An Analysis of Low Earth Orbit Launch Capabilities

OR 680 / SYST 798 Project Proposal

Sponsored by:

SPEC INNOVATIONS

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1.0 Executive Summary

Constantly changing political agendas have stagnated the progress of a space industry that relies on NASA and other government agencies for its growth. The private sector has responded to this challenge in the last ten years, with a flood of space-related investment from space tourism to innovative rocket design. SPEC Innovations hopes to take advantage of investment opportunities available in the private space sector by implementing their Interstellar Action Alliance project. This initiative is a long-term space exploration plan that uses private sector investment and a series of stepping-stones with individual Return on Investment to go from where we are today to interstellar travel. The first step in this project is to establish a permanent base in Low Earth Orbit, which can facilitate construction, and can be a base of operations for longer-range missions. A primary concern in the construction of this permanent base is the cost and feasibility of transporting materials and construction workers to Low Earth Orbit.

This project is an analysis of the current Low Earth Orbit Launch (LEO) Capabilities of Technology Readiness Level (TRL) of seven or above according to the NASA TRL scale. Constraints and goals were set by SPEC Innovations to provide bounds for the proposed model. The primary goals consisted of transporting 1000 metric tons of material to LEO in a timeframe of 30 months with a maximum total cost of $32 Billion.

This project will consist of an optimization model and sensitivity analysis to consider the most optimal mix of launch capabilities taking into consideration cost and performance. It will also take the stakeholder's values into consideration

2.0 Introduction

In April of 2010, President Obama drastically changed NASA's focus, cancelling the shuttle program, which has existed since Kennedy's presidency and was revitalized during that of George Bush; and setting a new goal, that mankind land on an asteroid by 2025. Although this goal may seem improbable to some, this announcement brings into focus two important aspects of the modern space program. The first is the changing goals of space exploration, moving from the moon to farther reaching goals such as landing on an asteroid or establishing a permanent space foothold. The goals of space missions have been stagnant for over 50 years, ever since the first moon landing. These recent developments demonstrate a shifting of goals from one of moon landing after another, to a vision of greater things, where space is not just a science experiment but an untamed land ready to be inhabited.

The second fact this announcement underlines is the difficulty of having NASA, or any government agency take the lead in space exploration. According to USA today, "During the past six years, NASA spent $9 billion building a spaceship, rocket and other gear to help reach the second Bush's goal of returning humans to the lunar surface by 2020." With a single presidential change, $9 billion dollars and six years of research and preparation are discarded. While NASA may have functioned well under the political pressure of Russia gaining dominance over space before the US, it does not work in a world where each successive president has his/her own new agenda. Government Agencies such as NASA are too prone to political pressure and funding cuts to quickly and efficiently produce the research and development necessary to achieve long term goals. With NASA's reassignment has come a void in the space exploration industry, a void that can be, and already is being filled by companies and individuals from the private sector. SPEC Innovations is one such company that hopes to find a place in research and development of a long-term space infrastructure. This project will support that effort through research into some initial capabilities necessary for the construction of a space infrastructure.

3.0 Background

In early 2011, DARPA released a Request for Proposal (RFP) offering seed money for any company that would be able to develop a sustainable model for an organization to build a vehicle capable of interstellar travel. SPEC Innovations responded to this RFP with a plan for the slow but steady buildup of a space infrastructure that would be sustainable, profitable, and allow for long term space exploration, extending even to interstellar travel. This plan, called the Interstellar Action Alliance (IAA), is based on initial research providing recommendations to SPEC in terms of the technologies to be focused on and the research to fund. Investments will be gathered based on these recommendations and RFPs released to private companies to build the pieces of the infrastructure on a contract basis. This gradual build up will continue until a permanent space infrastructure is completed and work on a starship can begin. This plan is diagrammed roughly in Figure 1 below.

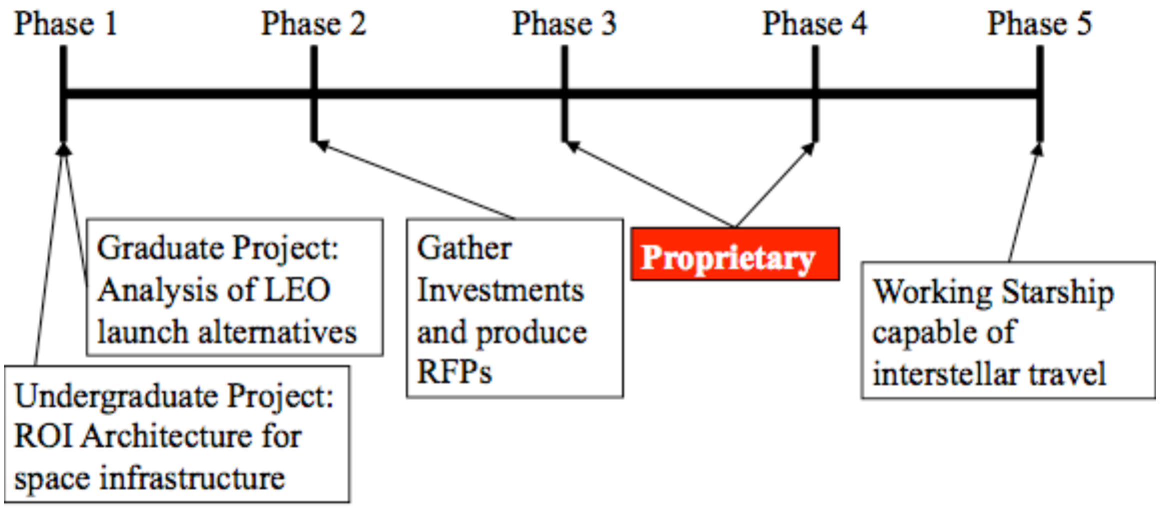


Figure 1: Basic steps of Interstellar Action Alliance

As stated above one of the primary tasks associated with the IAA is the initial research that provides the basis for investors to support the initiative, providing the money to fund research. This project fills a critical role in the IAA by providing analysis and modeling of the launch capabilities available to put mass into low earth orbit, enabling the potentially profitable construction of permanent infrastructure in space due to a reduction in launch costs. The International space Station has currently cost, at a rough estimate, $155 billion dollars, with launch costs reaching to about $76.5 billion. SPEC Innovations has the ambitious goal of transporting a similar amount of mass to low earth orbit for less than $5 billion. To achieve this goal, SPEC will try to take advantage of a new wave of technologies that are sweeping the private and government sectors. This project will examine these technologies and provide a summary of and recommendations for each.

4.0 Technical Approach

4.1 Problem Formulation and Analysis

Develop an optimal model for launching mass to Low Earth Orbit (LEO) from analysis of current and predicted capabilities. To do so, the LEO team will:

- Establish connection and dialogue with the client to understand the client's need and requirements;

- Conduct literature review on the launch technologies which are currently operational and those that are in development.
- Analyze launch capabilities for readiness, cost, and performance
- Compare capabilities according to performance, cost, and capabilities
- Provide recommendations based on comparison

As a result of this project, an optimal course of action is to be established to transport humans and materials into low earth orbit. With this portion successfully completed, a more long-term goal is to establish a commercially viable permanent human orbital platform in order to eventually capture an asteroid for the purposes of mining and future space development.

4.2 Assumptions and Limitations

The team must make clear here that prohibitive costs and the timeframe in which the permanent orbital platform must be established, as well as considered technologies based on NASA's TRLs, will narrow our study to a few competing technologies. This is because the stakeholders will be purely commercial and, since Return-On-Investment (ROI) will be the overriding concern, there will be no room for wasteful spending.

Data will be derived from readily available sources such as journals, reputable magazine, books and articles often cited in the aerospace industry. Wherever data is not readily available, the team will come up with reasonable estimates with the help of our sponsors. This will place limitations upon the depth with which theoretical launch methods can be considered, as there obviously will be no established timeframe, expenses, or viability associated with them. Another limitation that we hope to mitigate is the idea of using a cost per launch as an all-inclusive gauge of costs. With more research, the hope is that detailed cost information can be found for each method chosen to analyze. This will give far more flexibility in developing a strategy for the selection of launch technologies.

The feasibility of the various methods of launch and deployment would be as determined by NASA's Technology Readiness Levels (TRLs). The purpose behind this decision is to provide Spec Innovations with a strategy to move forward in the immediate future, which is what was indicated as needed to be done with this information. Also, the scope on the technologies considered will be limited to technologies that are at a maximum a few years away from production, with a few exceptions.

The team will not take logistical considerations like storage, building times etc. into account as it would be impossible to build such a detailed model in the time available. Aside from brief explanations of the competing technologies, there are no plans to devote efforts to gauge the scientific viability of the technologies beyond what NASA has determined. To this end, because Spec Innovations hopes to use this information to gain insight into strategy moving forward, there will not be proposals of any forms of launch methods nor technologies that are not already tested or established elsewhere, with a few exceptions. Aside from the lack of expertise possessed in this area, the consensus is that efforts should be focused on providing the best strategy moving forward, based upon what is readily available.

The notable exception to the short term focus is that a few technologies will be included that are more than a few years away from being viable. This decision was made solely due to the client's mention of them. Their inclusion will almost certainly create difficulties due to the lack of verifiable data available, as well as the uncertainty associated with their development. Not only would any such method require extensive guesswork in determining capabilities and cost, but there is the additional factor of research and development costs, as well as the unknown quantity of how long the technology would take to be operational. However, we cannot guarantee that those technologies will prove to be optimal method for undertaking this venture.

4.3 Sponsor Requirements and Constraints

Team LEO determined the following constraints after meeting the sponsor.

1) The total investment in this venture is not to exceed $32 billion.
2) The base is to be established 200 Km above the Earth's surface.
3) The total mass that needs to be transported is 1000 metric tons.
4) From the time of the first launch, the 1000 metric tons of materials should be transported within a year's time.

The requirements as listed above may well change as the project progresses.

4.4 Requirements Definition

Initially, the team will conduct careful research on currently operational and in development launch vehicles. This research will include journals and existing publications on space travel. Data will be collected for analysis. The point of focus will be the technological readiness of the methods and this will be done by the use of NASA TRL. This will ensure that the only technologies that are already available or will soon be available are employed.

The data that is collected will also include the cost and number of launches required to transport the huge mass of cargo into LEO effectively. It is expected that on this project several weeks will be devoted to research and gathering of necessary data that will be used in make a decision on the best method of getting to LEO within the given constraints.

4.5 Method of Analysis

Data obtained from research would be used to build a mathematical model. The four major constraints i.e. cost, distance, weight and time will all be factored simultaneously into the model so that a rudimentary sensitivity analysis might be performed. It is possible, if not probable, that not all of the constraints may be simultaneously satisfied. Under the circumstances, the team will talk to our sponsors to decide which constraints are non-negotiable i.e. “Hard” constraints and which are “Soft” constraints. The purpose of this compromise will be to make sure that the best possible result is reached without losing objectivity.

By differentiating between hard and soft constraints, the goal is to show an analysis of capabilities versus what is viable. In similar projects that are limited by time, money, and technological constraints, it is oftentimes the case that even though a decision is made based upon these constraints being static, by the completion of the venture, these requirements have been changed by unforeseen circumstances. By performing sensitivity analysis with combinations of constraints, it is our goal to provide a more comprehensive picture of what can be expected based upon different scenarios. The benefit of this will be twofold, in that it will provide the client more information to better formulate a course of action, and that it will force them to consider what may happen when unforeseen occurrences appear.

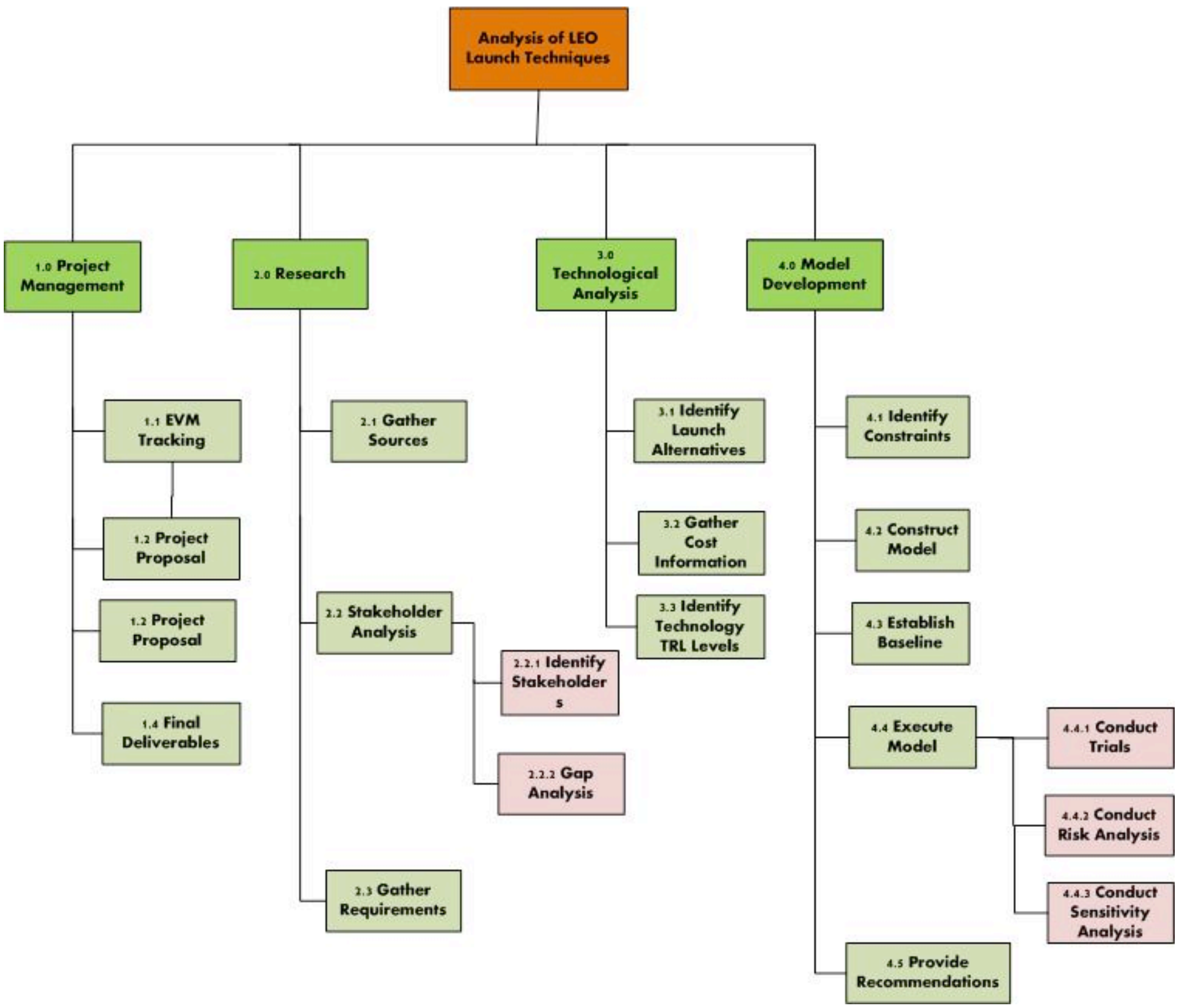
5.0 Expected Deliverables and Results

The expected deliverable at the end of the project is an optimal decision based on comparison of researched capability(s) subject to the performance, cost, and capabilities constraints. Also, a detailed analysis of the chosen launch capability(s) would be provided in the form of Architectural and operational designs. Additionally a sensitivity analysis will be performed on the results and the stakeholder’s values will be considered using a value function.

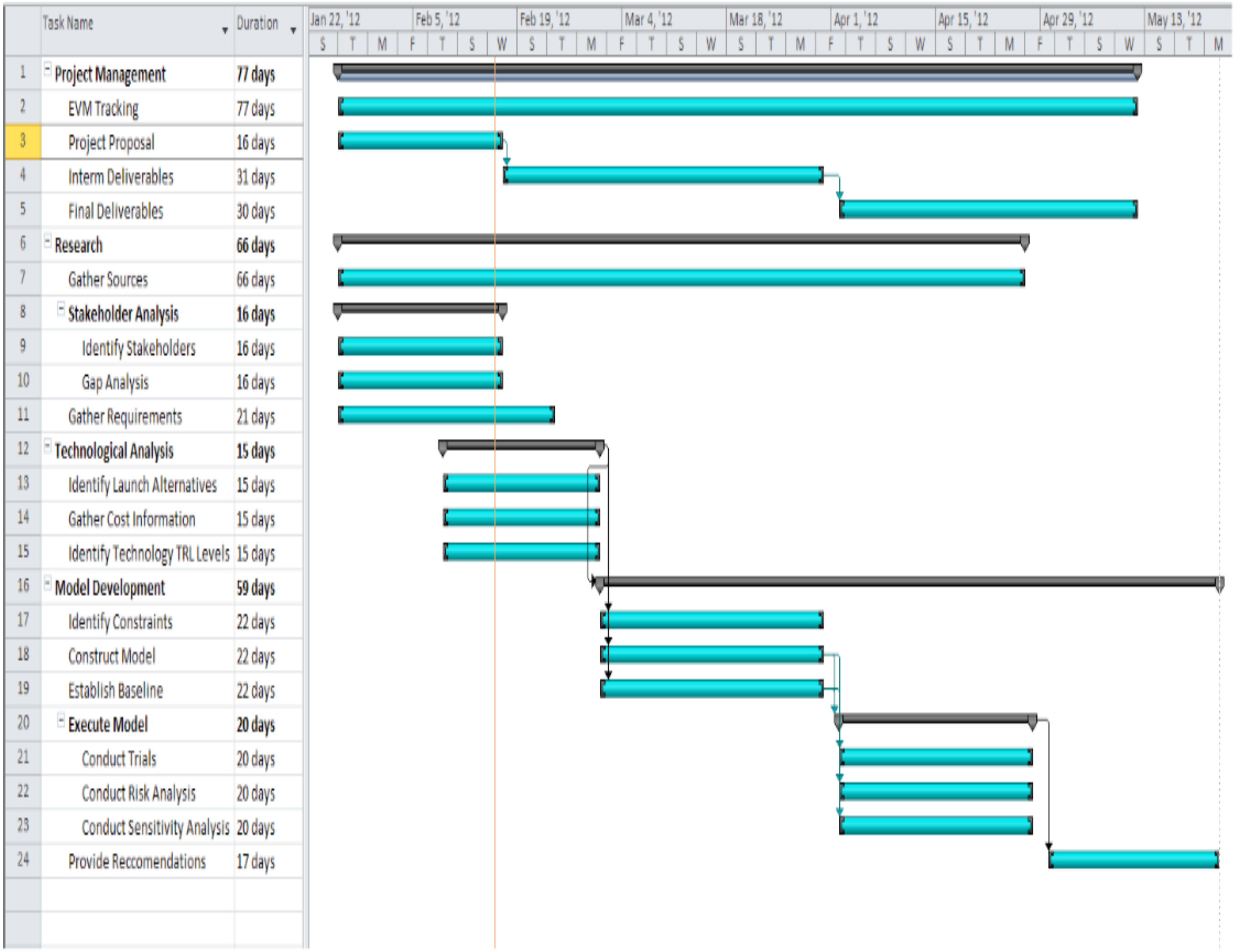
6.0 Project Plan

6.1 WBS

The WBS lays out the basic tasks our team must accomplish throughout the semester. This diagram shows the tasks and subtasks breakdown by category. These tasks are again reflected in our project schedule shown in section 6.2.



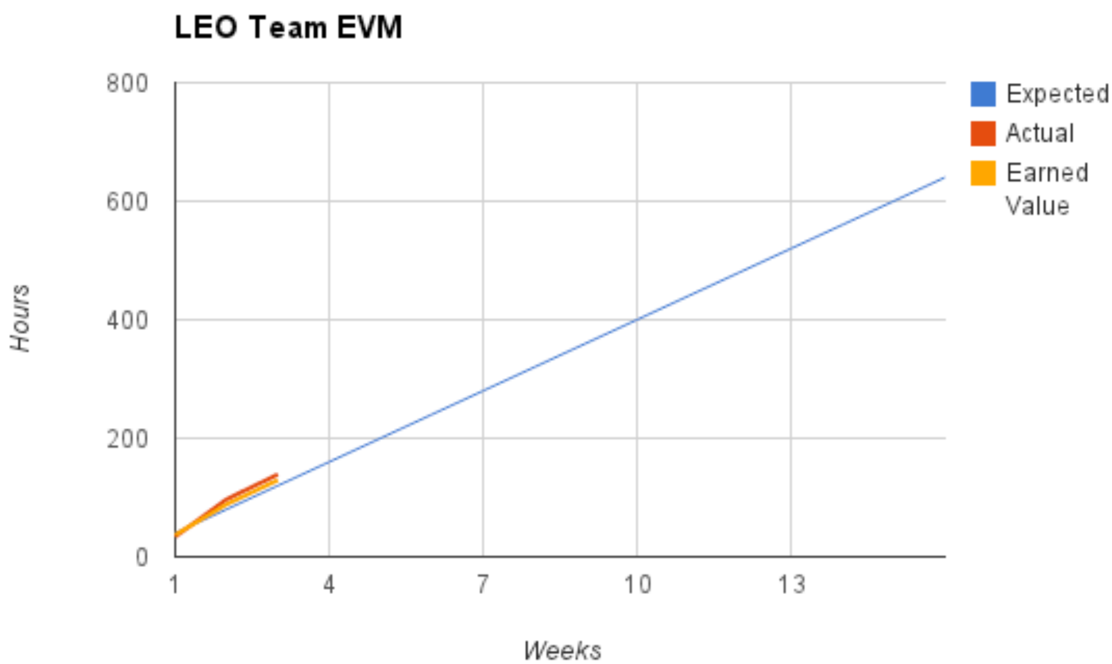
6.2 Project Schedule



	Task Name	Duration
1	Project Management	77 days
2	EVM Tracking	77 days
3	Project Proposal	16 days
4	Interm Deliverables	31 days
5	Final Deliverables	30 days
6	Research	66 days
7	Gather Sources	66 days
8	Stakeholder Analysis	16 days
9	Identify Stakeholders	16 days
10	Gap Analysis	16 days
11	Gather Requirements	21 days
12	Technological Analysis	15 days
13	Identify Launch Alternatives	15 days
14	Gather Cost Information	15 days
15	Identify Technology TRL Levels	15 days
16	Model Development	59 days
17	Identify Constraints	22 days
18	Construct Model	22 days
19	Establish Baseline	22 days
20	Execute Model	20 days
21	Conduct Trials	20 days
22	Conduct Risk Analysis	20 days
23	Conduct Sensitivity Analysis	20 days
24	Provide Reccomendations	17 days

6.3 Earned Value Management

The Earned Value Management chart reflects our progress as a team in the completion of our project schedule. The Expected line shows the average expected work to be completed each week. The actual shows the actual hours put into the project and the earned value shows the value gained by our stakeholder of the effort involved.



6.4 Project Deliverables

- Feb 9: Problem Definition and Scope
- Feb 16: Project Proposal Due
- Mar 8: Progress Report
- Mar 29: Progress Report
- April 26: Dry Run of Final Presentation
- May 7: Website and Final Report Due
- May 11: Final Presentation to faculty/sponsors

7.0 Sources

DARPA 100 Year Starship: http://www.100yss.org/

http://www.nytimes.com/2011/12/14/science/space/paul-allens-plan-airplanes-as-launching-pads-for-rockets.html

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