is no wearing of components. They can be designed for high speed operation, since the speed limitations of brushes and commutators are eliminated. Their properties are- speed proportional to supply voltage, torque proportional to the armature current, and start/stall torque higher than the running torque. BLDCs used for the proposed solution need to meet requirements of space applications like high reliability, robustness, reduced mass and power consumption, capability to withstand space radiation during operational life, vibration and shock. These criteria impose constraints on lubrications, bearings, and materials used.

Inadequate lubrication of sliding/ rotating metallic surfaces exposed to these environments, results in excessive wear, erratic performance and cold welding of surfaces and catastrophic failures. For space applications, the lubricants must have very low vapor pressure to prevent premature evaporation. Thus, solid lubricants like molybdenum-disulphide, provide for long life performance in spacecrafts. Thin film coatings are applied by vacuum decomposition and they adhere to metal surfaces by molecular bonding. Extremely low vapor pressure of solid lubricants permits the use of conventional open configurations eliminating complex seals of uncertain reliability. Lubrication mechanism is independent of ambient pressure and is only slightly affected by temperature. Additionally, they are not susceptible to radiation damage.

To prevent the motor from Europa's environment of low temperature and high radiation, it will be housed in an Aluminum encasing. Thus to meet project requirements, a BLDC motor with a power consumption of 34.2 W has been chosen. Low speed operations use brushed dc motors with gold plated commutators and silver/copper graphite/ self lubricating brushes for space applications.

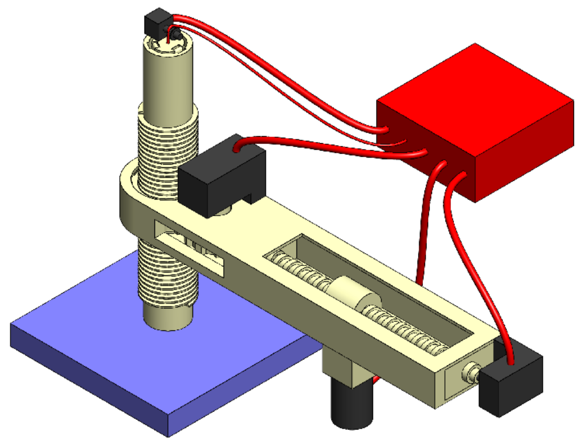


Figure 31: Ice Coring Drill

The control system intends to operate the four motors of the robotic arm and the motor that powers the drill. Since project requirements state that the maximum power available at any instant of time is 40W, only one motor can function at any given time, thus implying that only one component of the RA and drill will function. Thus the entire system works in a sequential fashion. Figure 31 depicts the Ice Coring Drill designed by CSULA.

F.2.5. Flight Systems Contingencies and Margins

The SARS spacecraft has a mass growth margin of 11% allocated to it. This margin is low because the design of the spacecraft cut deep into the mass margin. The SARS lander has a 25% mass growth margin and a 12% contingency. There is also an 11% contingency for the overall mission. This is also very low due to the design of the orbiter taking much more mass than was initially allocated to it.

F.2.6. Mission Operations

F.2.6.1. Deep Space Network (DSN) Usage

The SARS mission will use the Deep Space Network (DSN) to communicate with both the lander and orbiter. The extreme distance covered by the mission and constraints imposed by the launch vehicle have dictated that the SARS mission employ a telecommunications relay link between the lander and Earth. Therefore, an orbiter has been designed to serve as both a science platform and a relay link to the lander. Because the mission requirements vary over a broad range, it is not possible to provide a cost estimate for use of the DSN to support the SARS mission this early in the mission planning.

F.2.6.1.1. Tonal Signaling

In order to save money on DSN usage, the engineers decided to use a method of sending information over the DSN called tonal signaling. This method involves sending "notes" of certain pitches to indicate different statuses. Using this, a somewhat complex message can be sent using a very minute amount of bandwidth.

F.3. Development Approach

For this mission many different plans, tools, processes for requirements, and interfaces were used in order to maintain the level of communication needed for this project. Skype conference calls, DropBox, hundreds of emails, hundreds of text messages, and many phone calls allowed this project to come together. An ICD (Internal Control Document) was sent to ESTACA which defined what they were supposed to do. The actual management of the partners was a group effort by the Lead Systems Engineer, the Project Engineer, and the Project Manager. These three individuals were responsible for making sure that the heritage of mission elements was determined, trade studies were conducted, and that the special processes were not neglected.

F.4. New Technologies/Advanced Developments

No new technologies are suggested in this proposal.

F.5. Assembly, Integration, Test, and Verification

The test and verification for the SARS spacecraft will be performed by United Launch Alliance prior to launch. The test and verification procedures will be handled at Kennedy Space Center.

F.6. Schedule

Figure 32 shows the planned schedule for the proposed mission.

Mission Schedule	Start Date	Duration (days)	End Date	8/10/2010	5/1/2011	11/31/2012	2/28/2014	5/31/2015	12/31/2017	8/1/2026
Pre-Phase A	**8/10/2010**	275	**5/1/2011**							
Concept Studies	8/10/2010	275	5/1/2011							
Phase A	**5/1/2011**		**11/31/2012**							
Concept Development	5/1/2011	545	11/31/2012							
Phase B	**11/31/2012**		**2/28/2014**							
Preliminary Design and Fabrication	11/31/2012	485	2/28/2014							
Phase C	**2/28/2014**		**5/31/2015**							
Final Design and Fabrication	2/28/2014	460	5/31/2015							
Phase D	**5/31/2015**		**12/31/2017**							
System Assembly	5/31/2015	365	5/31/2016							
Test and Verification	5/31/2016	545	12/1/2017							
Launch	12/1/2017	30	12/31/2017							
Phase E	**12/31/2017**		**8/1/2026**							
VEEGA	12/31/2017	2912	1/1/2026							
Transition to Europa Orbit	1/1/2026	90	3/31/2026							
Orbiter Mission	4/1/2026	245	12/31/2026							
Lander Seperation and Touchdown	7/4/2026	5	7/9/2026							
Lander Mission	7/4/2026	28	8/1/2026							
Phase F	**8/1/2026**		**9/1/2011**							
Orbiter Closeout	**8/1/2026**	30	8/31/2026							
Lander Closeout	8/1/2026	30	8/31/2026							

Figure 32 – Gantt Chart

G. Management

G.1. Management Approach

The UAHuntsville team used a modified working group structure. The structure could not be truly considered a working group due to the use of a team-based structure several times throughout the course of the project. Weekly meetings were used as a time of status updates and group decisions. Work was assigned to team members each week, and status report of the previous week's work was expected upon the next meeting. The organizational structure can be seen below in Figure 33.

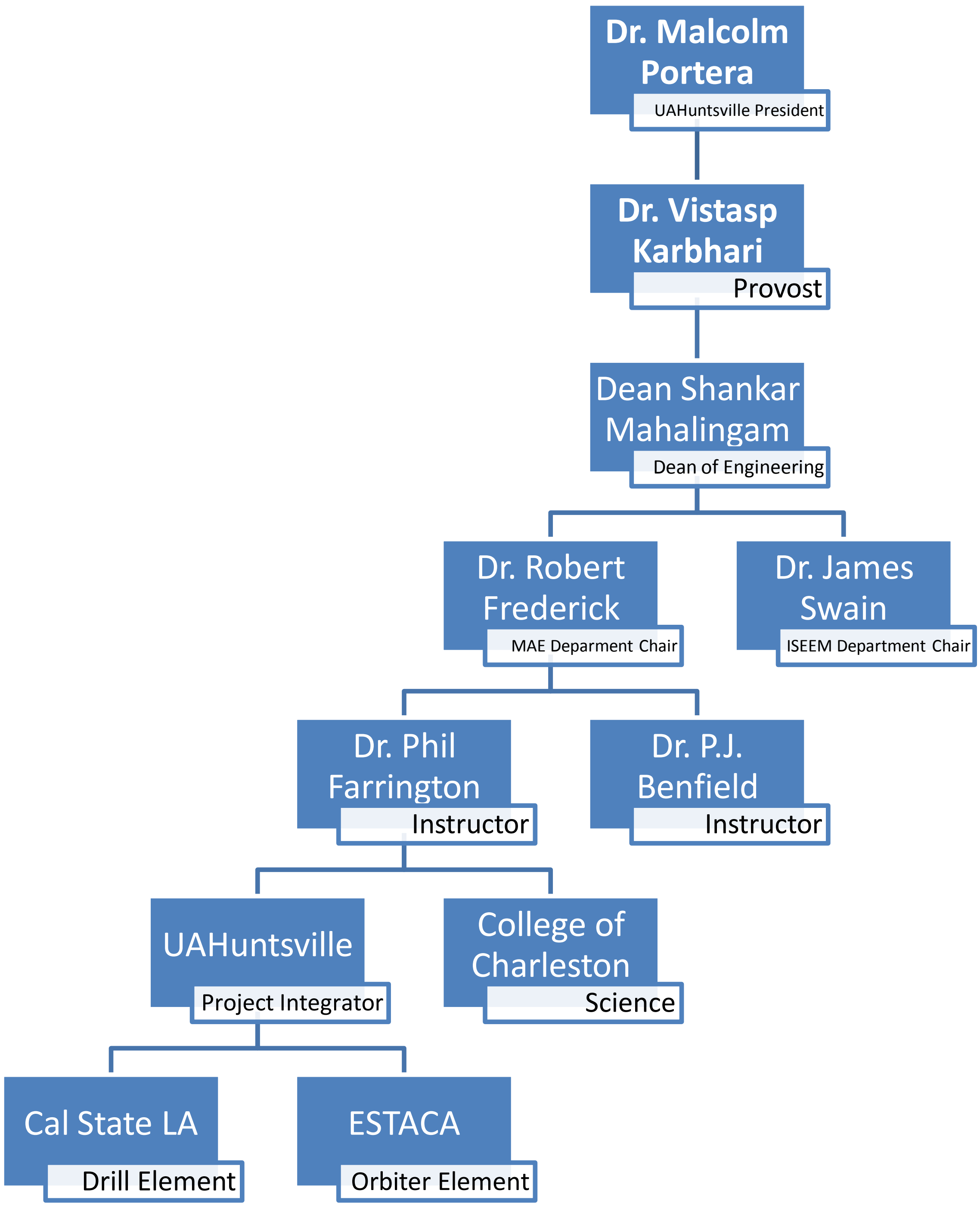


Figure 33 – Management Structure

G.2. Roles and Responsibilities

Project Manager – Phil Jackson

The project manager is responsible for successful integration of all mission elements, partner communication, and overall completion of the project.

Principle Investigator – Jordan Adams

The principle investigator is responsible for inventing a mission, and determining the instruments required to accomplish objectives required for the achievements of these objectives.

Chief Engineer – Robbie Hill

The chief engineer oversees the engineering of the project. All design decisions pass through him. He also manages all mass and power for the mission.

Lead Systems Engineer – Anthony Bekken

The lead systems engineer manages the integration of all design work. He also handles integration of partner elements into the UAHuntsville engineering design.

G.3. Risk Management

The team has identified several technical risks that may hinder the success of the EELS mission. Each risk is evaluated based on probability and result of the risk on a scale from 1-5. The Risk Assessment Matrix is shown below in Figure 34. The scale used for the risk assessment, in accordance with JPL's *Qualitative Risk Assessment* standards, is shown below in Figure 35. Plans for mitigation have been determined for each risk and the outcome to the mission assets has been determined in both scenarios: if the risk is mitigated, or if the risk affects the mission. The mitigations are of utmost importance for this mission to succeed.

	Probability	**Effect**
1	Very High	Disastrous
2	High	Critical
3	Moderate	Moderate
4	Low	Marginal
5	Very Low	Minimal

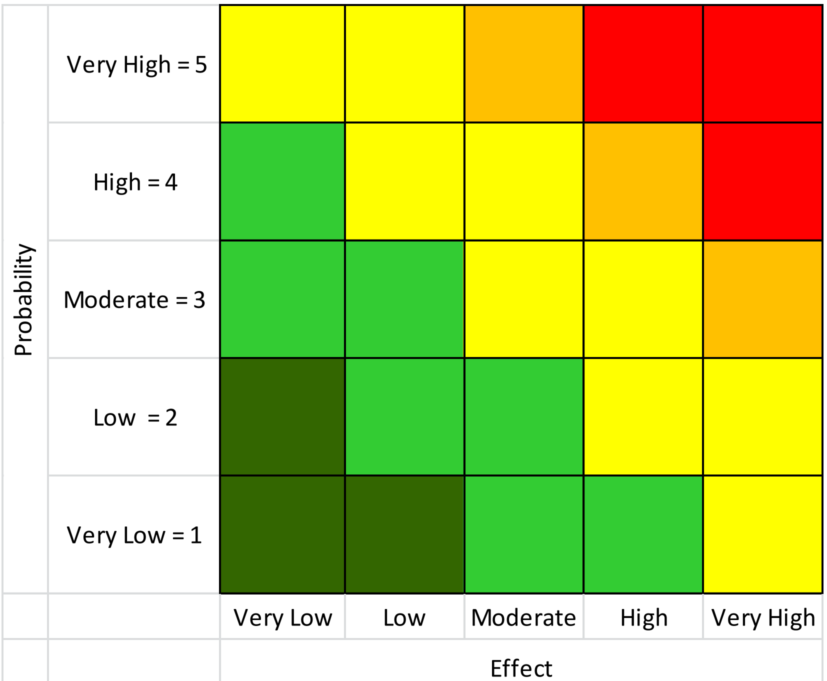
Figure 34.

Risk	Cause	Mitigation	Effect	Consequence
Radiation effects in parts, sensors, and materials	Considering the proximity to Jupiter and the large amount of radiation exposure to the spacecraft, if the radiation effects in parts and materials are greater in magnitude than expected, early failures may occur	1. Parts testing during Pre-phase A to consider radiation effects on circuits and systems 2. Develop an MIUL (Materials	Original: 3 Mitigated: 2	Original: 4 Mitigation: 4

		Identification Usage List) to incorporate Total Ionizing Dose		
Internal Charging	With the proximity to Europa and Jupiter in mind, there are many charged particles that are a source of internal charging via electrostatic discharge	1. strict design guidelines specifically encompassing max length of ungrounded wire and use of ungrounded metal	Original: 2 Mitigated: 2	Original: 1 Mitigation: 1
Instrument Development	The instruments on the payload are based on unradiated missions. For EELS, radiation will impact payload instruments to a large degree which must be resolved	1. develop higher fidelity shielding models 2. testing sensors and detectors to determine long term risks from radiation	Original: 4 Mitigated: 2	Original: 3 Mitigation: 2
Operations Complexity	science and spacecraft operations response to unplanned faults regarding recovery and ability to readjust risks some science goals	1. use new engineering methods to develop a balanced mission scope with complexity, risk and cost	Original: 4 Mitigated: 2	Original: 3 Mitigation: 2
Planetary Protection	contamination problems regarding enroute travel to launch pad and various testing sites	1. enclosure for traveling from site to site and from site to launchpad	Original: 2 Mitigated: 1	Original: 2 Mitigation: 1
ASRG Availability	considering the relative newness of the Advanced Stirling Radioisotope Generator, delays in production are crucial to this mission	1. ensure characteristics are well-defined and provide a proper justification for each to allow system engineers to incorporate the necessary characteristics into the system	Original: 3 Mitigated: 1	Original: 2 Mitigation: 2
Mission Lifetime	with travel time and required Jupiter orbit EELS exceeds a 10 year mission. Most electronics testing does not surpass 7 years, meaning results of testing will be inaccurate to a degree	1. Advanced parts testing, such as that on Voyager, New Horizons, and Galileo, must be performed on instruments 2. review *Long Life Design Guidelines* [JPL D-48271] which documents several long life missions designed by JPL	Original: 4 Mitigated: 2	Original: 3 Mitigation: 1

Figure 35 – Risk Mitigation

Risks critical to this mission, as show in the above table, are show below in the Risk Matrix. The key to the right correlates the values on the matrix to the table above. The subscript on each number refers to the original or mitigated value, with o and m respectively. The purpose of the risk matrix is to easily relate the risk explanations above with a numerical representation below in Figure 36.



Key	
1	Radiation Effects
2	Internal Charging
3	Instrument Dev.
4	Operations
5	Planetary Protection
6	ASRG Availability
7	Mission Lifetime

Criticality	
(red)	Change baseline plan
(yellow)	Consider Alternative process; Review regularly
(dark green)	Review periodically

Figure 36 – Risk Matrix

G.4. Contributions and Cooperative Arrangements

The SARS team contributors included the College of Charleston, California State University Los Angeles (CSULA), and ESTACA. The College of Charleston was an original contributor to the mission. They began working at the same time as SARS developing the objectives and goals of the science mission. SARS has communicated on a weekly basis with College of Charleston for the entire duration of the mission planning and design periods. California State University Los Angeles began their contribution to SARS three months into the project. Communication was not as strict at the beginning of the partnership. This led to issues with the CSULA team misunderstanding requirements and their contribution to the mission. These issues were quickly resolved and communication was strictly enforced for the remainder of the design period. The SARS team is pleased with the results ultimately obtained from the CSULA team. ESATACA's contribution began after the mission planning stage, at the beginning of the design stage. They did not have much to contribute at first due to delays in the SARS team establishing requirements and developing the Interface Control Document (ICD). Communication was also an issue with ESTACA. The flow of information was not as continuous and frequent as desired. Both sides were at fault for this and the issues that resulted. Had communication been better emphasized as with the other partners, the partnership would have gone much more smoothly and better results would have been attained.

H. Cost and Cost Estimating Methodology

H.1 Cost Model

The mission cost was calculated using the Hamaker Space Craft Cost Model Input. There are specific inputs that the model need, such as: dry mass, instruments mass, power sustainability, design length and so forth. The model is displayed below and shows what are the inputs and outputs of the calculated data. The model calculates cost in 2004 dollars and the total cost is multiplied by 1.15435 to obtain the mission cost in 2010 dollars.

Table 20 - Lander's Cost Module

Variable Description	**Input Cells**	**Variable Unit**
Enter Spacecraft Bus+Instruments Total Dry Mass	470	KG
Enter Spacecraft Total Power Generation Capacity(LEO Equivalent)	200	W LEO Equivalent Flux
Enter Design Life in Months	3	Months
Enter the Number of Science Organization	1	Count(Enter zero for projects with no science or science organization involvement)
Enter Apogee Class	4	LEO=1, HEO=/GEO=2, beyond GEO=3, Planetary=4
Enter Maximum Data Rate Requirements Relative to SOTA Expressed as Percentile	50.00%	Kbps requirements relative to the state -of-the-art for the ATP date expressed as a percentile where 0%= very low, 50%=SOTA, 100% is maximum
Enter Test Requirements Class	2	Less than average testing=1, Average=2, High=4, Very high Volatility=5
Enter Requirements Stability Class	2	Stable funding =1, some instability=2,significant instability=3
Enter Team Experienced Class [Derived from Price Model;with permission from Price Systems LLP]	4	Extensive experience=1, Better than Average=2, Average(mixed experience)=3, unfamiliar=4
Enter Formulation Study Class	2	Formulation Study(1=Major, 2=Nominal, 3=Minor)
Enter New Design Percent	51	Years Elapsed Since 1960
Enter ATP Date Expressed as Years Since 1960	$165.00	PPT&E + TFU(Phase C/D/E) in Millions of 2004 Dollars including fee, excluding fuel cost
Regression Model Result	$6.00	Refer to NASA TRL Scale(TRL 6 is nominal)
Enter Technology Readiness Level (TRL) Penalty Factor	2.2	Platform factor(Airborne Military=1.8, Unmanned Earth Orbital=2.0,Unmanned Planetary=2.2,Manned Earth Orbital=2.5, Manned Planetary=2.7)
Enter Platform Factor[Derived from Price Model; use with permission from Price Systems LLP)	To be added later	To be added later
Enter Functional Complexity Factor	$209.30	Subtotal(Millions of 2004 Dollars Including fee)
Subtotal (Non Full Cost Subtotal)	42.1	Civil Service Annual Full Time

		Equivalents(FTEs)
Calculated size of Government Project Office	42.1	Civil Service Annual Full Time Equivalents(FTEs)
Enter Override of Calculated Government FTEs	42.1	Civil Service Full Time Equivalents(FTEs)
Final Estimate of the size of the Government Project Office and other Oversight(Excludes Government Non-Oversight Labor which is included in Subtotal above)	$280,000.00	Thousands of Dollars
Enter Civil Service loaded Annual Labor Rate Including Center and Corporate G&A	42	Months
Calculated Project Phase C/D Schedule Duration(Excludes O&S Phase E)	42	Months
Enter Override of Calculated Phase C/D Schedule Duration(or leave zero to accept calculated duration)	42	Months
Final Estimate of the Project Phase C/D Schedule Duration	$41.00	Millions of 2004 Dollars
Calculated Cost of the Government Project Office	4	1=Minimum use of service pools, 2=Less than average, 3= Average, 4=More than average, 5= significantly more than average
Government Service Pool use Intensity Factor	$25.10	
Calculated Cost of Government Service Pool Use(or leave zero to accept the calculated service pool cost)	$0.00	
Final Estimate of the Cost of Government Service Pool Use	$25.10	
Subtotal (2004$)	$275.40	
Ground System	$24.80	
Enter Override of Calculated Ground System Cost	$0.00	
Final Estimate of the Cost of Ground System	$24.80	
Subtotal (2004$)	$300.20	
Enter Launch Services Cost	$79.00	
Enter Costs Reserve	$0.00	
Total(2004$)	$379.20	
Total(2010$)	**$437.71**	

Table 21 - Orbiter's Cost Module

Enter Spacecraft Bus+Instruments Total Dry Mass	903.8	KG
Enter Spacecraft Total Power Generation Capacity(LEO Equivalent)	353.45	W LEO Equivalent Flux
Enter Design Life in Months	1	Months
Enter the Number of Science Organization	1	Count(Enter zero for projects with no science or science organization involvement)
Enter Apogee Class	4	LEO=1, HEO=/GEO=2, beyond GEO=3, Planetary=4
Enter Maximum Data Rate Requirements Relative to SOTA Expressed as Percentile	50.00%	Kbps requirements relative to the state -of-the-art for the ATP date expressed as a percentile where 0%= very low, 50%=SOTA, 100% is maximum
Enter Test Requirements Class	2	Less than average testing=1, Average=2, High=4, Very high Volatility=5
Enter Requirements Stability Class	3	Very low volatility=1, low=2, Average=3,High=4, High Volatility=5
Enter Funding Stability Class	2.0	Stable funding =1, some instability=2,significant instability=3
Enter Team Experienced Class [Derived from Price Model;with permission from Price Systems LLP]	4	Extensive experience=1, Better than Average=2, Average(mixed experience)=3, unfamiliar=4
Enter Formulation Study Class	2	Formulation Study(1=Major, 2=Nominal, 3=Minor)
Enter New Design Percent	70.00%	Simple mod=30%, Extensive mod=70%, New=100%
Enter ATP Date Expressed as Years Since 1960	51 yrs	Years Elapsed Since 1960
Regression Model Result	$199.07	DDT&E + TFU(Phase C/D/E) in Millions of 2004 Dollars including fee, excluding fuel cost
Enter Technology Readiness Level (TRL) Penalty Factor	6	
Enter Platform Factor[Derived from Price Model; use with permission from Price Systems LLP)	2.2	Platform factor(Airborne Military=1.8, Unmanned Earth Orbital=2.0,Unmanned Planetary=2.2,Manned Earth Orbital=2.5, Manned Planetary=2.7)
Enter Functional Complexity Factor	To be added later	To be added later
Subtotal(Non Full Cost Subtotal)	$252.5	

Calculated size of Government Project Office	48	Civil Service Annual Full Time Equivalents(FTEs)
Enter Override of Calculated Government FTEs	48	Civil Service Full Time Equivalents(FTEs)
Final Estimate of the size of the Government Project Office and other Oversight(Excludes Government Non-Oversight Labor which is included in Subtotal above)	48	
Enter Civil Service loaded Annual Labor Rate Including Center and Corporate G&A	$280,000.00	Thousands of Dollars
Calculated Project Phase C/D Schedule Duration(Excludes O&S Phase E)	49	Months
Enter Override of Calculated Phase C/D Schedule Duration(or leave zero to accept calculated duration)	49	Months
Final Estimate of the Project Phase C/D Schedule Duration	49	Months
Calculated Cost of the Government Project Office	$55.20	Millions of 2004 Dollars
Government Service Pool use Intensity Factor	4	1=Minimum use of service pools, 2=Less than average, 3= Average, 4=More than average, 5= significantly more than average
Calculated Cost of Government Service Pool Use	$30.3	
Final Estimate of the Cost of Government Service Pool Use	$30.3	
Subtotal (2004$)	$338.0	
Ground System	$30.4	
Enter Override of Calculated Ground System Cost	$0.00	
Final Estimate of the Cost of Ground System	$30.4	
Subtotal (2004$)	$368.4	
Enter Launch Services Cost	$79.0	
Enter Costs Reserve	$0.00	
Total(2004$)	$447.4	
Total(2010$)	**$516.47626**	

The overall cost depends on the TRL levels. The table below shows the final cost of the mission, but the TRL level will be discussed in the next paragraph.

Table 22 - Total Mission Cost

	Costs	
Lander's Cost	$437.71 million	
Orbiter's Cost	$516.48 million	
NEPA	$20 million	
Atlas V551	$68 million	
Systems Cost	$1042.19 million	
Cost Margin	$312.66 million	Cost Margin is Reserved at 30%
Total Mission Cost(Bil)	**1354.847= $1.3548 billion**	

The TRL(technology readiness level) of 6 was chosen for the lander, because all the subsystems in the lander have been used in a successful mission by NASA or is going to be used on a NASA mission in the near future. To be more clear, TRL level 6, is the level by which a system or subsystem for a particular science design and instruments has been designed and tested in a relevant environment including ground and space. This is also the stage where the system or subsystem has developed beyond ad-hoc, patch-cord or a finite component level of bread boarding. These systems will be tested in a relevant environment of space and if a relevant environment of space cannot be duplicated, then the pro-type of the system/subsystem has to be tested in space.

Table 23 – TRL Explanation

Lander's Subsystem	**Mission**	**TRL Level**
Power	Europa Jupiter Mission(2020), Titan Saturn System Mission(2015)	6
Telecom	Cassini	6
Structures	Nasa Mars Polar Lander	6
Thermal	Gaileo	6
ACS	NASA Mars Polar Lander and Gaileo	6
Total		**6**

The spacecraft cost was calculated by adding up all the masses allocated for the subsystems. The lander and orbiter data was calculated separate because, even though ESTACA is responsible for their orbiter, we have to cost the orbiter in case ESTACA runs into any financial problems. The lander cost included, calculating the technology readiness level, power, mass, design life , and mission life. There are other factors in the regression model and heuristics that are included to get an accurate mission cost. The NEPA cost of $20 million and the launch vehicle upgrade cost of $68 million was also added to the cost. We were given a budget of eight hundred million dollars, but for just the lander and orbiter, the budget is only exceeded by $242.18 million. When the thirty percent margin is added into the cost, the total mission cost exceeded the budget by $554.84 million. The SARS final mission cost is $1.3548 billion.

I. Acknowledgement of Education and Public Outreach, and Optional Student Collaboration

I.1. Education and Public Outreach

I.1.1. "I understand the NASA SMD requirements for E/PO and I am committed to carrying out a core E/PO program that meets the goals described in the *Explanatory Guide to the NASA Science Mission Directorate Educational and Public Outreach Evaluation Factors* document. I will submit an E/PO plan with my Concept Study Report if this proposal is selected."

I.1.2. As part of an Education and Public Outreach section of this proposal, a number of post doc professionals, graduate, and undergraduate students will be hired to analyze the data over the duration of the mission. Currently it is planned to hire three post-docs to work full or part time (depending on the stage of the mission), four graduate students part time (during the academic year), four undergraduate students part time (during the academic year), and two more undergraduate students working part time during the summer break of their academic semesters.

I.2. Student Collaboration

I.2.1. Two high school teams design experiments to be integrated into the mission. These teams competed for the opportunity to have their elements included. UAHuntsville was the group that awarded the preferred design a spot on the spacecraft.

I.2.2. Buckhorn High School Proposal

This group's team name is the B.U.C.K.S. (Brainstorming Universal Creations Kick-starting Systematics in schools.) from Buckhorn High School. The payload that is being planning to send to Europa is named Spock. The team logo is shown below in Figure 37

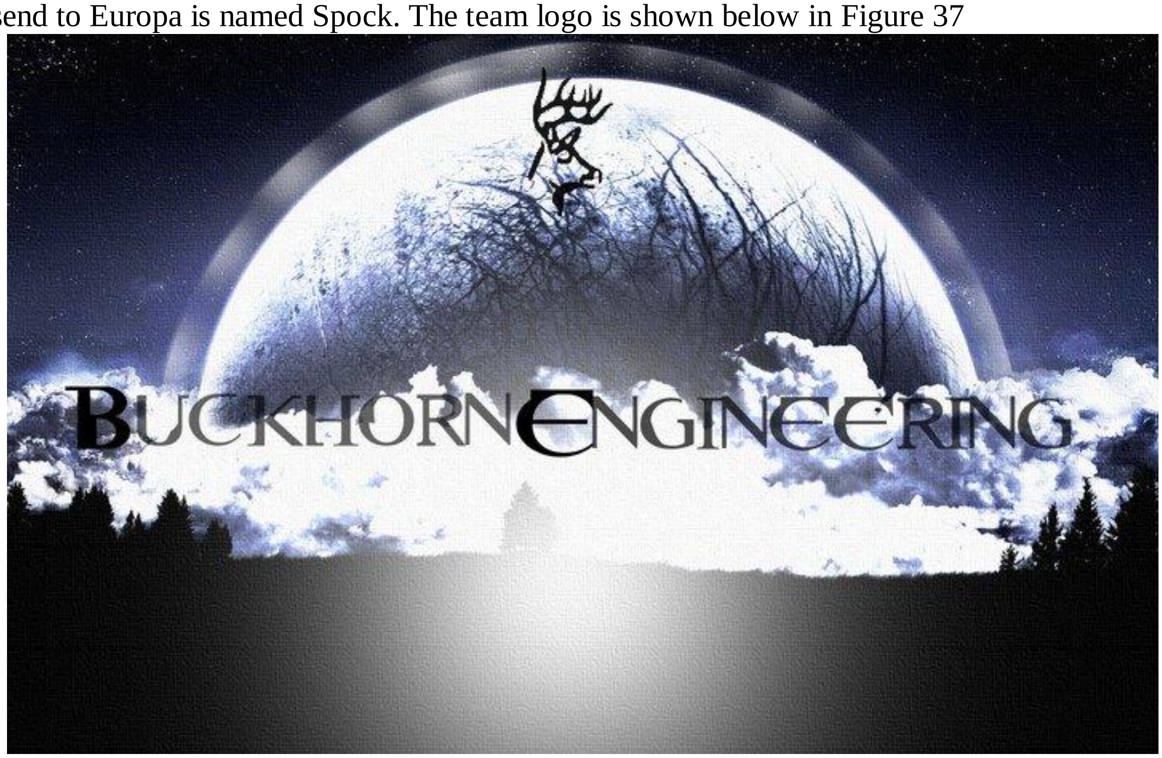


Figure 37 – Buckhorn Logo

The question that was asked was, "what is the elemental composition of the ice on Europa?" This question was chosen because knowing the contents of the ice on Europa can be very important. Since Europa is a candidate for having life on it, the team can find out if the elements needed to support life are even present on the planet. Knowing the elemental composition of the ice could also prove to be helpful for any future missions conducted on or near Europa.

I.2.2.1 Decision Analysis

In deciding how to answer the aforementioned question, an idea was developed of having some sort of device go out and collect a sample of ice to be tested. Three ideas were originally developed on how to collect the ice: a rover design, a rope climbing robot, and a device similar to a potato launcher. To decide which idea would be best, decision analysis and figures of merit were used. The results are shown in Figure 38

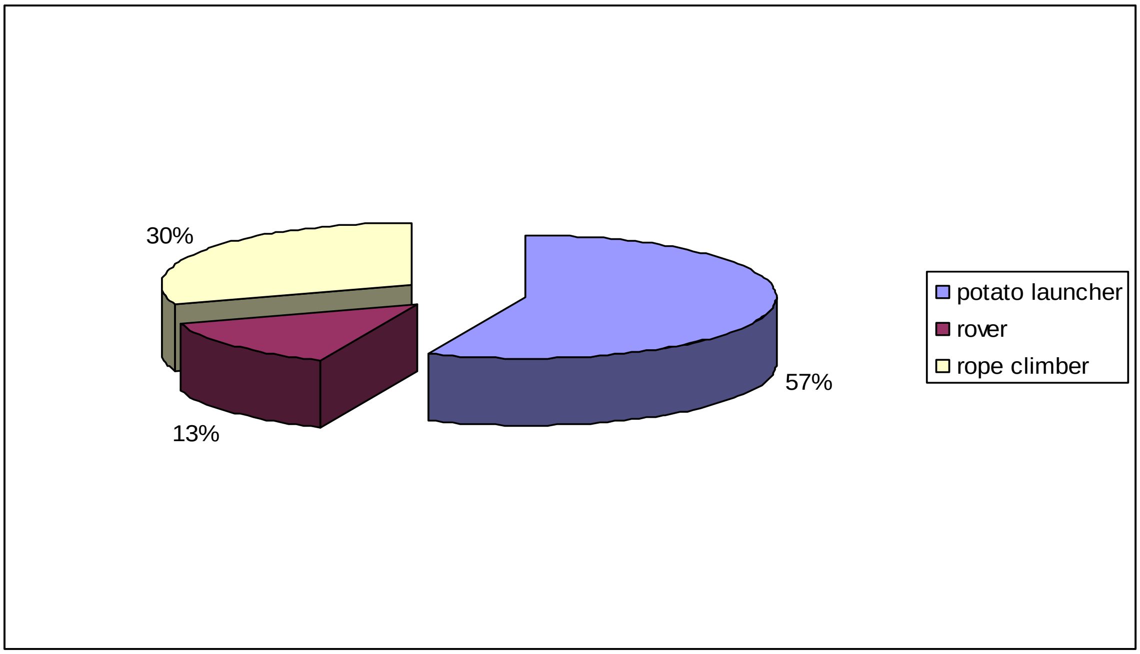


Figure 39 – BHS Decision Analysis

The potato launcher design was chosen because it won in almost every category in the figures of merit.

I.2.2.2 Element Design

The payload is going to contain two instruments, the ice collecting device and the gas chromatograph. The gas chromatograph will be placed inside the lander, and Spock will be near the outside of the main ship in a launch tube. The chromatograph will be inside the lander for the simple fact that it would be easier to have the sample come back to the lander than try to test it outside of the lander. Once the lander is on Europa and other missions are not being interfered with, and excess pressurized helium will be used to launch Spock. Spock itself will be a bullet shaped capsule. At one end of the capsule, there will be a spot where the tether will attached so the whole thing can be reeled back in. To get the sample of ice, Spock will scrape the ice as it is being reeled back in. To scrape the ice, there will be multiple microplanes outlining the capsule that will scrape the ice while it is being dragged back. At the tip of the capsule where the ice will gather, there will be a ball valve to close off the collect ice before it gets back to the lander where it could scrape contaminated ice. Once Spock returns to the lander, it will move the ice into the gas chromatograph to determine the elements in the ice. Figure 39 depicts the basic image of what the capsule of Spock looks like:

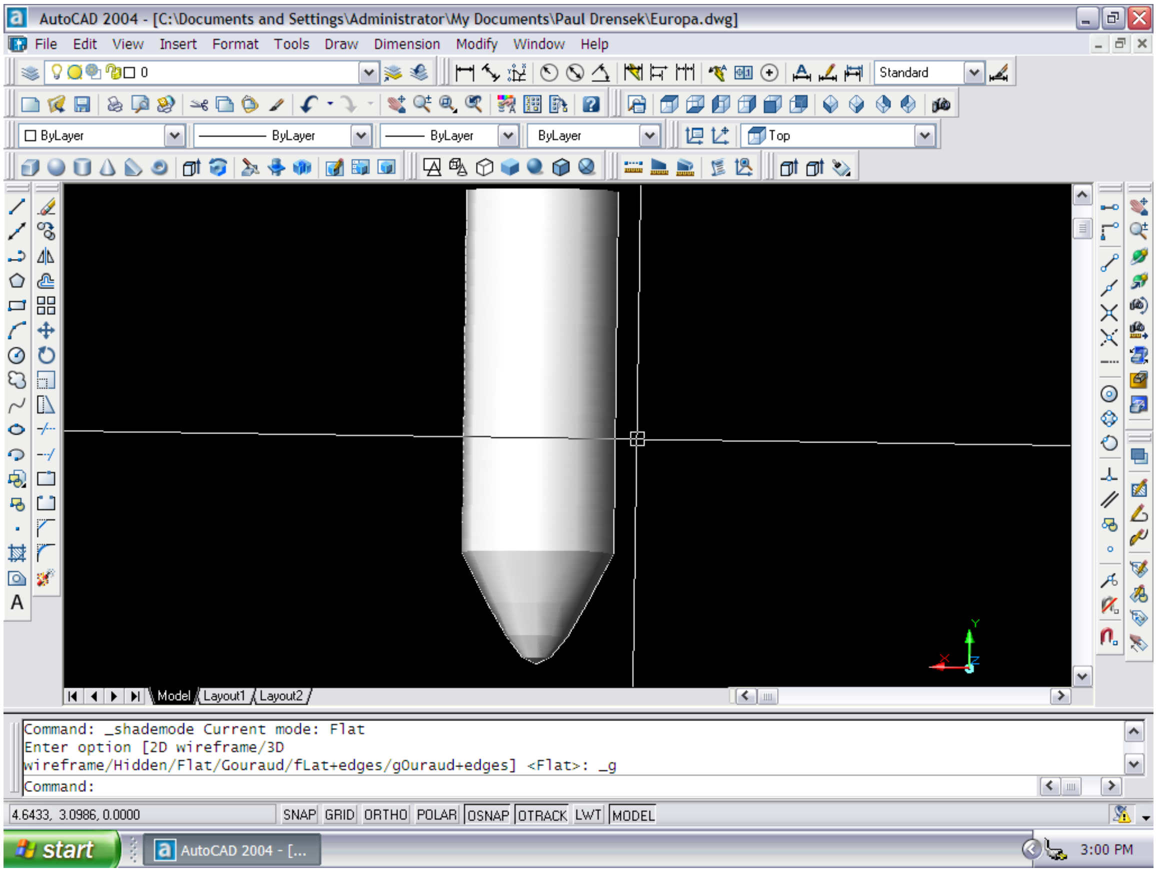


Figure 39 – BHS CAD Design

I.2.2.3 INSPIRES Team Proposal Summary

By determining the elemental make-up of the ice on Europa, an important question may be answered: "Is there life outside of Earth?" By knowing which elements are in the ice, it can determined whether Europa has the basic components to support life. If Europa does contain life-supporting elements, then it will help further develop to answer the question about life being present off of Earth.

I.2.3 Guntersville High School Proposal

Artemis Inc. is composed of students in grades 10-12 from Guntersville High School. The team is interested in researching Europa, a moon of Jupiter. A payload has been developed, named the Silver Bullet, which will be aboard a lander designed by students of UAHuntsville.

I.2.3.1 Science Question/ Objective

The Bullet's objective is to measure how the ice temperature changes on Europa at ten locations and at various depths ranging from the surface to one meter below the ice.

I.2.3.2 Approach

The Silver Bullet will determine how the temperature changes by depth on Europa by launching ten modified darts into the ice at different depths and recording the temperatures using thermocouples. The reason temperature is being measured is to see if the ice on Europa has similar properties to the ice on Earth. Since the Bullet requires power and communication from the lander, the darts are tethered.

Table 24 – High School Instrumentation

Instruments	**Task**
Thermocouple	Takes temperature
Dart	Projectile to be shot out of launcher; thermocouple is inside (See Figure 40)
Helium powered launcher	Object that shoots the darts (See Figure 41)

I.2.3.3 Payload Design

The Silver Bullets (penetration darts) will be launched out of a carbon fiber reinforced plastic box. The box is 38.1 cm long by 15.24 cm wide to accommodate 10 darts. Compressed helium already present on the lander will fill one of ten chambers to fire the Bullets out of the launcher into the ice of Europa. Ten barrels with pressure valves attached at the bottom will be inside the box, one for each dart. Each barrel will have a pressure regulator designed to release different amounts of helium so every projectile will be shot at different velocities, and thus go various distances and depths. The pressure and distance and depth are recorded in Table 27. The Silver Bullets are three inch long and are one-half inch in diameter. These will also be made out of carbon fiber reinforced plastic, with a thermocouple type T inside of each. Each dart will be tethered to the payload for communication of data. Figure 40 below shows a typical dart, and Figure 41 shows the launcher.

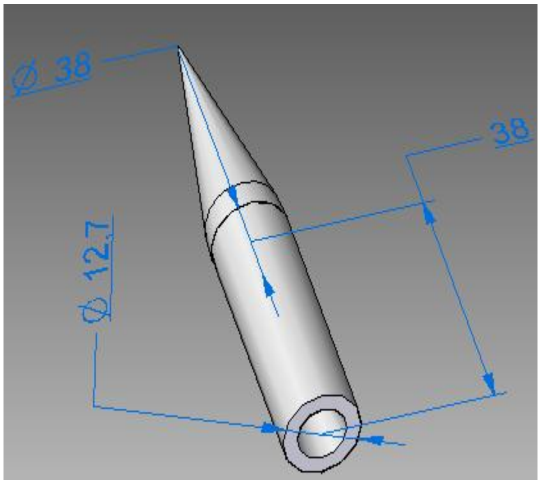


Figure 40. Typical dart

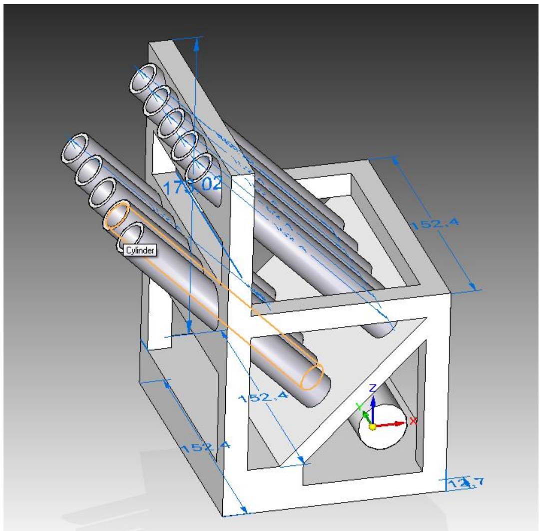


Figure 41. Launcher

The mass of the launcher, cylinders, and darts was determined using the density of carbon fiber reinforced plastic which is 1.8×10^{-3} kg/cm^3. Mass is determined from the equation mass = volume*density. Using the equation πr^2h, the volume of each cylinder is 18.85 cm^3, and the volume of each dart is found by subtracting $\pi r_1^2 h - \pi r_2^2 h + \frac{1}{3}\pi r_1^2 h$. The total mass of the payload is 5.26 kg.

Table 25. Individual Mass Calculations Summary

Launcher			
Density	1.80E-03	kg/cm³	(CFRP)
Volume	17698.03	cm³	(lwh)
Mass	3.19E+01	kg	(m=vd)
Tubing			
Density	1.80E-03	kg/cm³	(CFRP)
Volume	18.85	cm³	(2πrh)
Mass	3.39E-02	kg	(m=vd)
Dart			
Density	1.80E-03	kg/cm³	(CFRP)
Volume	6.43518	cm³	(2πrh)
Mass	.0116	kg	

Table 26. Total Mass Table

Part	**Launcher**
Launcher	3.19E + 01kg
10 Cylinders	.339 kg
10 Darts	.116 kg
Total Mass:	**I.2 g**

I.2.3.4 Concept of Operations

As the lander hits the ground, the individual pressurized chambers will be filled with _ psi pressure from the on board helium tank. Then, the darts will be launched at 45° angles using the pressurized helium already granted to us on the payload. Penetration equations were used to predetermine the depth that the darts will go into the surface of Europa. The distance each dart will travel from the lander was established from projectile motion equations as follows:

1. Using a given force, pressure is calculated using $P = \frac{F}{A}$ where P= pressure [N/m^2] , F = force [N], and A is area [m^2].

2. The mass of the dart is used to calculate the acceleration in the barrel using the following formula:
   F= ma.

3. The velocity of the dart leaving the barrel is calculated using $V^2 = V_o^2 + 2ad$., where V= velocity leaving the barrel [m/s], V_o = initial velocity [m/s], a = acceleration in barrel [$^{m}/_{s^2}$], and d = length of barrel [m].

4. The time of travel of each dart was calculated using the following equation: $y – y_o + v_o t + \frac{1}{2} at^2$ examining the motion of the dart in the y-direction. The acceleration on Europa is assumed to be 1.635 m/s^2.

5. The distance was found using the relationship distance = $v_x t$. Distances are reported in meters.

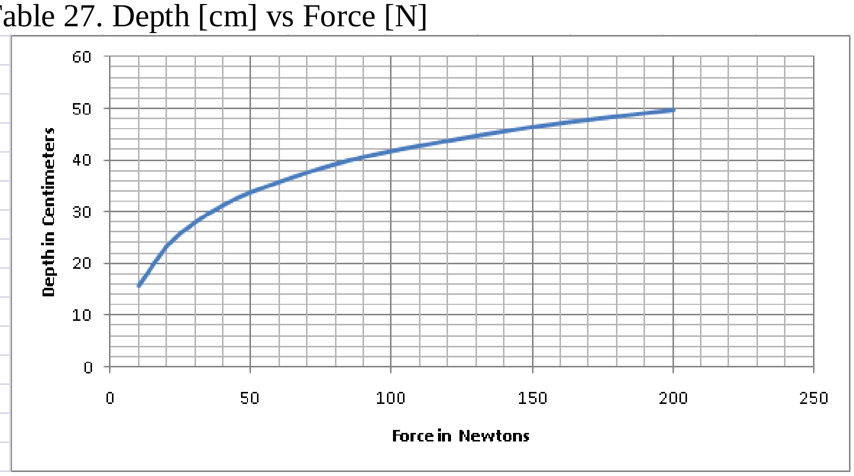
The depth of penetration for each dart was determined using penetration equations and inputting the velocity of the dart as it hits the surface (V).

$D = .0000046\ SN\ (m/A)^{0.6}\ (V - 30.5)\ \ln(50 + .29m^2)$. $S = 2.7\ (f_c' Q)^{-0.3}$.

Temperature will be taken for one (1) revolution of Europa (3.55 days). Each projectile will be tethered so the data will be transferred back to the lander.

Table 27. Depth [cm] vs Force [N]

16	Force (N)	Depth (cm)
17	10	15.79808
18	20	23.44783
19	30	28.03199
20	40	31.30338
21	50	33.84668
22	75	38.47152
23	100	41.76218
24	150	46.39706
25	200	49.68632
26		
27		
28		
29		
30		



I.2.3.5 Summary

In overview, the Silver Bullet will launch ten darts that will travel various distances into the icy surface of Europa. It will accomplish this task by using pressurized helium (provided by

UAHuntsville) to propel the darts. A thermocouple will be located inside the darts. The thermocouples will measure the temperature. The payload is important because it contributes to the research of other planets and their various environments. With the new information that will be gathered, scientists can conclude if life is possible on Europa.

I.2.4 INSPIRES Payload Decision

Due to the exceptional nature of Guntersville High School's report, SARS has decided to include their payload onto the lander. The proposed design compliments the mission developed by SARS. Both teams performed very well, and got a look into the engineering world earlier than most students their age. Hopefully, the students developed an interest in engineering that will encourage them to pursue a career in one of the engineering disciplines.

J. Appendices

J.1. Table of Proposed Participants

Table 28 – Table of Proposed Participants

Name	Role	Organization	Email
Phil Jackson	Project Manager	UAHuntsville	phil.jackson.ise@gmail.com
Robbie Hill	Chief Engineer	UAHuntsville	rah0005@uah.edu
Anthony Bekken	Lead Systems Engineer	UAHuntsville	arb0001@uah.edu
Jordan Adams	Principal Investigator	College of Charleston	jordanadams41790@gmail.com
Caitlyn Mayer	Co-Investigator	College of Charleston	caitdawg@hotmail.com
Ludovic Lugan	Team Lead	ESTACA	ludovic.lugan@estaca.eu
Sindhu Radhakrishnan	Team Lead	California State University in Los Angeles	sindhu.aahilyam@gmail.com
Bill Angotta	Engineer	UAHuntsville	wfaschism2@gmail.com
Chris Dolberry	Engineer	UAHuntsville	cjdolberry@yahoo.com
Shannon Grant	Engineer	UAHuntsville	lsg0001@uah.edu
Ryan Kirschbaum	Engineer	UAHuntsville	rgk0001@uah.edu
Christy McClain	Engineer	UAHuntsville	cem0015@uah.edu
Brittany Nelson	Engineer	UAHuntsville	grittybrittygrl@yahoo.com
Brad Townson	Engineer	UAHuntsville	townson.brad@gmail.com
Tarik Benabdelmounmene	Engineer	ESTACA	tarik.benabdelmoumene@estaca.eu
Alexandre Blemand	Engineer	ESTACA	Alexandre.blemand@estaca.eu
Azziz Miftah	Engineer	ESTACA	
Jonathan Sy	Engineer	ESTACA	jonathan.sy@estaca.eu
Mohammed Baten	Engineer	California State University in Los Angeles	Mohammedsadi@hotmail.com
Adam Dunn	Engineer	California State University in Los Angeles	AdamDunn52@gmail.com
Wilson Tam	Engineer	California State University in Los Angeles	wilson_tm79@yahoo.com

J.2. Letters of Commitment

To: The College of Charleston

Attention: Jordan Adams
Chief Investigator, College of Charleston
jordanadams41790@gmail.com

This is to certify that the aforementioned entity has been selected as the science team for the EELS (Europa Extraterrestrial Life Survey) project. This is in response to the Discovery Announcement of Opportunity, NNH10ZDA007O, released on June 7, 2010. The role of the College of Charleston in this mission is described in this proposal. If there are any questions about the roles or requirements, please contact any group member at any time.

From: The University of Alabama in Huntsville
Team SARS

____
Phil Jackson
Project Manager, UAHuntsville
phil.jackson.ise@gmail.com

____
Robert Hill
Chief Engineer, UAHuntsville
rah0005@uah.edu

____
Jordan Adams
Chief Investigator, College of Charleston
jordanadams41790@gmail.com

____
Anthony Bekken
Lead Systems Engineer, UAHuntsville
anthony.bekken@gmail.com

____
Caitlyn Mayer
Co- Investigator, College of Charleston
caitdawg@hotmail.com

____
Bradley Townson
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Bill Angotta
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Brittany Nelson
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____
Christy McClain
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____
Ginny Gibson
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veg0001@uah.edu

____
Karen Gibson
Technical Editor/Report Design, UAHuntsville
kea0001@uah.edu

J.3. Resumes

Jordan A. Adams

738 Rutledge Ave.· Charleston, SC · (803) 447 3677 · Jaadams@edisto.cofc.edu

Citizenship: United States of America

Technical Skills:

Microsoft Word, Excel, PowerPoint — Writing & Formatting consulting reports

ArcMap (GIS data) — Math education: Algebra; Calculus I - III

Professional Experience:

University of Alabama – Huntsville (funded by NASA)

Position: Principal Investigator — Employed: May 2010 – Aug 2010

Responsibilities: In conjunction with an engineering team, the Principle Investigator is to: design asteroid sample return mission through: researching past missions, current technologies, feasibilities, current & future science needs & goals. Manage science team. Writing & formatting final consulting report (electronic portfolio).

Contact: P.J. Benfield (UAH); (256) 824-2976

College of Charleston

Position: Research Assistant — Employed: June 2009 – Jan 2010

Responsibilities: Run Gamma Ray Burst (GRB) pulse fitting algorithm using IDL to fit GRB data collected by BATSE. Check for errors in fit, record and analyze parameters produced by model. Contribute to writing and formatting of final report and poster, prepared for American Astronomical Society Meeting (AAS) (electronic portfolio).

Contact: Dr. Jon Hakkila (CofC); (843) 953-6387

Position: GIS student (unpaid) — Employed: Aug 2010 – Dec 2010

Responsibilities: Complete a number of maps using ArcMap program. Some maps include detailed analysis and consulting reports (electronic portfolio)

Contact: Dr. Norm Levine (CofC); (843) 953-5308

Education:

College of Charleston; Charleston, SC — Attended: Aug 2009 – May 2012

Bachelors of Science in Geology; (in progress expected May 2012)

Affiliations:

Member of the American Astronomical Society

Bill Angotta

(256) 520-5387
angotta.bill@gmail.com

103 Creek Trail
Madison, AL, 35758

CITIZENSHIP U.S.

TECHNICAL SKILLS Windows 98, 2000, XP, Vista, and Windows 7 operating systems; Word, Excel, Publisher, and PowerPoint; Solid Edge's Solid Works; NX; MathCAD; Maple, and MATLAB

EDUCATION

University of Alabama in Huntsville **Huntsville, AL**

Bachelor of Science in Mechanical Engineering

GPA: 3.05/4.0 in major, Expected graduation: August 2011

WORK EXPERIENCE

July2007 – Present **Army Air Force Exchange Service** **Huntsville, AL**

Burger King crew member.

- Operated kitchen equipment (ovens, deep-fat fryers, grills, etc.) and assembled sandwiches and other food products
- Took customer orders, and accepted money and made change
- Accounted for cash funds, and participated along with supervisors in the establishment and achievement of service and sales goals

May 2006 – August 2006 **Redstone Federal Credit Union** **Huntsville, AL**

- Installed and maintained computers and related technologies.
- Installed software and hardware, peripheral devices, and created and maintained an up-to-date inventory of computers and devices
- Had a daily shift on the company's Information Technology support desk, to which all employees reported technical problems

May 2004 – August 2004 **Sparta, Inc.** **Huntsville, AL**

Technical Analyst

- Inputted data for the HAWK Obsolescence Database
- Inputted part information into the database and researched part information using the FEDLOG program
- Prepared a training class presented to all TASO employees during a working lunch, proposal preparation, briefing preparation, and data inputting.

Mohammed S. Baten
762 Via Altamira Apt#23
Montebello CA, 90640
(323) 578-1757
Mohammedsadi@hotmail.com

OBJECTIVE

Seeking to work as an Electrical Engineer. Looking forward to assist and contribute to the refinement of the process and procedures for your company.

EDUCATION

California State University-Los Angeles CA
Major: Electrical Engineering
Degree: Bachelor of Science
Graduation year: 9/11

PROJECTS

The objective was to build and construct a terrain rover-robot with Lego's that will operate on foreign landscape like Mars. The robot was to move using wheels and had limbs to lift foreign objects. It also was programmed to operate using remote control and touch and/or light sensors.

SKILLS

- Good communication skills
- Good teamwork & leadership skills
- Familiar with computer programs: Word, Excel, PowerPoint, Internet access, Photoshop, MATLAB, PSpice
- Dedication and work Ethic
- Able to Adapt to various environments

EXTRACULICULAR ACTITIVES

- Member of NSBE (National Society of Black Engineers)

- Currently working on senior design project with NASA to develop a subsurface penetration system to discover Liquid Ocean underneath Jupiter's moon Europa.

AWARDS

Four year high school perfect attendance award

REFERENCES

Available upon request

Anthony Bekken

(256) 508-5900
Arb0001@uah.edu
185 Dublin Circle
Madison, AL 35758

CITIZENSHIP U.S.

TECHNICAL SKILLS MATLAB, MathCAD, Micro Station, Solid Edge, Nastran, Patran

EDUCATION

The University of Alabama in Huntsville **Huntsville, AL**

Bachelor of Science in Engineering, with a concentration in Mechanical Engineering

GPA: 3.88/4.0, Expected graduation December 2011

WORK EXPERIENCE

March 2008 -- Present **U.S. Army – Redstone Arsenal Garrison** **Huntsville, AL**

Engineer's Aide and Project Manager for Work Orders

- Managed over 35 projects with the biggest having a final cost of $85,000.00
- Hired contractors to complete work orders and assisted two engineers
- HVAC design for 3000 sq. ft. building
- Visited major construction sites and inspected numerous projects

March 2003 -- Present **Lawn Boys** **Huntsville, AL**

Owner, Operator, and Manager

- Currently have over 40 clients, performed customer service, billing, equipment maintenance
- Managed and worked with 3 to 8 seasonal employees

CLEARANCE Secret; granted 5 September 2008 by US Army Central Clearance Facility

HONORS AND AWARDS Received UAH Academic Excellence Scholarship, 2007-present; Dean's List, 2007-present

AFFILIATIONS Alpha Lambda Delta Society (2008) and Tau Beta Pi Society (2010)

Community Service (260 hours per year)

Tarik BENABDELMOUMENE

Mobile: **+33 06 83 17 28 82**
E-mail: **tarik.benabdelmoumene@estaca.eu**
Nationality : French

9 rue des Amandiers (Gournay sur Marne, France)
21 years old
Driving License

Student engineer in fourth year, ESTACA Levallois (FRANCE)

Graduated from a five years engineering school, I am a motivated, rigorous and organized person.
Particularly interested in Structures & Materials, I am keen to develop a career in this field.

EDUCATION	
2007-2010	Fourth year at **ESTACA** (Engineering school dedicated to the training of students in aeronautical, automotive, rail and aerospace disciplines) which is situated in Levallois and is a five year engineering degree.
2006-2007	**Scientific Baccalauréat (French secondary school diploma)** specialty **Mathematics, 2.1.** Lycée Emily Brontë Lognes (France)
WORK EXPERIENCE	
Juin- Aout 2010 Personal initiative	Internship in **ITP - ALCEN Group**, Industry of precision engineering, Sousse (Tunisia) Target: Initiation on process a case in precision machining. Responsibilities: Documented and upgraded the data base which help technician to work (plan, machining range, control range). Established a nomenclature (settings and data) on Hérakles which is an ERP.
July to Aout 2009 Worker experience	Internship in **AGILE Aéroclub Airfrance, Flying Club** (Lognes, France) Target: Understand the profession of aviation mechanic. Responsibilities: Assisted mechanic in maintenance operation (on Cessna, Cirrus, DR400, Aquila, CAP 10).
July to Aout 2008 Paid work experience	Internship in **ALTI, Human Resources**,(Levallois, France) : Target : Discovering of the labor world Responsibilities: Assisted the responsible of the Human Resources to found computer engineer.
SKILLS	
Languages **Computer Skills**	French (mother tongue), English & Spanish: intermediate. Solidworks, Catia, Matlab, Patran, Word, Excel, PowerPoint.
ACTIVITIES AND INTEREST	
Sport	Running, Member of ESTACA Soccer Team. Reading aeronautic books (Air & Cosmos)

Alexandre BLEMAND
66 rue Berlioz, MITRY_MORY (FRANCE)
Cell phone: (+33) 615034389
Alexandre.blemand@estaca.eu

Education

Since 2007 E.S.T.A.C.A - Levallois-Perret, France.

Top Engineering School specialized in the Aeronautical domain (first to third year of a five-year Master degree). *Main subjects studied*: Aircraft structure/Aircraft architecture/Advanced aerodynamics/ Fluid mechanics/Finite Element Method/Numerical Method/Flight mechanics/Aeronautical certification/ Reliability, safety and dependability/M.D.O

2006-2007 Lycée Honorée de Balzac (High-School), France.

Baccalauréat (A Level/French High-School Diploma) in Mathematical Sciences

Projects

- 2009-2010 : **Aircraft architecture**: Computer-assisted aircraft drawing/designing of an UCAV (Catia V5, Solidworks) and performance calculations (mission analysis, payload/range, fuel capacity, MTOW, Engine sizing and power study)

Reliability, Safety & Dependability applied to aeronautics: Reliability and dependability calculation, maintainability, security and safety tests on reverse thrust of the B737.

- 2008-2009 : **Data processing**: Created and managed metro lines in C/C++ Language

Work Experience

- *During 2008 :* Gave Mathematics lessons to a student in order to obtain The French High-School Diploma.
- *07/2008* : Assisted an engineer in the mechanization automation of the metro line 1 of Paris.

Skills & Interests

Computer Skills:
Office software: Windows, Microsoft Office Suite
Computer-assisted drawing/designing: Solidworks, Catia V5
Computational Fluid Dynamics:
Reliability Block Diagram: BlockSim
Data processing programming: C/C++ knowledge (Dev C++)
Math computation: Matlab, Simulink.

Languages:
Native French speaker,
Fluent English
Fluent Spanish

Christopher J. Dolberry

(256) 609-0603
cjdolberry@yahoo.com
560 County Road 15
Woodville, AL 35776

CITIZENSHIP U.S.

TECHNICAL SKILLS Solid Edge, Nastran / Patran, MathCAD, MATLAB

EDUCATION

The University of Alabama in Huntsville **Huntsville, AL**

Bachelor of Science in Engineering with a concentration in Aerospace Engineering

GPA: 2.8/4.0, Expected graduation May 2011

- Selected by engineering professor to submit a 73-page paper on safety concerns to an ASME technical writing competition
- Completed the design, analysis, fabrication, and testing of a patentable transportation system for a plastic injection molding machine. Tasks included a feasibility study, trade study, cost analysis, stress and strain analyses, location of center of gravity, Factor of Safety, materials analysis, parts specification, hazard and risk assessment, fatigue and corrosion prediction, manufacturing requirements, verification tests, and detailed drawings. Results presented in a System Requirements Review, Preliminary Design Review, Product Readiness Review, and Final Technical Report.
- Assisted in the design and development of procedures for a laboratory experiment intended to verify the manufacturer's specifications for thrust and chamber pressure values for a solid rocket motor

WORK EXPERIENCE

June 2006-Present **High Country Automotive** **Scottsboro, AL**

Parts Sales Specialist

- Manage large inventory of automotive parts and accessories
- Interact with wholesale and retail customers as well as professional service technicians

March 2004-June 2006 **Advance Auto Parts** **Scottsboro, AL**

Parts Sales Specialist

- Responsible for store inventory and receiving of weekly shipments

Adam P. Dunn
405 Bay Hill Dr. , Newport Beach CA 92660 · (805) 704-0332
AdamDunn52@gmail.com

Objective

Contribute to an innovative fast paced biomedical design team and continue my growth in the field of biomechanics.

Educational Development

- Coursework in Rapid Prototyping and Design
- Mechanical Engineering Courses in Kinematics, Machine Design, Stress Analysis, Heat Transfer, and Fluid Mechanics
- Electrical Engineering Electives in Biomedical Instrumentation and Robotics
- Engineering GPA of 3.07

Computer Skills

- Solid Works, MatLab, and ADAM's
- PLC Programming
- Full Microsoft Office Package

Other Projects and Skills

- Officer in Pi Tau Sigma (Mechanical Engineering Honor Society)
- Mill and Lathe Operation
- Orthopedic Bracing Product Development
- Analysis of Hook Loop Performance and Testing

Biomechanical Skills and Experience

- Equip Biomechanical Devices with Sensors Equipment to Evaluate Function
- Signal Processing of Biomechanical Signals
- Developed Biomimetic Testing Equipment
- EMG Analysis
- Motion Lab Experience

Work Experience

- Össur Americas — June 2010-Current
  Position: Biomechanical Intern
- Home Depot-San Luis Obispo & Anaheim — September 2007-January 2010
  Position: Floor Associate
- Longevity Health Care — September 2004-June 2006
  Position: Medical Assistant

Education

- California State University, Los Angeles CA — September 2009-Current
  Mechanical Engineering — (Graduate June 2011)

La'Shannon S. Grant

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lsg0001@uah.edu

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Huntsville, AL 35816	Hayneville, AL 36040

CITIZENSHIP U.S.

TECHNICAL SKILLS IBM/ PC and Apple Macintosh systems, MS DOS, Windows, Microsoft Office Professional Package (Word, PowerPoint, Access, Excel), Word Perfect, FAX machines, copiers, and collators.

EDUCATION

The University of Alabama Huntsville **Huntsville, AL**

Bachelor of Science in Industrial and Systems Engineering

GPA: 3.0/ 4.0, Expected Gradation August 2011

WORK EXPERIENCE

June 2010-August 2010 **Southwire Company** **Carrollton, Georgia**

Summer Intern

- Worked on CIC Traveling Saw Project
- Performed Process Analysis on Inline Packaging Process
- Worked on safety improvements for VPP status
- Worked and talk to suppliers about designing a new traveling saw
- Organized first project meeting
- Helped with Inventor

HONORS AND AWARDS Valedictorian Scholarship- Auburn University (2006- 2008), Auburn University Board of Trustees Scholarship (2008)

AFFILIATIONS

- Institute of Industrial Engineering, The University of Alabama Huntsville
- Society of Mechanical Engineering, The University of Alabama Huntsville
- National Society of Black Engineers, The University of Alabama Huntsville
- National Society of Black Engineers, Auburn University
- AT&T Minority Engineering Program, Auburn University

Robert Anthony Hill

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rah0005@uah.edu

122 Whitt Haven Drive
Toney, Alabama, 35773

CITIZENSHIP U.S.

TECHNICAL SKILLS Microsoft Office Word, Excel, PowerPoint; MATLAB; MathCAD; Solidedge; NX

EDUCATION **The University of Alabama in Huntsville** **Huntsville, Alabama**

Bachelor of Science in Engineering with a focus in Aerospace Engineering

Cumulative GPA: 3.06/4.0 (3.3/4.0 in major), Expected graduation August 2011

PROFILE As the Chief Engineer for Team H of the Intergraded Product Team (IPT) Europa Extraterrestrial Life Survey (EELS), I was responsible for leading a multi-disciplinary team in the design of a surface landing system to be deployed to Europa. I was also responsible for communicating design requirements to engineering teams at ESTACA University in Paris, France and California State Los Angeles, as well as gathering mission requirements information from a team of science students at the College of Charleston.

HONORS AND AWARDS Academic Excellence Scholarship

Philip Alan Jackson

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600 Apache Drive
Hartselle, AL 35640

Permanent Address
768 Celia Drive SE
Hartselle, AL 35640

CITIZENSHIP U.S.

TECHNICAL SKILLS TopVue configuration management tool, Abacus 5000 voice and data simulation software, MySQL database, PHP, C++, BASIC programming languages

EDUCATION

University of Alabama in Huntsville **Huntsville, AL**

Bachelor of Science in Engineering, with a concentration in Industrial and Systems Engineering

GPA: 3.06/4.0, Expected Graduation: May 2011

WORK EXPERIENCE

August 2009 -- Present **UAH SMAP Center** **Huntsville, AL**

Research Assistant

- Oversaw life-cycle implementation of engineering change proposals
- Tracked configuration management data via TopVue web application
- Released drawings and associated data to approved contractors
- Created reports of configuration management statistics

August 2007 -- August 2008 **ADTRAN** **Huntsville, AL**

Co-op Engineer

- Configured test networks using ADTRAN products
- Ran voice and data simulation testing on networks using Abacus 5000
- Helped maintain MySQL database containing user certification data
- Maintained PHP website running training division information
- Set up exercises for customer training and certification

CLEARANCE Secret

AFFILIATIONS Institute of Industrial Engineers, University of Alabama Huntsville chapter

Ryan Gregory Kirschbaum

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RGK0001@uah.edu
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Decatur, AL 35603

CITIZENSHIP U.S.

TECHNICAL SKILLS HTML, C++, Perl, MatLab, Red Hat Linux, HP-Unix, SuSE Linux, Solaris, Multisim, MATLAB, AutoCAD, Microsoft Office, Pro/Engineer

EDUCATION

The University of Alabama in Huntsville **Huntsville, AL**

Bachelor of Science in Engineering, with a concentration in Mechanical Engineering

GPA: 3.54/4.0, Expected graduation August 2011

WORK EXPERIENCE

May 2010 – August 2010 **Electricfil Corporation** **Elkmont, AL**

R1T Design and Development Engineer

- Developed 3D models for sensors that were implemented in Ford cars
- Altered 2D model sketches to adhere to dimensioning and tolerance standards set by ASME
- Developed 2D and 3D models of fixtures to be used on various machinery

June 2009 – September 2009 **Marshall Space Flight Center** **Huntsville, AL**

Science Research & Technology Intern

- Developed a Material Identification Usage List (MIUL) to be used in verifying materials for the FASTSAT-HSV01
- Created and indexed multiple SketchUp drawings to portray various movements
- Researched and assisted with calculations relating to magnetic torque rods for attitude control of the FASTSAT-HSV01

August 2008 – December 2008 **Toyota Technical Center** **Ann Arbor, AL**

Plant Engineer Intern

- Developed various AutoCAD drawings for use in determining the best option for various projects, integrated Microsoft Excel spreadsheets into AutoCAD
- Project coordinator for various network reorganization projects

AFFILIATIONS

Member of Tau Beta Pi (Engineering Honor Society – Top 8th in class)
Member of Pi Tau Sigma (Mechanical Engineering Honor Society)
Member of Magna Cum Laude (National Scholars Honor Society)
Member of Alpha Lambda Delta, (National Academic Honor Society)

Mr. Ludovic LUGAN Nationality: French Born 21/10/1989
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TRAINING

Since 2008 ESTACA - Levallois-Perret, France. School of Engineering.

2007-2008 E.N.C.P.B - Paris 13th, France. MPSI scientific preparatory classes.

2004-2007 Lycée Notre Dame des Missions, France. Obtained Bachelor of Science with honors.

PROJECTS

2010-2011: Nonprofit Project: Design, manufacture and launch of an experimental two-stage rocket with a payload dump.

2009-2010: Architecture Aviation: Modeling a business jet type Very Light Jet in CATIA V5 and performance calculations (Work in group of five)

Draft dependability applied to aeronautics: Realization of a FMEA APU. (Work in groups of three)

Applied Process Engineering: Design of a headrest (Work in groups of seven)

2008-2009: Computers: Programming in C / C + + consisting of the creation and management of a railway line. (Work in groups of three)

PROFESSIONAL EXPERIENCE

08/2010: Summer Job: MONOPRIX, Malakoff (France) - Set radius of frozen products.

07-08/2009: Internship: SNCF, Ivry sur Seine (France). - Maintenance of locomotives.

LANGUAGE & COMPUTER SKILLS

Language

¬ Advanced English
¬ Intermediate Spanish

Computer: Pack Office, Solidworks, CATIA, Matlab, Simulink, Nastran, Patran, C + +

INTERESTS / HOBBIES

Hobbies: playing football, Memberships school named Estaca Space Odyssey (design, manufacturing and launching rockets)

Interests: astrophysics, Football, Basketball, Tennis, Music, Cinema.

Caitlyn Mayer
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Current Address
86 B Morris Street
Charleston, SC 29403

Permanent Address
2209 Guinevere Way
Atlanta, GA 30345

CITIZENSHIP: U.S Citizen

TECHNICAL SKILLS: Microsoft Word, Excel, and Powerpoint. CILAS Laser Particle Analyzer, Ro-Tap Sieving machine, Scanning Electron Microscope, Vibra-Core, Familiarity with standard chemical, biological and geological lab equipment and associated procedures

EDUCATION: College of Charleston
Bachelor of Science in Geology
GPA: 3.554

WORK EXPERIENCE: Summer 2008, 2009, 2010
Summer Intern at Sunoptic Technologies

- Organized engineering reports and instrument designs
- Filed packaging, shipment, payment and sale orders
- Updated and printed instrument manuals

AFFILIATIONS: National Society of Collegiate Scholars, College of Charleston Geology Club

Christy E. McClain

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cem0015@uah.edu

P.O. Box 53
Tony, AL 35773

CITIZENSHIP U.S.

TECHNICAL SKILLS NASTRAN, PATRAN, Solid Edge, Pro-E, MATLAB, MathCAD, C++, Visual Basic, Windows 98 through 7, Macintosh OS X, Microsoft Office, PowerPoint, Word, Excel, Access, and Project, Friction Stir Welding, Gas Tungsten Arc Welding (GTAW or Tig), Micro Plasma Transfer Arc (MPTA), HydroGen Systems (H2), Orbital Tube Welding Systems, laser welding, and pneumatic pressurized spray painting within tolerances

EDUCATION

The University of Alabama in Huntsville — **Huntsville, AL**

Bachelor of Science in Engineering – Mechanical Engineering
GPA: 3.24/4.0 in major, Expected Graduation: Summer 2011

Calhoun Community College — **Decatur, AL**

Associates of Science – General Education (Pre-Engineering requirements)
GPA: 3.8/4.0 in major, Graduation: August 2008

- Graduated Magna Cum Laude

Associates of Applied Science – Aerospace Technology: Welding & Coatings Specialty with a minor in Structures and Assembly.
GPA: 4.0/4.0 in major, Graduation: December 2003

- Graduated Summa Cum Laude

WORK EXPERIENCE

August 2005 – October 2010 — **Pratt & Whitney** — **Huntsville, AL**
Engineering Technician (Engineer in Training), Laser Safety Officer.

- Worked on Space Shuttle Main Engine (SSME), Cold-Wall Advanced Repair Systems (CWARS)

June 2003 – August 2005 — **The Boeing Company** — **Huntsville, AL**
Intern Engineer & Production Technician

- Worked on Delta II and IV

PUBLICATIONS Systematic Improvements in Leak Detection and Repair Techniques of the Space Shuttle Main Engine Nozzle - 53rd JANNAF Propulsion Meeting / 2nd Liquid Propulsion Subcommittee Meeting, December 2005

HONORS AND AWARDS NASA Space Flight Awareness Award, NASA Group Achievement Award, The Boeing Company Scholarship – 2 years, Air Force Association Scholarship, Dr. Mary Yarbrough Scholarship, and Collegiate All-American Scholar Award

Brittany Nelson

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bblache@craftongroup.com

Current Address	Permanent Address
1211 Grandeview Blvd #2624	2959 Elk Meadows Drive
Huntsville, AL 35824	Brownsboro, AL 35741

CITIZENSHIP U.S.

TECHNICAL SKILLS MS Office (Word, Excel, PowerPoint, and Outlook), FORTRAN/NASTRAN, Solid Edge, NX, MATLAB, MathCad, Americans In Orbit Space Science Module and Gemini Hatch Replica Project, and certified in Lean Manufacturing.

EDUCATION

The University of Alabama in Huntsville **Huntsville, AL**

Bachelor of Science in Engineering, with a concentration in Mechanical Engineering

GPA: 2.8, Expected graduation May 2011

WORK EXPERIENCE

February 2009 – Present **Crafton Communications, Inc.** **Huntsville, AL**

Assistant to Project Manager

- Evaluate applications and complete Scopes of Work for telecommunications sites
- Evaluate, modify, and submit building permit letters
- Complete and submit Notice to Proceed Construction and Purchase Order requests
- Office Management (bill payment, office supplies, etc)

February 2008 – June 2008 **Le Maitre Ltd.** **Owens Cross Roads, AL**

Pyrotechnics Assembly Specialist

- Assembled and tested various pyrotechnic products
- Due to exceptional work performance, was promoted to work with a product that was the most difficult to assemble and on a strict building schedule and exceeded established productivity goals
- Trained and certified in fire prevention and extermination
- Certified to carry explosives

SINDHU RADHAKRISHNAN
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Rancho Cucamonga,
CA 91739 sindhu.aahilyam@gmail.com

OBJECTIVE

As a focused, practical and energetic team player I want to convert my unabated passion for learning and technology into a career to comprehend design challenges of technology in various industries.

EDUCATION

B.S. Electrical Engineering (Power) at California State University, Los Angeles; Graduation Date: June 2011

ACADEMIC RECORD, AWARDS AND RECOGNITIONS

Overall GPA at California State University, Los Angeles: 3.744/4.000; CGPA: 3.509/4.00
Featured as Star Student for MESA(Mathematics Engineering & Science Achievement) at CSULA.
Named to the Dean's list for Spring 2010, Spring 2009, Fall 2009 and Fall 2008.
Named to the Honor's list for Winter 2010, Spring 2011.
Recipient of the Presidential Scholarship, University of Arizona, 2007-2008.
Mudra Scholastic Excellence Award for 5 years from 1995 to 2000.

EXPERIENCE

NASA Marshall, CSULA, Fall 2010 to Spring 2011- Senior design project for subsurface exploration of Europa.
Analyzed-Ground Penetrating Radar systems with respect to adverse environmental conditions, designed operational flowchart for control of the robotic arm with respect to the drill and power supply; as team leader, led team interactions with partnering team at University of Alabama at Huntsville.

TATA BP Solar, Bengaluru, India, Summer 2010- Engineering Intern
Collected data of performance parameters of solar photovoltaic roof top grid-connect systems.
Evaluated and interpreted the accumulated data.
Compiled efficiency and failure analysis of the system.

RmKV, Chennai, India, Summer 2009-Marketing Intern
Studied retail environment and learnt consumer behavior.
Analyzed competition in the market segment.
Observed and understood the varied influences of marketing and advertising on sales patterns.

Software/ Language and Linguistic Skills
PSPICE, Labview, THRSIM11, MATLAB, C, Microsoft Office, OPNET; English, Tamil, Kannada, Hindi, Sanskrit and Elementary spoken Mandarin.

LEADERSHIP AND EXTRA CURRICULAR ACHIEVEMENTS

President- Tau Beta Pi, California Iota, California State University, Los Angeles.
Vice President- IEEE Student Chapter, California State University, Los Angeles.
Mentor in the MESA mentorship program at California State University, Los Angeles.
Member of Eta Kappa Nu and Society of Women Engineers.

SY JONATHAN

22 year of age
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Tél. : +0033.1.40.18.91.05
Mobile : +0033.6.29.93.00.82
E-Mail : jonathan.sy@estaca.eu
Driver's license since 2008.

Work experience

June-July 2010 : Internship within **Dassault Falcon Service** – Le Bourget Airport.
- I had to lower the cost of the aircraft scheduled maintenance.
- I had to enhance the calibration intervals of the tools used by the aircraft mechanics.
- *Skills* : project management, knowledge of the aircraft systems.

2008 – 2009 : Limited term contract within **Air France** - Charles de Gaulle Airport.
Stopover agent at terminal 2F during summer holidays.
- Checking, boarding of the passengers.
- *Skills* : teamwork, customer relationship.

Education

2006-2010: 4^{th} year student at ESTACA-Paris (5-year Masters Engineering Program in Aeronautical, Aerospace, Automobile & Railway), Aeronautical specialisation.

2003-2006: Victor Hugo Secondary School (Paris) – Scientific Baccalaureate
Cum laude distinction.

Skills

Computer: CATIA V5, Langages C and Visual Basic, Matlab, Patran, Nastran, Fluent.

Language: Intermediary level in English and in Spanish.

Qualities: Ability to adapt quickly, good listening and understanding skills.

Activities

Aeronautics: Private Pilot License in progress.

Sport : Football, snowboard, swim.

Travels : Spain, Greece, USA, Honduras, Mexico, Guadalupe, Martinique, Italy, Croatia, Tunisia, Portugal.

Music : 11 years of piano, jazz, blues, reggae.

Readings : Aeronautics books: travel narratives, magazines such as Air & Cosmos.

Wilson Tam

Work Experience

Advanced Engine Management, Inc.

2205 126th Street, Unit A
Hawthorne, Ca 90250
(310) 484-2322

Warranty Repairs Service Technician August 2007-Present

- Diagnosis of failures and repairs of programmable automobile engine control units
- Diagnosis of failures and repairs of electronic gauges and automobile monitoring systems.
- Repair of all warranty electronics

Integrated Access Systems, Inc.

10755 Sherman Way
Unit #4
Sun Valley, CA 91352
(818) 764-7010

Service Technician May 2006-August 2007

- Troubleshoot and resolve issues with parking equipment, card access systems and computer hardware/software
- Electrical wiring of parking equipment (up to 110 VAC) with various voltage rated power supplies
- Wiring and powering of relays and card access panels
- Soldering, repairing and testing of damaged boards with associated wiring
- Software setup for access control systems
- Wireless local area network systems setup

EDUCATION

California State University, Los Angeles March 2008-Present

Mechanical Engineering Major

Pi Tau Sigma Member

SKILLS

Solidworks CAD modeling and modeling analysis

Soldering of electronic components on boards

Mechanically inclined (engine rebuilds, complete automobile builds)

Bradley Townson

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606-A John Write Drive	1900 Dunham Circle
Huntsville, AL 35899	Huntsville, AL 35816

CITIZENSHIP U.S.

TECHNICAL SKILLS SolidWorks Computer Aided Design (CAD) Package; Microsoft Word, Excel, PowerPoint, Publisher, Project, Visio, and Outlook; Solid Edge CAD Package; SolidWorks CAD Package; NX 3.0 CAD Package; Maple 12; C++

EDUCATION

University of Alabama in Huntsville (UAH) **Huntsville, AL**

Bachelor of Science in Mechanical Engineering with a focus in Aerospace Engineering

GPA: 3.2/4.0 (X/4.0 in major), Expected graduation May 2011

- Have completed the UAH Honors Program and will receive a Honors Degree
- Have completed six semesters of work in the UAH Cooperative Education Program and hold over 2 years of engineering work experience.

WORK EXPERIENCE

August 2007 to Present **Prototype Integration Facility** **Huntsville, AL**

General Engineer

- Provided Quality Engineering (QE) support to the Army Airborne Command & Control System (A2C2S)
- Performed as part of the Prototype Integration Facility's (PIF) Quality Team to establish and implement an AS9100 / ISO 9001:2000 compliant quality management system in the PIF and worked on a Black Belt Project aimed at improving the quality of the Statements of Work generated at the PIF.
- Led all PIF Calibration activities and was responsible for over 700 calibrated items
- Prepared Rough Order of Magnitude (ROM) schedule and execution strategy for Hellfire Dome Cover Assembly to provide to JAMS project Office
- Developed required components of contractual packages. Developed an Independent Government Estimate (IGCE) and worked with Government Project Leads to develop Statements of Work (SOW) for the SWICE program.
- Provided quality engineering support on all CH-47 programs within the PIF. Active participant in weekly Integrated Product Team (IPT) meetings.
- Provided QE support for PIF weekly Corrective Action Request Board meetings that identified root cause and implemented corrective and preventative actions.
- Worked with the quality team and material review board to review and evaluate dispositions on Nonconforming Material Reports (NMRs)

CLEARANCE Secret Clearance, granted August 2007

J.4. Summary of Proposed Program Cooperative Contributions

This section not applicable to this proposal.

J.5. Draft International Participation Plan – Discussion on Compliance with U.S. Export Laws and Regulations

This section not applicable to this proposal.

J.6. Planetary Protection and/or Sample Curation Plan

The SARS planetary protection plan is intended to minimize the contamination to Europa and the Jupiter system. The primary goal of the protection plan is to dispose of the orbiter at the end of its life by sending it on a crash trajectory into Jupiter. The orbiter will be crushed by the immense gravitational force and leave no impact on the local environment.

Not all contamination will be preventable. The lander's propulsion system uses hydrazine as the propellant, which is a highly caustic chemical substance. The lander will have an ASRG onboard to power its subsystems. The ASRG uses plutonium as its fuel and generates power from nuclear decay. This raises the problem of leaving nuclear material on the surface of Europa. Nuclear decay is a very slow process meaning that the plutonium from the ASRG will be on Europa for many years to come.

J.7. Discussion of End of Mission Spacecraft Disposal Requirements

Please refer to appendix J.6. for information regarding the disposal of the spacecraft at the end of the mssion.

J.8. Compliance with Procurement Regulations by NASA PI Proposals

This section not applicable to this proposal.

J.9. Master Equipment List (MEL)

The master equipment list shown below in Table 29 details every currently known component on the spacecraft

Table 29 – Master Equipment List

Subsystem	Equipment	Mass (kg)	Power (W)	Quantity	Total Mass (kg)	Total Power (W)	Heritage
Science Instruments (Lander)	Microscopic Imaging Camera	0.1	<1	1	0.1	<1	Near Earth Asteroid (NEA)
Science Instruments (Lander)	Gas Chromatograph / Mass Spectrometer	11	40	1	11	40	NEA
Science Instruments (Orbiter)	Ground/Ice Penetrating Radar	26	45	1	26	45	NEA
Science Instruments (Orbiter)	Laser Altimeter	5	12	1	5	12	NEA
Science Instruments (Orbiter)	Stereo Camera	20.4	43.4	1	20.4	43.4	Mars Express
Science Instruments (Orbiter)	High Resolution Spectroscopic Camera	2.28	8.4	1	2.28	8.4	NEA
Science Instruments (Orbiter)	Gamma-ray / Neutron Spectrometer	4.08	3.6	1	4.08	3.6	NEA
Science Instruments (Orbiter)	Radio & Plasma Wave Science Instrument	6.8	7.0	1	6.8	7.0	Cassini
Science Instruments (Lander)	Advanced Gravimeter, Seismometer, Accelerometer	0.1	0.3	1	0.1	0.3	Unknown
Science Instruments (Orbiter/Lander)	Magnetometer	1.6	1.65	2	3.2	3.3	NEA
Science Instruments	Thermal Radiometer	1.2	0.6	1	1.2	0.6	NEA

(Orbiter)							
Science Instruments (Lander)	Atmospheric Science Package	2	3.2	1	2	3.2	NEA, Venus Flagship
ACS (Orbiter)	Astrix 3M2	4.2	15	1	4.2	15	High
ACS (Orbiter)	SED 36	3.7	8.4	1	3.7	8.4	High
ACS (Orbiter)	AeroJet MR-111C	0.33	13.64	16	5.28	218.24	High
ACS (Orbiter)	AeroJet MR-107K	0.91	39	4	3.64	156	High
ACS (Lander)	AeroJet MR-111C	0.33	13.64	12	3.96	163.68	High
ACS (Lander)	SED 26	3	10	2	6	20	High
ACS (Lander)	SIRU Inertial Measurement Unit	7.1	43	1	7.1	43	High
ACS (Lander)	Radar Altimeter (No Specific Model Identified)	5	10	1	5	10	Medium
CDS (Orbiter)	CORECI (Compression Recording Ciphering Unit)	14	75	1	14	75	High
CDS (Orbiter)	Solid State Recorder (No Specific Model Identified)	8	40	1	8	40	High
CDS (Lander)	SEAKR GEN-I	8.7	37	1	8.7	37	High
CDS (Lander)	AMPEX DSR400B	9.07	40	1	9.07	40	Low
Communications (Lander)	Ka-Band Transmitter (No Specific Model Identified)	0.2	10	1	0.2	10	High
Communications (Lander)	Antenna (No Specific Model Identified)	3	N/A	1	3	N/A	None
Power (Orbiter/Lander)	Advanced Sterling Radioisotope Generator (ASRG)	19	N/A	2	38	N/A	None

Power (Orbiter)	VES-180 Rechargeable Lithium Battery	1.11	N/A	2	2.22	N/A	High
Power (Lander)	Nickel Hydride Battery (No Specific Model Chosen)	N/A	N/A	N/A	N/A	N/A	High
Propulsion (Orbiter)	AeroJet HiPAT DM	5.2	46	1	5.2	46	High
Propulsion (Orbiter)	Spherical Propellant Tank	115	0	1	115	0	High
Propulsion (Orbiter)	Spherical Oxidizer Tank	69	0	1	69	0	High
Propulsion (Orbiter)	Spherical Pressurant Tanks	4.84	0	2	9.68	0	High
Propulsion (Lander)	AeroJet MR-80B	7.94	168	2	15.88	336	High
Propulsion (Lander)	Barrel Shaped Propellant Tank	12	0	1	12	0	High
Propulsion (Lander)	Spherical Oxidizer Tank	20.5	0	1	20.5	0	High
Structure (Orbiter)	Carbon Fiber and Aluminum Honeycomb Sandwich Structure	238	0	1	238	0	High
Structure (Orbiter)	Reinforcements	72	0	1	72	0	High
Structure (Lander)	Main Legs	16.67	0	3	50	0	Mars Polar Lander
Structure (Lander)	Support Legs	8.75	0	6	52.5	0	Mars Polar Lander
Structure (Lander)	Footpads	6.62	0	3	20	0	Mars Polar Lander
Structure (Lander)	Main Science Truss Structure	75	0	1	75	0	Mars Polar Lander
Structure (Lander)	Aluminum Honeycomb Leg	0.4	0	3	1.2	0	Mars Polar

	Cores						Lander
Thermal (Lander)	Multi-Layer Insulation Blanket	Varie s	0	11	12	0	High
Thermal (Lander)	Aluminum Louvers	0.35	0	30	11	0	High
Thermal (Lander)	Aluminum Honeycomb Radiator	2.1	0	1	2.1	0	High

J.10. Heritage

Please refer to the MEL in appendix J.6 for heritage information.

J.11. List of Abbreviations and Acronyms

Table 30, below, lists all acronyms and abbreviations used in this proposal.

Table 30 – List of Abbreviations and Acronyms

Acronym	**Meaning**
ACS	Attitude Control System
AMBR	Advanced Material Bipropellant Rocket
AO	Announcement of Opportunity
ASGARD	Advanced Seismometer, Gravimeter, Accelerometer
ASI	Atmospheric Science Instrument
ASRG	Advanced Sterling Radioisotope Generator
BLDC	Brushless Direct Current motor
CDS	Command and Data System
Co-I	Co-Investigator
ConOps	Concept of Operations
CORECI	Compression Recording Ciphering Unit
CSULA	California State University Los Angeles
DDD	Displacement Damage Dose
DSN	Deep Space Network
EAR	Export Administration Regulations
EELS	Europa Extraterrestrial Life Survey
EOI	Europa Orbit Insertion
E/PO	Education and Public Outreach
ESTACA	Ecole Supérieure des Techniques Aéronautiques et de Construction Automobile
FEA	Finite Element Analysis
FY	Fiscal Year
GIPR	Ground Ice Penetrating Radar
GCMS	Gas Chromatograph Mass Spectrometer
HiPAT DM	High Performance Liquid Apogee Thruster Dual Mode
HGA	High Gain Antenna
IMU	Inertial Measurement Unit
ITAR	International Traffic in Arms Regulations
JEO	Jupiter Europa Orbiter
JOI	Jupiter Orbit Insertion
JPL	Jet Propulsion Laboratory
LOLA	Lunar Orbiter Laser Altimeter
LV	Launch Vehicle
MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MIC	Microscopic Imaging Camera
MEL	Master Equipment List
MLA	Mercury Laser Altimeter

MPL	Mars Polar Lander
NASA	National Aeronautics and Space Administration
NEA	Near Earth Asteroid
NEPA	National Environmental Protection Agency
NLA	NEAR Laser Altimeter
NTO	Nitrogen Tetroxide
PI	Principle Investigator
PLF	Payload Fairing
PM	Project Manager
RA	Robotic Arm
RPWS	Radio Plasma Wave Science Instrument
SARS	Space Analysis and Reconnaissance System
SC	Stereo Camera
SEO	Science Enhancement Option
SMD	Science Mission Directorate
TID	Total Ionized Dose
TRL	Technology Readiness Level
VEEGA	Venus Earth Earth Gravity Assist
UAH	University of Alabama in Huntsville
USO	Ultra Stable Oscillator

J.12. List of References

This section not applicable to this proposal.

J.13. Infusion Plan for NASA-Developed Technology

No NASA developed technology is being used in the proposed mission.

J.14. Description of Enabling Nature of ASRG

The EELS team performed a technical study as to why the ASRG is the most compatible power system for this spacecraft. The ASRG provides a significant mass, cost and plutonium savings. Furthermore, the power available is a significantly larger amount than other options, such as the RTG. The power output of an ASRG that operates at 650^{o}C is approximately 143 Watts, whereas, an ASRG that operates at 850^{o}C outputs approximately 160 Watts. In knowing these outputs, it can be determined that two 850^{o}C ASRGs are needed. In knowing that there is a .8% per year power degradation, the final power output, upon arrival of Europa and assuming an 8.5 year travel time, is 298.24 Watts. A trade study between the ASRG and RTG is show below in Table 31:

Table 31 – ASRG Trade Study

	Weight Factor	ASRG	MMRG
Power	7	8	6
Mass	6	7	4
Resource Depletion	5	5	4
Cost	7	3	4
Heritage	6	5	7
Testing	8	5	6
Lifetime	5	5	5
Radioactive Decay	4	5	3
Efficiency	3	7	5
	Totals:	280	256

J.15. Calculations

Propulsion System Calculations

Known:

$m_{prop} := 484.1kg$ $\rho_{n2h4} := 1008\frac{kg}{m^3}$ $P_{total} := 2068425Pa$ $P_{He} := 31026375Pa$

$T_i := 300K$ $R_1 := 2077.3\frac{J}{kg \cdot K}$

Propellant and Pressurant Volume:

$$V_{prop} := \frac{m_{prop}}{\rho_{n2h4}} = 480.258L$$

$$V_{ullage} := 0.03 \cdot V_{prop} = 14.408L$$

$$V_{pmd} := 0.03 \cdot V_{ullage} = 0.432L$$

$$V_{total} := V_{prop} + V_{ullage} + V_{pmd} = 495.098L$$

$$m_{He} := \frac{P_{total} \cdot \frac{m_{prop}}{\rho_{n2h4}}}{R_1 \cdot T_i} \cdot \frac{1.67}{1 - \frac{P_{total}}{P_{He}}} = 2.852kg$$

$$V_{He} := \frac{m_{He} \cdot R_1 \cdot T_i}{P_{He}} = 57.288L$$

Tank masses:

$m_{ptank} := 0.0116 \cdot 2068.4 \cdot 0.495 \cdot 1kg = 11.877kg$

$m_{Hetank} := 0.0116 \cdot 31026.4 \cdot 0.057 \cdot 1kg = 20.515kg$

Thrust to Weight Calculations

$m_{dry} := 615kg \qquad m_{prop} := 981.155kg + 29.435kg = 1.011 \times 10^{3} kg$

$m_{wet} := m_{dry} + m_{prop} = 1.626 \times 10^{3} kg$

$g = 9.807 \frac{m}{s^{2}} \qquad TW := 0.4$

$Tmax := TW \cdot m_{wet} \cdot g = 6.377 \times 10^{3} N$

$T_{min} := TW \cdot m_{dry} \cdot g = 2.412 \times 10^{3} N$

$Num_{eng} := \frac{Tmax}{3100N} = 2.057$

Attitude Control System Propulsion Calculations

Known:

$m_{prop} := 15kg \qquad \rho_{n2h4} := 1008 \frac{kg}{m^{3}} \qquad P_{total} := 2068425Pa \qquad P_{He} := 31026375Pa$

$T_{i} := 300K \qquad R_{1} := 2077.3 \frac{J}{kg \cdot K}$

Propellant and Pressurant Volume:

$V_{prop} := \frac{m_{prop}}{\rho_{n2h4}} = 14.881L$

$V_{ullage} := 0.03 \cdot V_{prop} = 0.446L$

$V_{pmd} := 0.03 \cdot V_{ullage} = 0.013L$

$V_{total} := V_{prop} + V_{ullage} + V_{pmd} = 15.341L$

$$m_{He} := \frac{P_{total} \cdot \frac{m_{prop}}{\rho_{n2h4}}}{R_1 \cdot T_i} \cdot \frac{1.67}{1 - \frac{P_{total}}{P_{He}}} = 0.088\,kg$$

$$V_{He} := \frac{m_{He} \cdot R_1 \cdot T_i}{P_{He}} = 1.775\,L$$

Tank masses:

$m_{ptank} := 0.0116\,2068.4\,0.015\,1kg = 0.36kg$

$m_{Hetank} := 0.0116\,31026.4\,0.0000881kg = 0.032kg$

Structure Calculations

Crushable Material Calculations

Aluminum Honeycomb Material properties

$\sigma_{al.hc} := 4100\,psi = 2.827 \times 10^{7}\,Pa$

$$\rho_{al.hc} := 22.1 \cdot \frac{lb}{ft^3} = 354.008 \frac{kg}{m^3}$$

Stroke Length

$a := 9 \cdot g = 88.26 \frac{m}{s^2}$ $\qquad v := 8 \cdot \frac{m}{s}$ $\qquad d := 1 \cdot m$

Given

$$\frac{v^2}{2} = a \cdot d$$

$Find(d) = 0.363m$

Determining the required area and radius

$m_l := 500 \cdot kg$

$Force := m_l \cdot a = 4.413 \times 10^{4} \cdot N$

$A_s \cdot \sigma = Force$ $\qquad A_s = \pi \cdot r^2$

$$A_s := \frac{Force}{\sigma_{al.hc}} = 1.561 \times 10^{-3}\,m^2$$

$$r := \left(\frac{A_s}{\pi}\right)^{\frac{1}{2}} = 0.022m$$

Lander and Europa Properties:

$\sigma := 5.6704\cdot10^{-8}\frac{W}{m^2\cdot K^4}$ **Stephan-Boltzmann Constant**

$T_{pole} := -223°C$ **Temperature at pole on Europa**

$Albedo := 0.67$ **Albedo of Europa**

$Q_{DS} := 51\frac{W}{m^2}$ **Direct solar energy - assumed about same as Jupiter**

$Q_{IR} := 13.6\frac{W}{m^2}$ **Planetary IR energy - assumed about same as Jupiter**

$F_1 := \frac{1}{4}$ **View factor on surface of Europa**

$F_2 := \frac{1}{4}$ **View factor for reflected sunlight on Europa (UNSURE ABOUT THIS)**

$A_{hex} := 2\cdot\left[\frac{3\sqrt{3}}{2}\cdot(1m)^2\right] + 6(0.5m\cdot 1m) = 8.196m^2$ **Total Surface Area of Spacecraft**

Power for internal components:

$Microscopic\_Camera := 1W$

$Magnetometer := 1.65W$

$Seismometer := 0.3W$

$Atmospheric\_Science\_Package := 3.2W$

$Drill\_Camera := 1W$

$GCMS := 40W$

$Lander\_Instruments := Microscopic\_Camera + Magnetometer + Seismometer + Atmospheric\_Science\_Package + Drill\_Camera + GCMS$

$Attitude\_Control := 72W$

$Power := 500W$

$CDS := 77W$

$Propulsion := 336W$

$Mechanisms := 40W$

$Telecom := 10W$

$\eta := 0.32$

Assumed highest mechanical efficiency

$P_{int} := Lander\_Instruments + Power + Propulsion + Attitude\_Control + CDS + Telecom + Mechanisms$

$RHU := 1W$

$P_{max} := P_{int}$

$Q_{max} := P_{max} \cdot (1 - \eta) = 735.862W$ **Maximum internal heat generation**

$$Q_{max\_flux} := \frac{Q_{max}}{A_{hex}} = 89.781 \frac{W}{m^2}$$

$P_{min} := Power$

$\varepsilon_{IR} := 0.05$ **IR emissivity of polished aluminum**

$Q_{min} := P_{min} \cdot (1 - \eta) = 340W$ **Minimum internal heat generation**

$$Q_{min\_flux} := \frac{Q_{min}}{A_{hex}} = 41.483 \frac{W}{m^2}$$

Temperature Calculations:

Maximum internal temperature:

$T_{max} := 40°C$

Given

$$0 = \left[\left(1 - \alpha_K\right) \cdot A_{hex} \cdot Q_{DS}\right] + \left(F_1 \cdot A_{hex} \cdot \varepsilon_{IR} \cdot \sigma \cdot T_{max}^4\right) + \left[F_2 \cdot \left(1 - \alpha_K\right) \cdot (1 - Albedo) \cdot A_{hex} \cdot Q_{DS}\right] - \left(A_{hex} \varepsilon_{IR} \cdot \sigma \cdot T_{max}^4\right) + Q_{max}$$

$T_{max} := Find\left(T_{max}\right) = 232.916°C$

Tmin > 40C so dissipation of excess heat is needed - Radiator/Louvers

Radiator Properties:

$$Q_{radiator} := Q_{DS} \cdot \alpha_K 0.25 + Q_{IR} \cdot \varepsilon_{IR} + Q_{DS} \cdot Albedo \cdot \alpha_K + Q_{max\_flux} = 95.153 \frac{W}{m^2}$$

$$Q_{rad} := Q_{radiator} \cdot A_{hex} = 779.892 W$$

$\alpha_A := 0.2$ $\varepsilon_A := 0.8$ **Emissivity and Absoptivity of Aluminum**

$T_{abs} := 40°C$ **Would like to keep the internal temperature between 0C and 40C.**

$$A_{rad} := \frac{Q_{rad}}{\sigma \cdot \varepsilon_A \cdot T_{abs}^4} = 1.788 m^2$$

Area of radiator required

$$A_{louver} := 12 in \cdot 10.5 in = 0.081 m^2$$

http://www.atk.com/capabilities_multiple/cs_ss_subsys_tms_tl.asp

$$n_{louvers} := \frac{A_{rad}}{A_{louver}} = 21.993$$

Shielding Materials, Area of equipment and instruments, and weight of Shielding:

$\rho_{poly} := 67 \frac{lb}{ft^3}$ $t_{poly} := 25 mm$ **for 5% Borated Polyethylene**

$\rho_{Ta} := 0.564 \frac{lb}{in^3} = 974.592 \frac{lb}{ft^3}$ $t_{Ta} := 0.35 cm = 3.5 \cdot mm$ **Tantalum (Ta - Tungsten 80 Copper 20)**

$\rho_{AL} := 0.0975 \frac{lb}{in^3} = 168.48 \frac{lb}{ft^3}$ $t_{AL} := 25.4 mm$ **6061-Aluminum - 150krad**

$$A_{spec} := (480 mm 470 mm 2) + (275 mm 270 mm 2) + (480 mm 275 mm 2) = 0.864 m^2$$

$$A_{mc} := (19 mm 96 mm 2) + (40 mm 96 mm 2) + (19 mm 40 mm 2) = 0.013 m^2$$

$$A_{seis} := (200 mm 200 mm 2) + (250 mm 200 mm 4) = 0.28 m^2$$

$$A_{mag} := (100 mm 100 mm 2) + (50 mm 100 mm 4) = 0.04 m^2$$

$$A_{asp} := (100 mm 100 mm 6) = 0.06 m^2$$

$$A_{dc} := (5 mm 20 mm 4) + (5 mm 5 mm 2) = 4.5 \times 10^{-4} m^2$$

$$A_{seakr\_gen} := (0.234 m \cdot 0.114 m \cdot 2) + (0.368 m \cdot 0.114 m \cdot 2) + (0.234 m \cdot 0.368 m \cdot 2) = 0.309 m^2$$

SEAKR GEN-I (CDS) - rad hardened to 30 krad - no extra shielding necessary

$A_{DSR400B} := (0.254m \cdot 0.133m \cdot 2) + (0.184m \cdot 0.133m \cdot 2) + (0.184m \cdot 0.254m \cdot 2) = 0.21m^2$

DRB400B (CDS) - assumed needs to be shielded to 150 krad with the rest

$A_{ant} := (0.025m \cdot 0.025m \cdot 2) + (0.025m \cdot 0.165m \cdot 4) = 0.018m^2$

Telecom antenna - assumed needs to be shielded to 150 krad with the rest

$m_{rad\_shield\_Ta} := \rho_{Ta} \cdot t_{Ta} \cdot (A_{spec} + A_{mc} + A_{seis} + A_{mag} + A_{asp} + A_{dc} + A_{DSR400B} + A_{ant}) = 81.126kg$

MASS OF THERMAL SYSTEM:

$\rho_{rad} := 2.1 \frac{lb}{ft^3}$

$t_{rad} := 1in$

5056 Aluminum honeycomb radiator

$m_{radiator} := \rho_{rad} \cdot t_{rad} \cdot A_{rad} = 1.528kg$

http://www.atk.com/capabilities_multiple/cs_ss_subsys_tms_tl.asp

$m_{louver} := 0.89 \frac{lb}{ft^2} \cdot A_{louver} = 0.353kg$

$m_{louvers} := 22 \cdot m_{louver} = 7.771kg$

$m_{Thermal\_System} := m_{radiator} + m_{louvers} + m_{rad\_shield\_Ta} = 90.424kg$

ESTACA Orbiter Propulsion System Calculations

The engine is DiPAT DM which is a bi-propellant engine, it contains hydrazine (N_2H_4) as fuel and nitrogen peroxide (NTO) as an oxidizer. The tanks are built from titanium ($\rho_{titanium}$=4429.89 kg/m^3). First, determine the mass of each propellant in the satellite knowing that the total mass of propellant is about 2769.4Kg. The data sheet concerning the engine gives the oxidizer/fuel ratio (RM= 0.85) so the propellant masses can be determined:

$$RM = \frac{Moxidizer}{Mfuel}$$

$$Moxidizer = 0.85 \times Mfuel$$

$$Mtotal = Moxidizer + Mfuel$$

$$Mfuel = \frac{Mtotal}{1.85} = 1496.97Kg$$

$$Moxidizer = 1272.43\ Kg$$

The corresponding volumes are:

$$Vfuel = \frac{Mfuel}{\rho fuel} = 1482.15\ L$$
$$Voxidizer = \frac{Moxidizer}{\rho oxidizer} = 880.27\ L$$

Taking into account the volume of propellant that is unusable:

$$Vunusable = 0.03 \times V$$
$$Vtotalprop = V + Vunusable$$

For each propellant there is a part that is used to pressurize the tank, calculated as:

$$Vempty = \frac{V}{2}$$

$$Vtot = Vtotalprop + Vempty$$

Now, the diaphragm volume:

$$Vd = 0.01 * Vtot$$

Finally, the total volume of the tank:

$$Vtank = Vtot + Vd$$

Therefore:

$$VtankHydrazine = 2312.82\ L$$
$$VtankNTO = 1373.61\ L$$

Now, the goal is to determine tank radius, tank thickness, and tank mass.
Data given:

- Maximum working pressure : P_{max}= 4653960 Pa
- Maximum stress : σ_{max}= 690000 kPa

The membrane thickness is given by:

$$r = (0.75 \times \frac{Vtank}{3.14})^{\frac{1}{3}}$$

The tank radius, minimum and maximum tank thickness are calculated as follows:

$$tmin = \frac{Pmax \times r}{2 \times \sigma max}$$

$$tmax = tmin + 0.0002$$

$$Rtank = r + tmax$$

This results in:

$$tminHydrazine = 2.77\ mm$$

$$tminNTO = 2.326\ mm$$

$$tmaxHydrazine = 2.97\ mm$$

$$tmaxNTO = 2.526\ mm$$

$$RtankHydrazine = 0.8235m$$

$$RtankNTO = 0.6922m$$

We can calculate membrane masses:

$$Mmem = \frac{4}{3} \times \pi \times \rho titanium \times (Rtank^3 - r^3)$$

The tank has reinforced area and must take it into consideration for mass calculation:

$$Mgirthweld = 2 \times 3.14 \times Rtank \times tmin \times 0.05 \times 0.02 \times \rho titanium$$

$$Mpenetration = 2 \times 3.14 \times 0.075^2 \times tmax \times \rho titanium$$

The mass of the diaphragms also must be considered:

$$Md = Vd \times 0.09965$$

Finally, tank mass is given by:

$$Mtank = Mmem + Mgirthweld + Mpenetration + Md + 0.02 \times (Mmem + Mgirthweld + Mpenetration)$$

Resulting in:

$$MtankHydrazine = 114.32\ Kg$$

$$MtankNTO = 68.89\ Kg$$

ESTACA Orbiter Telecommunication System Calculations

Calculations for the Antenna:

Defining the size of antenna:

- Light celerity = 3.00*10^8 m/s
- Frequency = 2.60*10^10 Hz
- Wavelength = $\lambda = \frac{\text{Light celerity}}{\text{Frequency}}$ = 0.012 m
- k = 55%

Gains and angles:

- Gain max = G_{max}= $10 * \log\left(k * (pi * diameter/\,\lambda)^2\right)$ = 55.6460913 dB
- Gain to -3dB = G-3dB = G_{max}-3 = 52.6460913 dB
- Gain to -4dB = G-4dB = G_{max}-4 = 51.6460913 dB
- Θ-4dB = $\sqrt{\frac{(G-4dB\ \ )-c}{a}}$ = 0.31088091 °

Antenna geometry:

- Diameter = 3 m
- Depth = 0.6 m

This results in a focal length of 0.9375 m

Distances across space

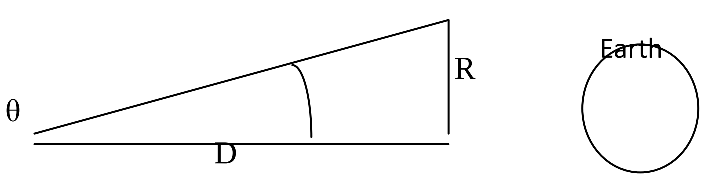
- D_{Max} = 968.1*10^6 km
- D_{min} = 58805*10^6 km
- $D_{average}$= 628.76*10^6 km

Field of emission of the antenna compared to the distance with this formula: R=D*sin θ. Firstly, θ -3dB:

$$\theta - 3\text{dB} = 70 * \frac{\frac{\text{lightcelerity}}{\text{frequency}}}{\text{diameter}}$$

Defining the field of emission of the antenna

- R_{Max} = 3.4*10^6 km
- R_{min} = 2.075*10^6 km
- $R_{average}$= 2.217*10^6 km



This field of emission of the antenna is the surface which allows it to send information.

Then, we have done the same for the distance Earth-satellite:

- R_{Max}= 4.545*10^6 km
- R_{min} = 2.763*10^6 km
- $R_{average}$= 2.952*10^6 km

Finally, the distance lander-satellite for a satellite altitude of 100 km, the field of emission:
R = 469.5 m

ESTACA Orbiter Mass Calculations

Antenna System:

Mass of the deflector, $Md = \frac{M \times Sa}{0.99} = 130.97\ kg$

Mass of receptor, Mr = 226.8 g

Total antenna system mass,
$Ma = Md + 0.1 \times Md + Mr = 144.07\ kg$

Lander/Orbiter Adapter:

$$Vcone = \frac{1}{3} \times \pi \times R \times h$$
$$Vadapter = 9.7 \times 10^{-3} m^3$$
$$Madapter = Vadapter \times \rho aluminum = 26.18\ kg$$

ESTACA Power Calculations

Worst Case Power Calculations:

Necessary Power= ΣPower need of (Measure Instruments+ Antenna receptor+ Storage Tools + Navigation Instruments)

Data rate available =Σ Data rate of (Storage Tools)

Data rate needed by the orbiter =Σ Data rate of (Measure Instruments + Storage Tools + Navigation Instruments)

However, we have 2 types of data rate: data rate available from storage tools and data rate used from equipments. In our case, we have 21,400-28,600 kpbs available and since only 1153 kpbs is needed by the equipment on the orbiter, then the data rate available is enough for both the lander and orbiter.

Mass = Σ Mass of (Measure Instruments+ Antenna receptor + Storage Tools + Navigation Instruments + Power control)

Source of energy = Σ Power of (Battery + ASRG)

Power Balance Determination: In preparation for any mission, the overall power supply and demand has to be determined to ascertain that everything has been accounted for in mission calculations. Since power is required for anything to operate, this section discusses the power balance. The HiPAT DM Engine needs 46W of power; the first secondary thruster needs 8.25W and the second 37W. Given the preceding data, the mission will have a total of 326W. Next we have to consider the amount of power that the equipment needs which is 353.45W. By combining, we obtain a total of 679.45W. However, we never need all of this power at the same time. Therefore, in order to check if we have sufficient power, we have to examine the different flight phases.

We have three significant phases on the orbiter:

- Main impulses of propulsion with the purpose of going to Europa.
- Orbit maneuvers
- Observation
- Information transmission

Main impulses

In the main impulses, we only use the HiPAT DM Engine and navigation equipments.

We obtain a power of 69.4W.

Orbit maneuvers

In these phases, all of the navigation instruments need to be supplied. There are two types of orbit maneuvers on our satellite: maneuvers around the cylindrical axis and the other axes. These two engines will use 37W which gives a necessary power of 97.4W. The second maneuver will use the maximum of 6 thrusters which each needs 8.25W. This gives a necessary power of 72.9W.

Observation phases

In observation phases, we need to supply all of the measurement instruments but also the storage tools.

We obtain a necessary power of 296.65W.

Information transmission

In the information transmission phases, we need to supply the storage tools, the receptor of the antenna and navigation instruments in order to maintain the satellite in optimum position for the emission and reception of data.

We obtain a necessary power of 208.4W.

If we want to include the losses and take other possible electronic components into consideration by putting a percentage of 30%, we can see that we greatly exceed the needed powers with two batteries. In case one battery fails, we can alternate the supply from measurements and instruments supplied so that the mission will still continue.

J.16. Sources

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J.17. Letter of Acknowledgement

UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

April 24, 2011

Phil Jackson
Project Manager
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Dear Mr. Jackson,

The University of Alabama in Huntsville is pleased to formally acknowledge your team's design for an Europa Extraterrestrial Life Survey (EELS) mission as part of NASA's Discovery Program. We believe, should your design be selected, the science gained from this mission will not only provide a greater understanding of our solar system, but will help to distinguish our institution as a premier center for engineering education, research, and technological development. With this said, The University of Alabama in Huntsville is fully committed to support your team in its current and future endeavors. Best wishes on being selected!

Sincerely,

Michael P.J. Benfield, Ph.D.
Europa Extraterrestrial Life Survey Mission Manager
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J.18. Alternate Mission

Detailed in this section is an alternate mission designed to be compatible with the Falcon 9 family of launch vehicles. The Discovery Announcement of Opportunity states that this mission must be compatible across three families of launch vehicles. The mission being proposed is only compatible with two of the launch vehicle classes. The Falcon 9 is the only class of required launch vehicles that the SARS mission is not compatible with.

The elements in this configuration of the SARS mission will be capable of completing most of the threshold science mission. The mass limitations of the Falcon 9 LV will not allow for a lander to be implemented in the design of the mission. Because of this, the objectives of sampling the icy surface of Europa cannot be accomplished. Mass has been allocated for some kind of impact probe or other small element that can be deployed from the orbiter. The other objectives can be accomplished with just an orbiter. Below, in Table 32, is the mass breakdown for the mission:

Table 32 – Alternate Mass Table

Element	**Mass (kg)**
Spacecraft Propellant	995
Spacecraft Dry Mass	175
Spacecraft Margin	75
Deployable Science Element	300
Margin	432
Total	1975