4-20-2023

ARISE Project Management Review

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by

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An Honors Capstone

submitted in partial fulfillment of the requirements

for the Honors Diploma

to

The Honors College

of

The University of Alabama in Huntsville

April 20th, 2023

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ABSTRACT

This document shall serve as a guide and tool used to identify project management tools and review the effectiveness of using these methods during the senior design class for the Autonomous Research Investigating the Surface of Europa (ARISE) project for the Fall 2022 semester and the Spring 2023 semester for senior level Mechanical and Aerospace Engineering (MAE) majors and Industrial and Systems Engineering (ISE) majors at the University of Alabama in Huntsville (UAH). These MAE and ISE students will combine into different teams to create Integrated Project Teams (IPTs), which are teams consisting of members of different backgrounds all working together towards a common goal or objective. In this document, the systems engineering processes will be defined and explained, and then related to how these concepts and processes were used throughout the ARISE project. Keeping documentation and following the processes in place are helpful to keep a project organized and on schedule.

ARISE is composed of developing and designing three spacecraft vehicles to gather scientific data to determine if there is life or the capability of life on Europa. Each vehicle team is composed of eleven students, three of which are in leadership positions, and eight are subsystem engineers. The Fall 2022 semester focuses on a theoretical mission designed to get the students and teams thinking critically to accomplish mission requirements. In the Spring 2023 semester, the students and teams will meet with the scientists from the College of Charleston to develop real scientific objectives and design a vehicle capable of carrying out its specific objective. ARISE focuses on producing a design concept along with the College of Charleston to accomplish this mission and will be presented to NASA at the end of the Spring 2023 semester for review and evaluation.

1.0 OVERVIEW

1.1 Introduction

Autonomous Research Investigating the Surface of Europa (ARISE) is a project based out of The University of Alabama in Huntsville (UAH), where it is being given to Senior Design Integrated Project Teams (IPTs) to explore and evolve the mission of exploring Europa and Jupiter in collaboration with the College of Charleston.

1.2 Objectives and Goals

ARISE's purpose is to transport three spacecraft to Europa, a moon of Jupiter, to explore and gather scientific data showcasing that there can be signs of life. These three spacecrafts will consist of an orbiter, lander, and probe, with each vehicle having a separate team focused on developing their respective vehicle concept and design. Each vehicle will have a different scientific objective to complete as they collaborate with the College of Charleston to figure out the most effective way to gather the necessary data. At the end of the Spring 2023 semester, each IPT will have a final design concept.

2.0 ROLES AND RESPONSIBILITIES

There are many different roles amongst each IPT and within ARISE itself. In Figure 1, we can see a breakdown of the different roles for each team, although they can be categorized into a few groups, which are program manager, lead systems engineer, chief engineer, and subsystems engineer, and scientist. Each person has a different responsibility to the project with their roles listed as follows:

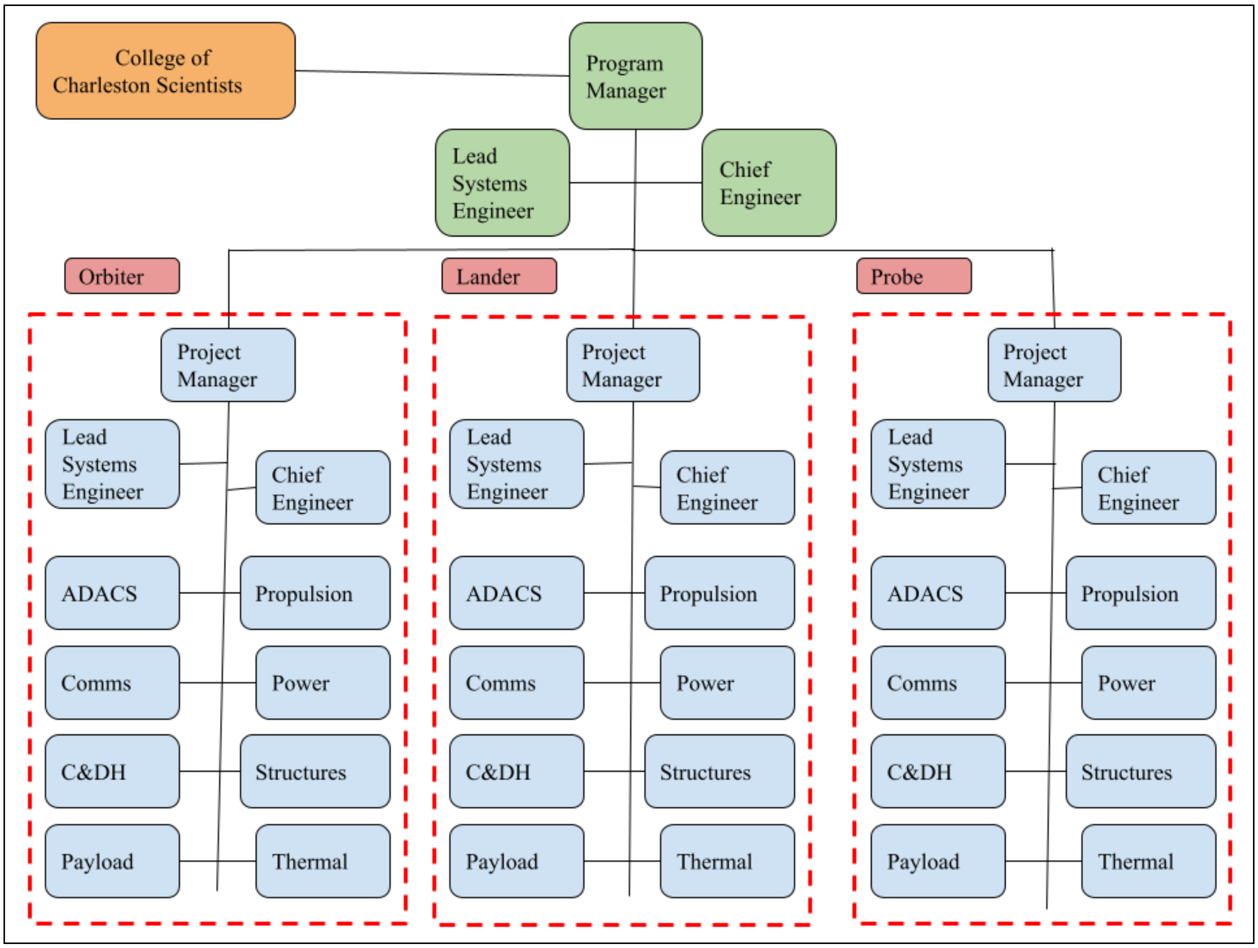

Figure 1: ARISE Organizational Structure

2.1 Program/Project Manager (PM)

2.1.1 Oversees vehicle/program team.

2.1.2 Ensures teams are communicating accordingly and keeping to schedule.

2.1.3 Communicate with scientists to determine scientific objectives.

2.1.4 Determine vehicle requirements for each team.

2.1.5 Communicate with other vehicles about design and requirements needed from them.

2.1.6 Resolve disputes amongst team members if necessary.

2.1.7 Communicate with LSE and CE about design and implementation.

2.1.8 In charge of making final calls and decisions if an agreement cannot be reached.

2.2 Lead Systems Engineer (LSE)

2.2.1 Assist in technical and design decisions for vehicle/program team.

2.2.2 Analyze subsystems to ensure all vehicle subsystems are working together.

2.2.3 Determine risks for vehicle/mission.

2.2.4 Communicate with PM about vehicle design updates and systems issues.

2.3 Chief Engineer (CE)

2.3.1 Assist in technical and design decisions for vehicle/program team.

2.3.2 Oversee trade studies for each vehicle subsystem.

2.3.3 Communicate with PM about vehicle design updates.

2.3.4 Assist vehicle subsystems in design decisions and developing their subsystem.

2.4 Subsystems Engineer

2.4.1 Gather research for assigned subsystem.

2.4.2 Conduct trade studies for assigned subsystem.

2.4.3 Contribute to design decisions for assigned subsystem, other subsystems, and vehicle design.

2.4.4 Communicate with other subsystems, project manager, lead systems engineer, chief engineer, and other vehicle teams, and update on progress made within their assigned subsystem.

2.4.5 Compute calculations required for their assigned subsystem.

2.5 Scientist

2.5.1 Determine plausible scientific objectives.

2.5.2 Communicate science objectives to PM to determine what is possible or not.

2.5.3 Choose scientific instruments that will accomplish scientific objectives.

2.5.4 Provide scientific instruments to PM.

3.0 PROJECT LIFE-CYCLE

The ARISE project had four Design and Analysis Cycle (DAC) reviews, where each IPT team will brief the progress on their design after each phase. ARISE uses NASA's project life-cycle, included in Appendix B, as a baseline for each set of phase requirements in order to create Figure 2. Each DAC coincides with one of NASA's phases. As there are only four DACs, only the first four phases of NASA's life cycle will be completed, which include Pre-Phase A, Phase A, Phase B, and Phase C, and will coincide with DAC 1, DAC 2, DAC 3, and DAC 4 respectively. Every IPT will complete the four following phases with requirements as follows:

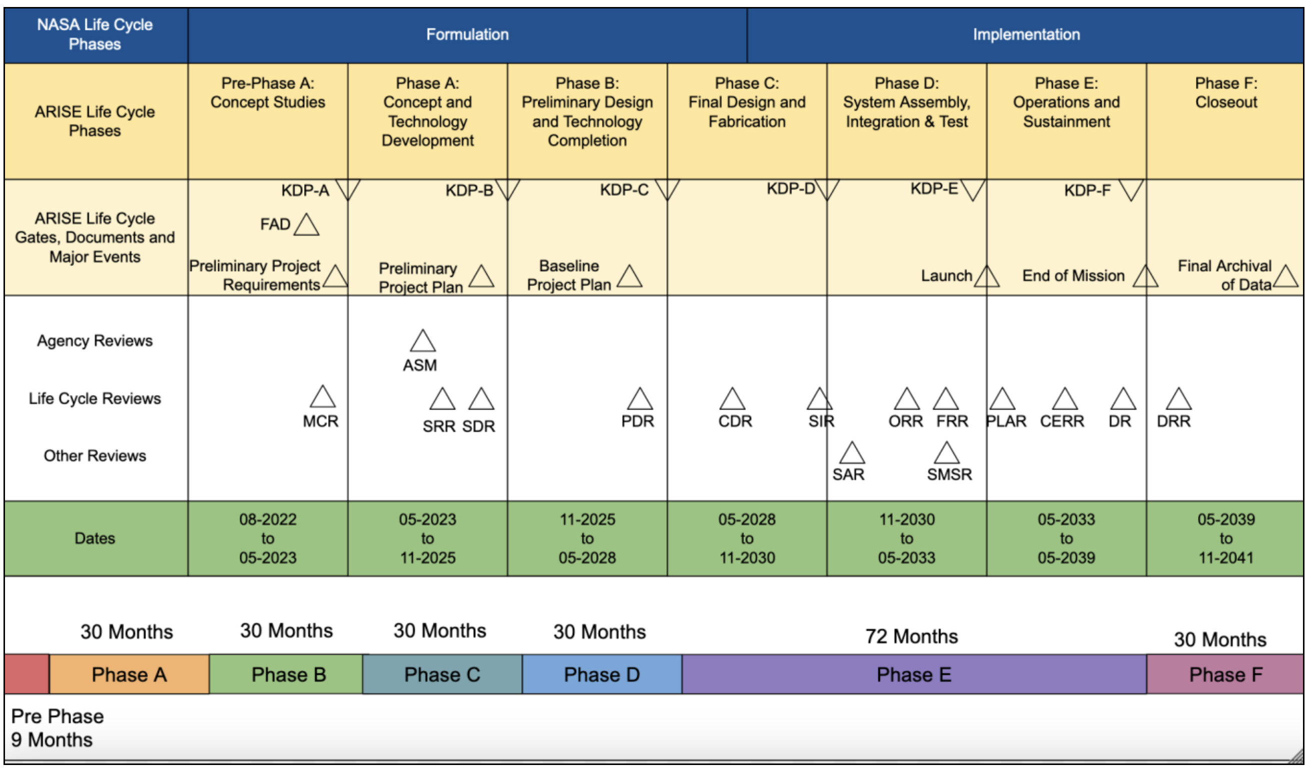

Figure 2: ARISE Project Life-Cycle

3.1 Pre-Phase A: Concept Studies

3.1.1 Leadership positions will be interviewed and chosen by instructors.

3.1.2 Leadership will recommend and choose subsystem engineers.

3.1.3 Mission and Objectives are determined.

3.1.4 Introductory and preliminary resources will be available for use, provided by the instructors.

3.1.5 Research will be done by each team on prior historical missions relative to their vehicle.

3.1.6 DAC 1 Review for the program team will include:

3.1.6.1 Options for launch vehicle.

3.1.6.2 Breakdown of management structure.

3.1.6.3 Initial list of Technical Performance Metrics (TPMs) for mission.

3.1.6.4 Develop assumptions and ground rules for initial architecture.

3.1.7 DAC 1 Review for the vehicle teams will include:

3.1.7.1 Research from historical mission.

3.1.7.2 Design philosophies and decisions gathered from historical mission.

3.1.7.3 Vehicle trades from historical missions.

3.1.7.4 Develop subsystem mass allocations based on prior historical missions.

3.2 Phase A: Concept and Technology Development

3.2.1 Tentative science objectives are determined.

3.2.2 Tentative instruments will be selected for each vehicle.

3.2.3 Vehicle constraints and requirements will be determined.

3.2.4 Develop baseline mission for each vehicle.

3.2.5 DAC 2 Review for program team will include:

3.2.5.1 Baseline mission breakdown of mass and cost allocations.

3.2.5.2 Explain assumptions and ground rules chosen for baseline mission.

3.2.5.3 Baseline mission list of Technical Performance Metrics (TPMs).

3.2.6 DAC 2 Review for vehicle team will include:

3.2.6.1 Baseline mission for vehicle with specific scientific objectives.

3.2.6.2 Conduct subsystem and vehicle trade studies.

3.2.6.3 Ensure design meets specific needs for safety and welfare.

3.2.6.4 Explain design decisions in relation to their impact in an economic, environmental, global, and societal context.

3.3 Phase B: Preliminary Design and Technology Completion

3.3.1 Science objectives will be determined amongst the program manager and the scientists.

3.3.2 Final launch vehicle system will be chosen.

3.3.3 Options for vehicle trades will be proposed with initial decisions being made.

3.3.4 Final mission architecture will be decided.

3.3.5 Major risks will be identified with risk mitigations being developed.

3.3.6 DAC 3 Review for program team will include:

3.3.6.1 Preliminary requirements and Concept of Operations (ConOps) for the mission.

3.3.6.2 Final mission architecture decisions.

3.3.6.3 Preliminary risks and margins for mission.

3.3.6.4 Preliminary vehicle masses and margins for mission.

3.3.6.5 Preliminary mission cost.

3.3.7 DAC 3 Review for vehicle team will include:

3.3.7.1 Identify scientific requirements and objectives to be met.

3.3.7.2 Identify scientific instruments being used.

3.3.7.3 Preliminary vehicle and subsystem designs.

3.3.7.4 Identify vehicle constraints.

3.4 Phase C: Final Design

3.4.1 Final science objectives and instruments selected.

3.4.2 Final mass allocations and cost breakdowns determined.

3.4.3 Final vehicle and subsystem design.

3.4.4 All risks identified.

3.4.5 DAC 4 Review for program team will include:

3.4.5.1 Final mission vehicle determined.

3.4.5.2 Final mass and cost allocations determined.

3.4.5.3 Identify constraints amongst mission.

3.4.5.4 Identify final risks and mitigation strategies for mission.

3.4.5.5 Final schedule of mission events and future events decided.

3.4.5.6 Final Technical Performance Metrics provided.

3.4.6 DAC 4 Review for vehicle team will include:

3.4.6.1 Final mission ConOps identified.

3.4.6.2 Subsystem and vehicle final design decisions made.

3.4.6.3 Allocate mass and power amongst subsystems.

3.4.6.4 Final scientific instruments and objectives identified.

4.0 SYSTEMS DESIGN PROCESSES

4.1 Stakeholder Expectations Definition

Stakeholders involve entities and/or individuals that have an interest in the system or project and have either an active or passive stake in the project. Active stakeholders interact with the project or system directly and they can directly inform the constraints and requirements for the project. There are two active stakeholders for ARISE, which consist of the College of Charleston scientists and the University of Alabama in Huntsville's IPTs. The scientists will create requirements in the form of scientific objectives that they are hoping to accomplish for this mission. UAH's IPTs will be designing proposed vehicles and provide operational requirements for the operation and success of each vehicle to accomplish the mission at hand. Passive stakeholders indirectly interact with the project or system by influencing the success of the system from afar and not directly interacting with the project at hand, thus creating nonfunctional requirements for the project. There is one passive stakeholder for ARISE, which would be NASA. NASA has set requirements for the mission in terms of providing an estimated budget and recommended capabilities of the mission. The instructors involved with the ARISE program serve as both active and passive stakeholders. They can directly interact with the project and teams, if need be, but let the IPTs proceed with the design process and operate on their own, so they indirectly influence the project by giving feedback on the progress of each team. Sponsors are also stakeholders, as they are the ones funding the project. In this case, NASA is arbitrarily funding the project, if the concept designs from the IPTs prove successful, so they would be the sponsors for the ARISE mission.

The Concept of Operations (ConOps) is a group of expected operational points or activities in a project that a system must perform successfully. These activities should include the capabilities for the mission throughout its lifetime, as well as operations and interactions that will be occurring throughout the project life-cycle. Each vehicle will have a different ConOps relative to their individual science objectives. The ARISE ConOps as a whole consists of key points of launching the SLS Block 1B with the ARISE vehicles, where the ARISE vehicles will be deployed once reaching Jupiter. Another key point is the orbiter

vehicle releasing the lander vehicle to descend towards Europa. Following the release of the lander vehicle, the probe vehicle will be released to begin its orbit of Europa. Below is an overall trajectory overview for the ARISE mission.

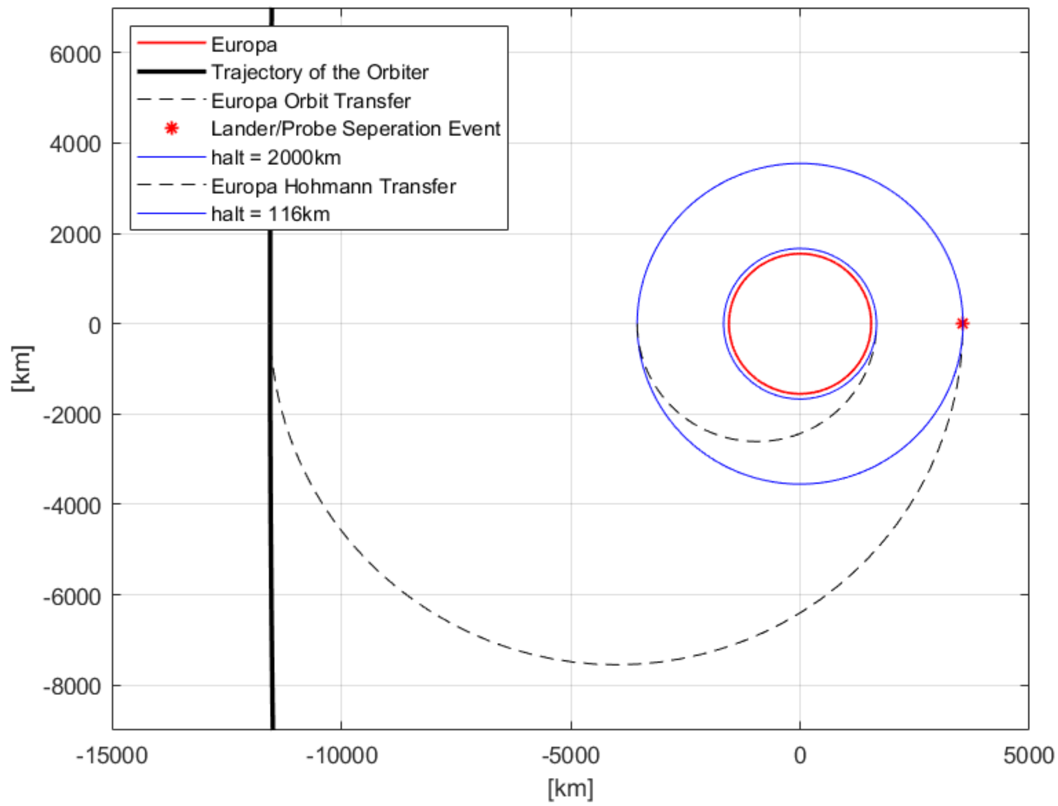

Figure 3: ARISE ConOps

4.2 Technical Requirements Definition

Technical requirements will be derived from the requirements set by the stakeholders into performance and functional requirements. Functional requirements specify all the functions for the vehicle system. Performance requirements assess how well the vehicle system performs its functional requirements. These requirements will establish how to assess the performance of the vehicle through Technical Performance Metrics (TPMs).

4.3 Logical Decomposition

System architecture shows the entire system and its main functions at a high-level. The architecture describes what the system and its capabilities do and how the system itself is organized. In the system architecture, the relationship between all the vehicles and each vehicle's major functions should be defined. The architecture's main goal is to showcase how the system, consisting of the three spacecraft and the launch vehicle, are organized and how they all work together as a cohesive unit.

4.4 Design Solution Definition

The design solution focuses on how the system will accomplish its requirements and objectives. This aspect of design is the culmination of the ARISE project for all IPTs involved. Design decisions will be backed by trade studies showcasing different options to designing subsystems and vehicles in order for these aspects to be at their most effective operating level. The design solution will involve using the system's architecture and requirements and will focus on improving the performance and capabilities for the system as a whole.

5.0 PRODUCTION REALIZATION PROCESSES

This project focuses less on the final product due to time constraints and the main aspect of the project is to design a product, not implement it. These processes are still important for the success of the project due to making sure the design will fulfill its requirements for creating a product.

5.1 Product Implementation

Product implementation focuses on each element in the system individually. The process of implementation involves implanting parts to create a subsystem and procuring individual elements that will make up a subsystem. This involves making sure the correct elements are functioning properly. The ARISE mission does not procure the elements themselves, but designs and produces concepts for potential elements if this project were to continue further.

5.2 Product Integration

Product integration combines all the elements in the system into one complete system. The process of integration focuses on the interfaces that are between system elements. The types of interfaces are defined later in section 6.3. Integration often involves the assembly of the different subsystems into a complete united system. ARISE does not involve integrating a product at this time.

5.3 Product Verification

Product verification focuses on providing evidence that the performance and functional requirements are being met and that the system is operating as intended. The process of verification is completed during system assembly, where subsystems will go through a verification check sheet to ensure that their subsystem is meeting all requirements. Verification involves testing the system to ensure it is meeting requirements and developing a set of metrics for the system to meet for verification purposes. These metrics should include something that can be measurable, testable, and quantitative, with the goal in mind being a pass or fail for the task or subsystem at hand. Since ARISE is focusing on the design of spacecraft, product verification is not required at this time.

5.4 Product Validation

Product validation focuses on providing evidentiary support that the elements of a system or the system itself that the requirements and objectives set by the stakeholders are being fulfilled. The process of validation is completed during system assembly. Validation involves the stakeholders, if they choose to do so, and is often more subjective as it focuses on proving that the requirements are being met. Since ARISE is not producing a product, product validation is not necessary for the mission requirements at this time.

5.5 Product Transition

Product transition is the process of transferring the completed system between organizations. If the IPTs were developing their finished vehicles into products, a transition plan would need to be fabricated in order to transfer the system from the builders and designers, which would be UAH, to the entity operating the launch vehicles, which would be NASA. The product transition can include a physical delivery of the spacecraft, the training of operators, and accounting for problems that could occur during the transition period. Since ARISE is focused on the design of the product, there will be no transitional period between organizations.

6.0 TECHNICAL MANAGEMENT PROCESSES

6.1 Technical Planning

Technical planning occurs at the beginning of the project to lay out all expectations for the upcoming activities needed to complete the project. The processes used in system engineering are a baseline for all technical plans and are laid out as such within this document.

6.2 Requirements Management

Requirements for ARISE are initially laid out in the AAO and are defined further by each IPT to fit their mission and requirements. These requirements are managed by the program team and distributed to each vehicle team accordingly. The stakeholders will also ensure that their requirements are correct and are being followed.

6.3 Interface Management

Each IPT should document all the interfaces within their vehicle system. An interface can be defined as the connection between two elements. These elements are categorized as being one of the following: spatial, energy, material, and information. A spatial interface is the physical connection between two or more elements. The energy interface involves the energy transfer that takes place between two or more elements. A material interface involves the material exchange between two or more elements. The information interface is the exchange of a signal or information between two or more elements. There can be more than one type of interface for each vehicle system, as well as having multiple interfaces of the same category.

6.4 Risk Management

Risks are possible within every vehicle and will be managed by the program team, with each vehicle providing risks for their vehicle and its mission. The risks will be put into a five-by-five matrix where each risk will be rated on a scale of one to five on how likely the risk is to occur and what the consequence of that risk occurring would be. For the risk matrix, a one is considered the lowest and a five is considered the highest. For ARISE, the following risk matrix was concocted:

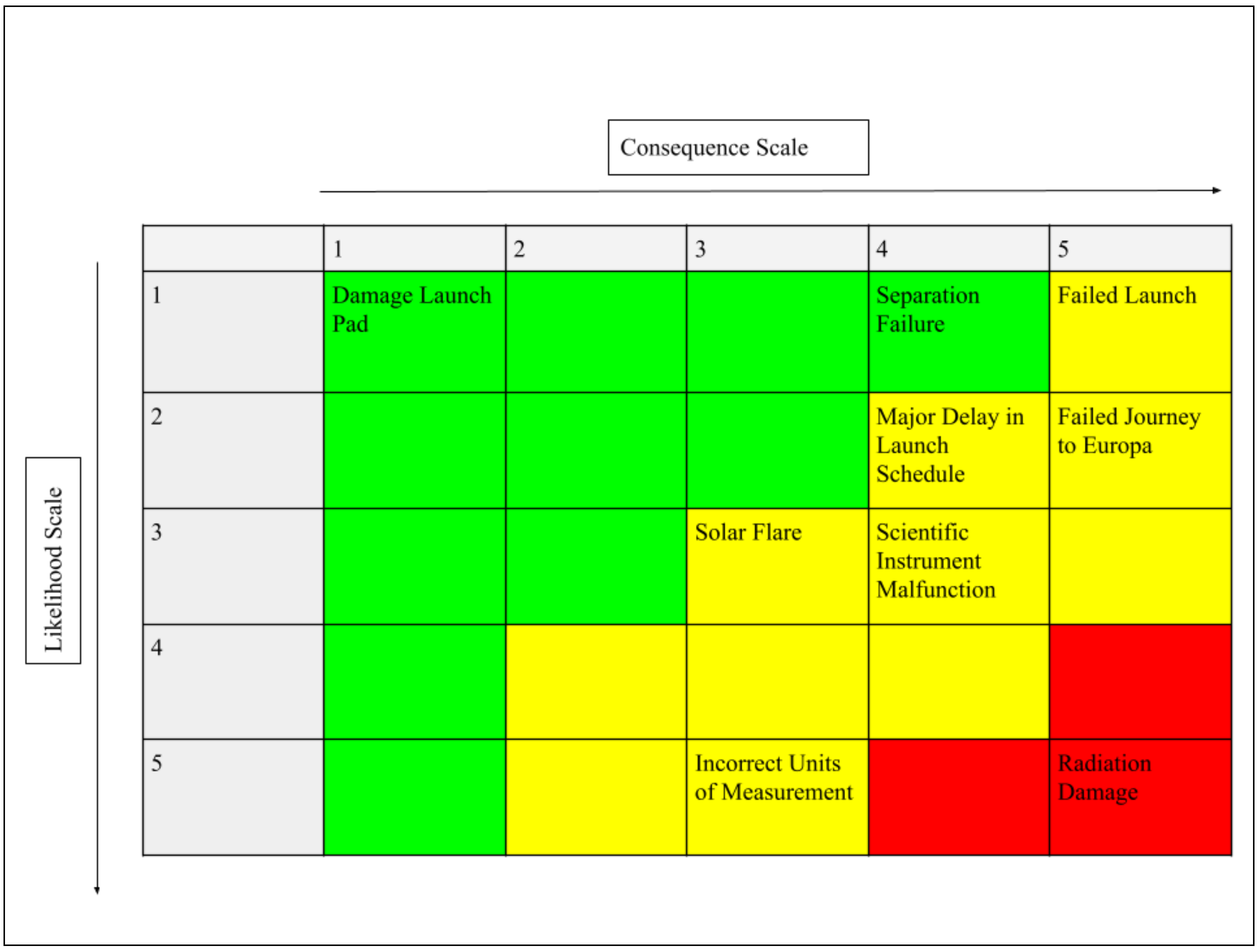

Figure 4: ARISE Risk Matrix

Code	Likelihood	Probability	Consequence	Definition
1	Rare	<10%	Negligible	No measurable impact on mission or system
2	Unlikely	10-25%	Minor	Minor mission or system capabilities restricted
3	Plausible	25-50%	Moderate	Minimal use of system or shortage of mission
4	Likely	50-80%	Critical	Total loss of subsystem or extreme mission shortage
5	Almost Certain	>80%	Catastrophic	Total mission loss

Table 1: Risk Definition

6.5 Configuration Management

Configuration management tracks the process of changes to the project in order to keep the IPTs on the same page and pace. Changes made to the vehicle throughout the decision process will be brought before the entire vehicle IPT team and discussed. Should changes occur, each subsystem engineer will ensure that their subsystem is updated to accommodate the change.

6.6 Technical Data Management

Data management is essential to keeping control over the plethora of information gathered throughout the course of the project. To keep all this data, the ARISE program will be utilizing a cloud-based file-storing system. This database will be used amongst each IPT to keep track of all data collected and be shared with the program team so that they can track the progress of all IPTs effectively. Using a cloud-based system ensures that all team members can contribute to and update files accordingly, so everyone is on the same page for the course of the project. The program team will maintain contact with the scientists and distribute changes to the science objectives accordingly. Each IPT will also be able to contact their assigned scientist to change scientific instrumentation as necessary to meet the requirements and constraints of the vehicle.

6.7 Technical Assessment

Assessments are necessary to perform in order to check if the entirety of the project is staying on schedule, within budget, and following all given requirements. These aspects will be tracked throughout the duration of the project and assessed during every review to determine progress. Each IPT will track the Technical Performance Metrics (TPMs) for their team and will present their findings and ensure that each review objective during each DAC is satisfied.

DAC	DAC Review	Review Objective
1	Mission Planning	Provide background information on historical missions that will be a benefit to the ARISE mission objectives.
2	Subsystem Planning	Provide initial design for mission objectives.
3	Mission Definition	Identify science objectives and instrumentation compatible with vehicle design.
4	Final Concept	Provide final design of vehicle with scientific instrument capabilities.

Table 2: Design Analysis Life-Cycle Reviews

6.8 Decision Analysis

Decisions will be the responsibility of the program team and the leaders elected for each vehicle. Each subsystem engineer will be a part of the decision analysis and participate should their subsystem be a part of the decision. Every decision will start with creating a decision statement that describes the decision being made, along with analyzing the impact of making the decision. Decisions should try to be quantified by a list of criteria or backed up through evidentiary support. These decisions will then be implemented accordingly after a consensus amongst the team has been reached.

7.0 TRADE STUDY REQUIREMENTS

Trade studies will be conducted by all members of the IPT for design decisions, subsystem components, and scientific instruments. Each trade study will be different depending on the topic of the trade study, but each trade study needs to have a criterion that is applicable for the decision that is attempting to be made. Any trade studies concocted should include any or all of the following Figures of Merit (FOM):

7.1 Cost

7.2 Performance

7.3 Safety

7.4 Risk

7.5 Success of Mission

7.6 Success of Science Objectives

8.0 WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure (WBS) is used for identifying all tasks that needed to be tracked within the project, as well as how the project components will be integrated effectively. Tasks are assigned to each element in the WBS where they will be defined further in the WBS dictionary. A WBS allows for budget, schedule, and technical performance to be assessed at multiple levels, as well as allowing the entirety of the project to be seen at a broken-down level, where every aspect is accounted for.

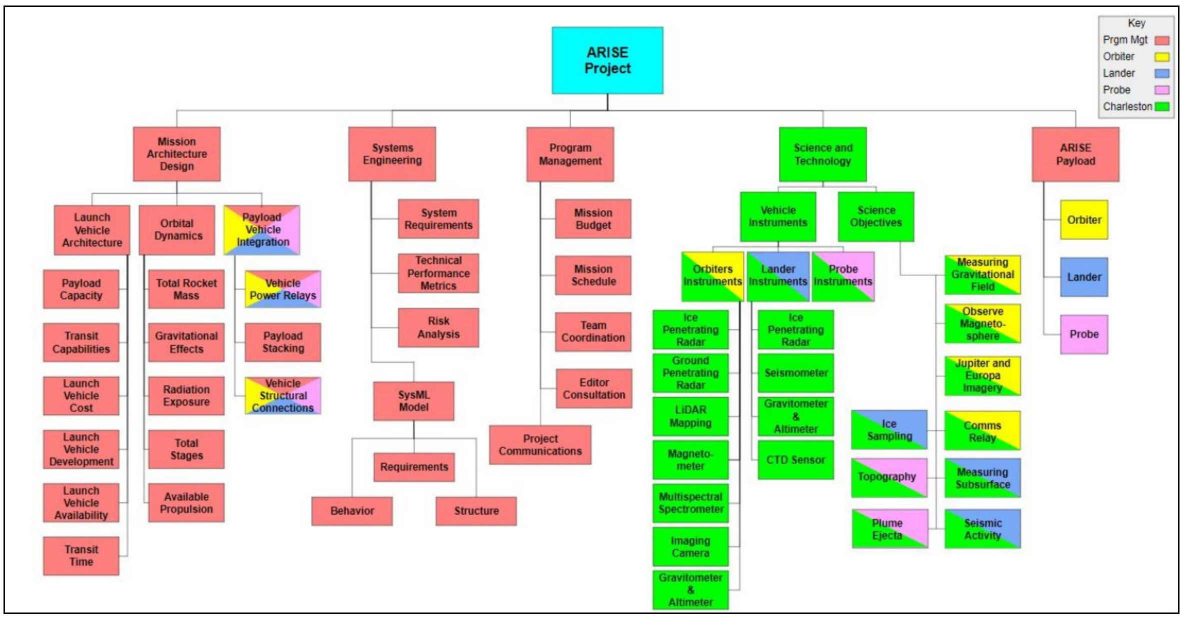

Figure 5: ARISE Work Breakdown Structure

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Appendix A: Acronyms

ADACS	Attitude Determination and Control System
ARISE	Autonomous Research Investigating the Surface of Europa
C&DH	Computer and Data Handling
CE	Chief Engineer
ConOps	Concept of Operations
DAC	Design and Analysis Cycle
FOM	Figures of Merit
IPT	Integrated Project Team
ISE	Industrial and Systems Engineering
LSE	Lead Systems Engineer
MAE	Mechanical and Aerospace Engineering
NASA	National Aeronautics and Space Administration
PM	Program/Project Manager
TPM	Technical Performance Metrics
UAH	University of Alabama in Huntsville
WBS	Work Breakdown Structure

Appendix B: NASA Project Life-Cycle

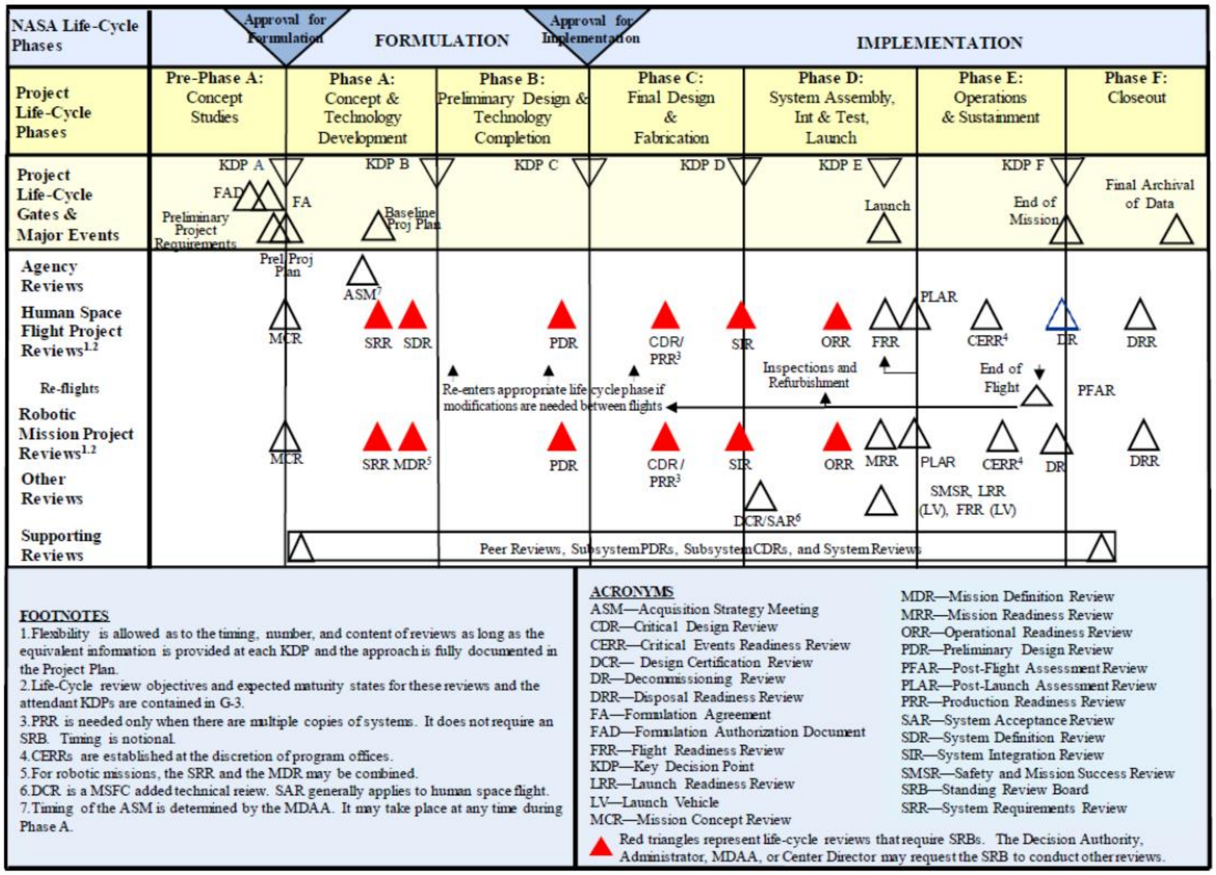

Figure : NASA Project Life-Cycle. NASA. *MPR 7120.1, MSFC Engineering and Program/Project Management Requirements.* Huntsville, AL: 2015.