TEXAS SPACE GRANT CONSORTIUM
DESIGN CHALLENGE

LEVEL I - CHECKLIST [ALL TEAMS]

SPRING 2009

INST	**University of Texas at Austin**	**TEAM NAME**	**NASA Elevator**

This *Level I Checklist* is to be completed, attached, and submitted as a cover sheet to the project proposal.

LEVEL I REQUIREMENT CHECKLIST – DEADLINE MIDNIGHT FEBRUARY 16TH

Format Check:

- ☒ Typed – Spacing: 1.5x or 2x – Font Arial, Helvetica or Verdana – Font Size 10 or 12
- ☒ Avoided writing in first-person
- ☒ Spell-Checked / Page Layout Checked
- ☒ Grammar / Punctuation checked

Semester I Proposal Requirements:

☒ Cover Page
☒ Table of Contents
☒ List of Figures

☒ Abstract or Introduction
☒ Identification of Mentor & Research Group
☒ Strategies for Collaboration
☒ Team Profile / Member ID / Faculty ID
☒ Overview of Type & Scale of Research Conducted
☒ Background Information - Topic Centered
☒ Design Objective
☒ Design Specifications
☒ Design Plan /Methodology
☒ Key Accomplishments to Date
☒ Projected/Draft Timeline / Budget Plan
☒ Conclusion
☒ List of Six References / Resources

Semester II SOW Requirements/Options:

Requirements:
☐ Cover Page
☐ Table of Contents
☐ List of Figures

☐ Re-Introduction of Project
☐ ReCap of Semester I [Results]
☐ Key Accomplishments to Date
☐ Design Goal or Objective for Semester II
☐ Design Plan for Semester II.
☐ Idea for Project's Future
☐ Updated Project Timeline
☐ Updated Budget Plan

☐ Conclusion
☐ Extensive List of References / Resources

May also include:
☐ Updates Collaboration Efforts
☐ Updates to Team Membership
☐ Updates to Design Objective
☐ Updates to Plan / Methodology
☐ Updates to Graphics

Appendices attached include:

☐ Option Area Reports: ☐I ☐II ☐III
☐ Team Travel & Expense Report w/ Photos for this period (UNABLE TO ACCESS LINK ON WEBSITE)
☒ Budget Report [Team Spending] for this period
☒ High Resolution Digital Photo of team in .jpg format / labeled left-to-right with team members' names
☒ High Resolution Head Shots of individual team members
☐ Other ______

Copy provided via email to: ☒TSGC ☒ Advisor ☒Mentor

Notes:

Proposal for the Design of a Crew Elevation Device for the Altair Lunar Lander

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ABSTRACT

A new generation of space craft such as Altair Lunar Lander has the capability to support extended mission, but with that ability comes an increase in size and weight. The senior design team's project this semester is to propose a creative and reliable design of an elevation device that can transport the astronauts and equipment back and forth from the airlock high atop the lunar lander to the surface of the moon. The background research to support this project has begun and most of the design specifications have been established with the help of a NASA engineer who is mentoring the team in its endeavor.

The team has established a methodology and schedule that will be used to resolve this problem. The next step will involve concept generation using a variety of methods and finalization of all requirements and constraints. Later in the semester the team will work towards selecting the concept variant that has the greatest probability of solving the design problem. Once the concept variant is selected, the team with perform a detailed analysis to determine the strengths and weaknesses of the design. It is the hope of the design team to end up with a viable concept that has the potential for actual application.

TEAM BIOGRAPHY

Carolyn C. Seepersad (Faculty Advisor)

Carolyn Conner Seepersad received her PhD in Mechanical Engineering in 2004 from the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. As a graduate student, she was a Hertz Fellow and a National Science Foundation Graduate Research Fellow. She received a B.S. in Mechanical Engineering from West Virginia University in 1996, a B.A. in Philosophy, Politics, and Economics from Oxford University as a Rhodes Scholar in 1998, and a M.S. in Mechanical Engineering from the Georgia Institute of Technology in 2001. She is currently an assistant professor in the Mechanical Engineering Department at the University of Texas at Austin.

Research Interests:
- Multiscale and multidisciplinary product and materials design
- Design for solid freeform fabrication
- Cellular (honeycomb) materials design
- Product flexibility and mass customization
- Green design
- Predictive process control

John Schoellmann (Team Lead)

John R. Schoellmann is a senior in the Department of Mechanical Engineering at the University of Texas at Austin where he maintains both University and Engineering Honors status. He is currently a member of Tau Beta Pi, an engineering honors society, where he severed as the Service Coordinator in the fall of 2008. His upper level coursework focuses on the area of systems and controls which is supplemented by a keen interest in system design. John went to high school in Salado, Texas where he became involved with a local amphitheater as technical volunteer and worked his way up to becoming the head sound technician for multiple performances. John continues to be involved in theatre as he pursues his goals of a graduate level education and a challenging career.

Rey Guzman

Rey Guzman is a senior at The University of Texas at Austin. He will be graduating with a B.S. in Mechanical Engineering in May of 2009. He grew up in Brownsville, Texas, the son of a Tool and Die Maker. This early experience piqued his interest in the world of machine design and manufacturing. Rey is currently employed in the Mechanical Engineering Machine Shop and is also a Lab Research Assistant for the Machine Tool Operations for Engineers class, where he assists other students in the proper technique for machining different materials. His hobbies include being a member of a bowling league for the last 3 years and a local adult men's baseball league for the last seven years. After graduation, Rey plans to become a licensed Professional Engineer and work as a Design and Manufacturing Mechanical Engineer in a field dedicated to the advancement of renewable energy sources.

Steven Tang

Steven Tang is a senior at The University of Texas at Austin. He is currently majoring in Mechanical Engineering and is a member of Tau Beta Pi, an Engineering Honors Society. He was born in Taiwan then moved to the United States as a teenager where he spent the majority of his time in Texas. While in college, he has worked as a commercial HVAC technician. This experience has helped him to develop his knowledge of designing and installing many mechanical components. In his free time, Steven loves outdoor activities, including fishing, camping, skiing and mountain biking. His favorite participatory sport is handball. He also loves arts and crafts, including pencil drawing, leather craft and water color. After graduation, he will be working with a research and development group at a sub-sea oil equipment production company. His future goal will be to receive an MBA from Rice University.

1 INTRODUCTION

Due to the recent push towards expanding space exploration efforts along with returning to the moon, a variety of new engineering problems have been encountered. These engineering problems have come about due to a variety of new demands being placed on equipment designed to reach these goals. One such piece of equipment is the Altair Lunar Lander which, unlike the previous lunar lander, will be required to support astronauts on the surface of the moon for extended periods of time. This requires the Altair to carry a significant amount of supplies which in turn increases the overall size of the lander. One particular engineering problem that has come forth from this design is the need for a reliable method to transport astronauts from the top of the lander, to far below on the lunar surface.

In order to adequately address this problem, we first must understand the background associated with the Lunar Lander and the reason why this design problem has appeared. The background information can then be used to fully establish the design problem and the methodology that will be used to solve it. The team has already established and begun using this methodology to address this design problem. Their current accomplishments and overall status is described in the current work section of this proposal. Finally, this proposal contains the schedule for project completion along with a summary of expected expenditures.

1.1 Background

The National Aeronautics and Space Administration (NASA) was established in 1958 by President Dwight D. Eisenhower. The creation of NASA incorporated several research organizations into one agency dedicated to aeronautics technology and space flight. In the early 1960’s, President Kennedy focused NASA and the country on the goal of landing an astronaut on the moon by the end of the decade. This goal was accomplished on July 20, 1969 with the Apollo 11 mission. After the Apollo missions, NASA focused on developing a reusable spacecraft that would allow for ready transport to space. The space shuttle launch in 1981 made this goal a reality. After 120 successful flights, the space shuttle is still in use [1].

Today NASA has long range goals which include continued exploration of Mars and the solar system, sending people beyond low Earth orbit, beginning robotic missions to the moon, retiring the space shuttle by 2010, completing the International Space Station, and returning people to the moon by 2020 [1]. To accomplish these last three goals, NASA is developing a larger space craft that can carry the heavier payloads and can travel further distances for longer periods of time. To this end, the Ares I and Ares V are in development [2]. See Figure 1.

The Ares I will carry the astronauts in the Orion space craft into space while the Ares V will carry the Altair Lunar Lander shown in Figure 2. In orbit, the Orion and the Altair Lander will rendezvous and the astronauts will move from the Orion to the Altair Lander and detach in order to steer the lander down to the lunar surface [2]. Once on the lunar surface the astronauts will egress the Altair Lunar Lander airlock shown in Figure 2. Our goal is to design a device that will allow the astronauts to move out of the airlock, down to the lunar surface, and back safely and reliably.

Figure 1. Concept image of Ares V [3].

The new device is necessary because the Altair Lunar Lander has an overall height of 32.48 ft. while the Apollo Lunar Lander used in the previous lunar missions was only 23.10 ft. This height difference coupled with the fact that missions will be extended from three days to seven will increased the duration and number trips taken to the lunar surface [4].

A team of NASA engineers from the Johnson Space Center Structural Engineering Division also researched our goal and has provided us with their data. We will consider their findings, along with conceptual designs of our own to determine the best method of transgressing the 20 feet necessary to reach the lunar surface.

The Johnson Space Center (JSC) formally known as the Manned Space Center has been the heart of the manned space flight program since 1963. It is the responsibility of JSC scientists, engineers, astronauts and other staff members to control flights from Gemini and Apollo through the current Shuttle program [5].

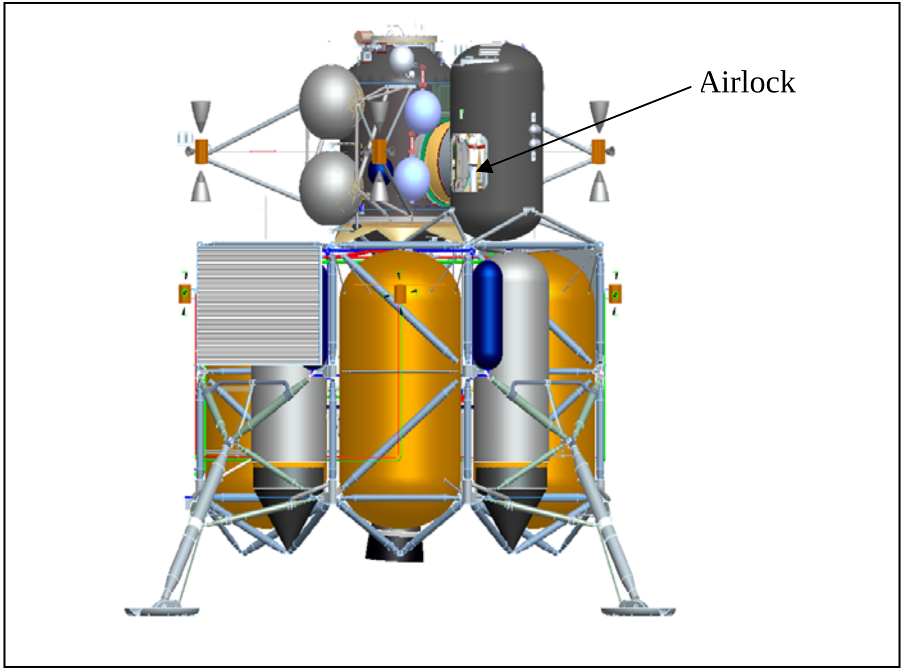


Figure 2. CAD model of the Altair Lunar Lander [6].

1.2 Problem Statement

Compared to the previous Lunar Lander, the new design has increased the distance between the airlock and the lunar surface by almost three times. Therefore, new methods for transporting astronauts and equipment from the airlock to the lunar surface must be undertaken to both prevent falls and minimize crew fatigue when traversing this large distance [7]. There are numerous challenges anticipated with the design of such equipment due to the constraints created by the location of thrusters, the astronaut's mobility in a space suit and the shroud configuration. Once the Lunar Lander reaches the moon's surface, another set of issues emerge. These concerns include the possibility of the spacecraft landing at an angle on the lunar surface. This could be due to the lunar surface itself not being level or uneven compression in the 'honeycomb based' shock absorbing devices within the legs of the Lunar Lander [8]. All of these issues can generate concerns when searching for the best possible design. It is the responsibility of the team to design a transporting device for the Altair Lunar Lander that can safely convey crew members and equipment back and forth from the airlock to the surface of the moon while taking into account all of these factors. The senior design team will then perform an in-depth engineering design process, followed by a detailed analysis in order to create a method to solve this problem and overcome any obstacles related to this project.

As seniors in the Mechanical Engineering Department at The University of Texas at Austin our team has excelled in many engineering disciplines, including design methodology. Through our education we have learned to use both analysis and synthesis to solve open-ended problems. In addition to these general qualifications, some members of the team have unique experience which will be very beneficial to accomplishing our goals; this includes advanced computer modeling skills, 'real world' experience with multiple forms of elevation devices, and advanced knowledge of control systems and applications. We will utilize the skills and knowledge we have gained throughout the undergraduate program to meet and surpass the expectations of our sponsor.

2 METHODOLOGY

The overall design process is divided up into four phases. Each phase has its unique purpose and a set of individual and group tasks that assist the team in systematically furthering the design process. They incorporate a variety of design activities that will ensure the team establishes as many feasible concepts as possible. The four phases are pre-concept generation, concept generation, concept selection and concept analysis.

2.1 Pre-Concept Generation

During the pre-concept generation phase of the project, the design team will focus on preliminary work that is used to give a strong working base for concept generation. This includes setting up a schedule, establishing customer needs, creating a specifications sheet, identifying the required functions and performing preliminary research. In order to keep track of the schedule, a Gantt chart will be created. This will allow the team to monitor the progress of the project while at the same time establishing a baseline schedule for when certain activities will take place. Should the team find the need to break up larger sections into multiple pieces for distributive work, task lists will be created in order to monitor individual progress. A detailed breakdown of the schedule can be found in the Outlook section of this proposal.

In order to understand exactly what NASA wants from this design, it may be beneficial to perform a customer needs analysis. In order to assist with this analysis the team will act in a manner resembling a consulting firm who has been hired by NASA for the specific purpose of solving this design problem. Similar to that of a consulting firm, the team will gather the customer’s needs through a meeting with NASA engineers where probing questions will be asked to reveal needs not articulated in the project description. This will help the team to identify and rank the needs, and also help the team to decide if a specific need is a demand or wish. A demand is a feature required to make the device fully functional, while a wish is a feature that is a welcome bonus. This information will then be used to create a specifications sheet which will explicitly list all of the functional requirements and constraints of this project.

In addition to a customer needs analysis, functional analysis methods will be used to help better understand the fundamental operation of the teams design. One such method that will be used by the team is a black box diagram. A black box diagram allows you to see the inputs and outputs of a system without dealing with the exact reasoning behind it. These inputs and outputs can be in the form of energy, materials, and/or signals. By looking at the information shown in a black box diagram the team can determine what inputs are available for design along with what is required as output. Also, any input or output not actively used in the design must be able to be 'handled' in an appropriate manner. This technique will allow the team to look at the project from a more basic perspective and therefore allow the team to have a broader starting point which will lead to a wider breadth of ideas [9].

The last step that will be taken prior to concept generation is performing preliminary research. This preliminary research includes basic research into aspects of this project which the team is not entirely familiar with along with a patent search. The goal of the patent search is to give the team some basic ideas as to what devices and technology already exist that could be useful for this design project. In general, the purpose of the pre-concept generation steps is to create a broad base set of information that will provide a strong foundation for concept generation.

2.2 Concept Generation

The next phase is the concept generation. During this phase the team will use the information gathered during pre-concept generation to facilitate multiple concept generation methods. The first concept generation method that will be used is brainstorming with mind mapping. Mind mapping is a way of recording a brainstorming session that helps to facilitate the creation of new ideas by dividing possible solutions into categories by type. Each type of solution can then be separately focused on in order to maximize the number of possible concepts. The use of a mind map also provides insights that allow the team to create more possible concepts than brainstorming alone.

Next, the team will conduct a method of concept generation called '6-3-5' which is also referred to as the 'brain writing' method. Fundamentally, the idea behind brain writing is very similar to that of brainstorming with the main difference being that instead of using verbal communication, the team uses only visual communication in the form of sketches and drawings. Usually, the initial designs sketched are taken from the previous concept generation method, in this case brainstorming. The combined use of brain storming, mind mapping and 6-3-5 allows you to ‘see’ your ideas from multiple perspectives and fosters the creation of even more ideas [9].

Once these methods are completed the team will move to a more focused concept generation method such as design by analogy. This method will take one particular issue associated with the problem and look to nature and other objects to determine how they would overcome a similar problem. This will assist the team in developing additional solutions along with resolving some dilemmas that may have made certain concepts unfavorable.

The final step in this phase is to use a morphological matrix to take the collection of ideas obtained through the previously mentioned methods and combine them to create a variety of complete theoretical concepts. This is done through a matrix (table) which lists the possible solutions for each functional requirement found during the pre-concept generation phase. A complete concept is then created by taking one solution for each functional requirement and combining them. By creating more concept variants, the morphological matrix increases the chance of finding an ideal solution to the problem [9].

2.3 Concept Selection

The third phase is the concept selection phase. This phase begins with the creation of a House of Quality (HoQ) which shows the relationships between multiple customer needs by using metrics to establish a standard for evaluation. Also, a HoQ will allow the team to easily see the positive and negative correlations between various needs. An example of this would be a conflict between material strength and weight. It is important to have some metric or other standard which can be used to evaluate the merits of each design concept in order remove any bias that may be present. Overall this method will help the team analyze different designs with performance parameters and conflict ratings [9].

Another decision making tool that the team will use is the Pugh chart. The Pugh chart uses a more detailed ranking system for each criterion in the design which the team will use to evaluate all possible designs developed in the previous phase. The Pugh chart is different from the HoQ in that instead of looking at the performance of a concept in regard to individual parameters, it looks at the performance of the entire concept relative to a functional requirement. In other words, the HoQ looks at a concept from the microscopic perspective while the Pugh chart looks at the concept from a macroscopic perspective. The use of both of these methods will help the team to make a final decision as to which design best solves the problem [9].

2.4 Concept Analysis

The final phase consists of the analysis of the selected concept. This design will first be modeled in Pro/ENGINEER, a 3D CAD model environment, and then finite element analysis will be used to analyze the design for possible failure in a variety of loading situations. Hand calculations will be used to verify the results of the finite element analysis along with performing an analytical analysis for both fatigue and reliability. This analysis will either help validate the design or show where weak points exist.

During the concept analysis phase the team will also verify that all of the requirements and constraints of the specifications sheet are met. This will include a detailed mass analysis of the concept assisted by the computer model. A bill of materials will then be created to analytically confirm the mass analysis by the computer model. The team will then strive to minimize the mass of the overall system while still maintaining all safety requirements. There are a variety of ways mass can be reduced in a system including combining parts and/or removing redundant parts. A force flow analysis can be used to identify such areas in a design. This method maps the flow of force through a design. It can identify where components have no relative motion, and therefore, have the potential to be combined. The force flow method can also identify possible redundant parts by looking at parallel force paths and determining whether the device will function with only one path.

Finally, an economical analysis will be performed by using the bill of materials to determine an estimate of material costs necessary to bring this design to fruition. Although cost is not of primary concern with this design, it is appropriate to relate the cost of the device to important parameters such as mass. For example, it may be possible to slightly reduce the overall mass of the device by using a specialized material. However, if the use of such a material incurs a significant price increase it may not be cost effective despite its benefits.

3 CURRENT WORK

Since the start of this project the design team has been able to complete a substantial portion of the pre-concept generation phase. This includes the creation of a specifications sheet and completion of a portion of the preliminary research. The team anticipates completion of the entire pre-concept generation phase within a week of this reports submittal.

3.1 Specifications

The requirements and constraints that surround this project mostly stem from the desire to translate crew and equipment from the airlock to the lunar surface and back both safely and reliably while maintaining the requirements of the lander itself [7]. Safety and reliability are important due to the hazardous environment in which the device we design must operate [8]. Any operation on the lunar surface is considered to be a ‘criticality one’ operation. This means that any malfunction in equipment can result in loss of life which supports the prioritization of safety and reliability. Although these two factors are of primary concern, it is also necessary to make sure that the device does not cause the lander to violate its own specifications such as weight and size. All of the requirements and constraints associated with the design of this transportation device can be found on the specifications sheet (Table 1).

Table 1. Specifications Sheet [8,10].

Date	Demand or Wish	Project: Design of a Crew Elevation Device for the Lunar Lander	Quantification	Test/Verification
		Functional Requirements		
10-Feb	D	Functional translation length	20.0 ± 3 ft [6]	Analytical analysis of design
10-Feb	D	Transport mass	0 lbm to 1380 lbm	Analytical analysis combined with FEA
10-Feb	D	Functional temperature range	-200°C to 150°C [12]	Material analysis (strength, expansion, etc.)
		Constraints		
		Geometric		
10-Feb	D	Platform size	≥ 60 in x 60 in	Dimensional check of engineering drawings
10-Feb	D	Must fit within Aries V shroud	≥ 10 inches clearance (TBD)	Verify size with CAD model of device with Lander
10-Feb	D	Must work around existing Lander structure	Altair Lander Design	Check device against Altair Lunar Lander dimensions
		Force		
10-Feb	D	Withstand G-forces on liftoff	5g axial, 2g lateral	FEA on CAD model
		Materials		
10-Feb	D	Total device weight	≤ 250 pounds mass [7]	Bill of materials mass analysis
10-Feb	W	80% max allowable device weight	≤ 200 pounds mass	Bill of materials mass analysis
		Energy		
10-Feb	D	Voltage	28 Volts [7]	Verify with electric specifications
10-Feb	D	Power Consumption	TBD	Verify with circuit simulation
10-Feb	W	80% Power Consumption	TBD	Verify with circuit simulation
		Safety		
10-Feb	D	Astronaut movement clearance	≥ 6 inches	Compare with astronaut size/movement standards
10-Feb	D	Metallic Safety Factor	1.4 [11]	Analytical Analysis or FEA
10-Feb	D	Composite Safety Factor	2 [11]	Analytical Analysis or FEA
10-Feb	D	Criticality 1 failure tolerance	TBD	TBD
		Ergonomics		
10-Feb	D	Astronaut operational force	≤ 15 pounds force	Analytical Analysis of operational design
10-Feb	D	Retain current egress procedure	"Diving Out" method	Compare design with current method
		Assembly		
10-Feb	D	Deploy Location	From Airlock or 'porch'	Check of design, updated activity diagram
		Operation		
10-Feb	D	Must function in dusty environment	TBD	TBD
10-Feb	D	Must function if lander is at an angle	±12°, any axis	Experimental test with model or Analytical analysis
		Maintenance		
10-Feb	W	Maintenance time required	0 hours	Check final design maintenance requirements

3.1.1 Functional Requirements

There are three functional requirements that the device must meet in order to be considered a solution to the problem. First, the device must be able to translate 20.0 ± 3.0 feet from the airlock to the lunar surface [6]. The variability in this length exists in order to compensate for a variety of lunar surface landscapes. Second, it is necessary for the solution to be able to transport between 0 to 1380 pounds mass [10]. This range of weights come from the varying masses between having no load on the device to having two astronauts in full gear with a rock box full of samples. However, it may not be necessary to support the entire 1380 lbm at once depending on the configuration of the device and the solution obtained. The third and final functional requirement is the ability for the device to operate in the temperature ranges from -200°C to 150°C which are present on the moon [12].

3.1.2 Constraints

There are many constraints associated with the design of a transportation device for the new lunar lander. These range from geometric and material constraints to ergonomic and operational constraints and each of these constraints exists in order to promote the creation of a successful device.

One of the geometric constraints is that the device must fit within the Ares V shroud which has a clearance of at least 10 inches from the frame of the lander. The assumed clearance value was taken from the maximum size of the current device assuming that it meets specifications. Also associated with the Ares V rocket is the force constraint that the device must be able to withstand 5g axial and 2g lateral accelerations. These accelerations are felt during the launch of the rocket and therefore it is necessary for any design to withstand these forces if it is to be a viable design [10].

Material constraints also exist such as the constraint that the total device weight must be less than or equal to 250 pounds mass [10]. This constraint goes back to maintaining the requirements of the lander itself. If one were to increase the mass of the lander beyond the specified limits, it becomes difficult or impossible to launch given the Ares V rocket design. Another limitation that is tied to the lunar lander is the energy constraint of power consumption. Although the team currently does not know that maximum amount of power that an elevation device is allowed to use during operation, it is important that our design does not exceed the allotted power so as not to risk disrupting vital systems such as life support. Once we are told the allotted power we wish to only use 80% of it, as this will allow us to save power for other applications and any unexpected usage.

There are also safety constraints that restrict our design. An example would be the factors of safety for both metallic and composite components; 1.4 and 2.0 respectively [11]. These values may seem low due to the catastrophic effect that can result from a structural failure, but the mass of the design must also be taken into account. Due to the fact that mass and strength are usually directly correlated, there must be a balance between the two. It is for this and similar reasons that engineering for space applications must be extremely thorough and precise.

Some areas within the specifications sheet, Table 1, are marked as ‘to be determined’ (TBD). These values must either be found through continued contact with the teams sponsor at NASA or through research that has yet to be completed. There are a variety constraints associated with this design and while they are not all described in this section, each of them is valuable and will be considered with equal importance.

3.2 Preliminary Research

The preliminary research serves two main purposes during pre-concept generation. First, research is used to help determine some of the unknown values in the specifications sheet. This research can also find constraints that were previously unknown. Secondly, the research can be used to look at designs that already exist to solve similar problems. This can be done primarily through a patent search.

In regards to determining values for the specification sheet, most of the research performed by the team was done so in regards to lunar dust. Lunar dust is described as being “an insidious problem for human exploration” [13]. This is primarily due to some of the dust’s characteristics which include being clinging, abrasive, penetrating, and fine grained. Lunar dust created a variety of problems during former missions including causing the space suits to wear down extremely fast and air tight seals to leak [14]. In regards to our particular applications, we need to be aware of the effect the abrasive nature of the lunar dust will have on moving joints. Although we have not quantified lunar dust and its potential effect on our project, this research increases our understanding of the environment in which our project will be operating.

Many devices that already exist can give ideas as to possible solutions to the current problem. Ideas of this nature can often be found through general searching as well as using a patent search. One such example found using a patent search is the “dovetail track elevator,” invented by J.J. Kiraly, which uses a dovetail shaped track to guide a gear driven elevator [15]. While this entire setup might not be helpful to solve our problem, pieces of the concept such as the dovetail design can be useful. Patent searches have also led to the discovery of a variety of track systems which have the potential for being useful during concept generation. These track systems were often found in unsuspecting places such as a patent for an “Airline Service Cart” system [16]. This patent revealed the design for an internal track system that allows for a variety of sharp angled turns to work with the confined nature of an airplane. Research will continue in this area in order to find as many ideas as possible that can be used during concept generation.

4 OUTLOOK

4.1 Schedule

The design team will be making use of a running task list and Gantt chart, which will be updated bi-monthly. See Appendix A. The project has been divided into three levels by the sponsor. Level I begins by reviewing the basic project information and gathering questions for the NASA mentor to answer. After clarifying the information provided by NASA the team establishes the constraints and specifications of the project. Next, background and patent research begins on different elevation devices, including a ladder, to better acquaint the design team with the different elevation possibilities. The ultimate goal from this research is to possibly build or improve upon an idea that already exists. To maximize the number of design ideas the design team establishes the design methodologies that will be of greatest value to the project. All of this information is gathered and compiled into a project proposal for approval from both the sponsor and the University of Texas Design Projects Program. Once the proposal has been approved, Level II can be started [11, 12].

To begin Level II the team reviews and refines the needs from NASA to make sure nothing has changed and with this information the specifications sheet is revised as needed. The next step is to design a team patch and to utilize the established design methodologies to generate an abundance of design concepts. The details of each of the established methodologies have been discussed earlier in this proposal. The team then establishes a selection criterion, selects the final design and develops a design review presentation for the Design Projects Program. At this point in the project the information from Levels I and II is gathered and assembled in a midterm report and PowerPoint summary for NASA to examine and provide feedback. With this feedback enough information is accumulated to begin Level III [11, 12].

Level III begins by developing a synopsis of the project that will be used in the program for the final oral presentations for the Design Projects Program. The team then moves on to refining the selected design and creates either a CAD model using Pro Engineer or an engineering drawing followed by a safety and risk analysis of the final design. With the analysis complete, the outline of the final report is created and preparation for the Final Showcase at NASA can commence. After presenting at NASA the team returns to Austin and presents the final oral presentation to the Design Projects Program. While preparing for the two presentations the final report is written for the team to have ready for submission on May 1, 2009 [11, 12].

4.2 Expenditures

Due to the nature of this project being mostly concept generation, there is not expected to be any expenditures during Level I of the project. However, during Level II, we anticipate a field trip to NASA which will require traveling costs. The team plans to build a working model of our chosen design for this project during Level III, which will lead to an additional expenditure for parts and supplies. It is estimated that the supply cost to build such a model is between $200 and $300 based on assumed costs for rapid prototyping. The showcase presentation, which also occurs during Level III, will incur both traveling and lodging costs as it will take place over two days. The total travel grant is set at $500 for each team [18]; therefore, we anticipate that at the most we will spend approximately $800 for this project.

4.3 Deliverables

NASA and the Texas Space Grant Consortium (TSGC) work jointly to provide design projects to undergraduate student groups. As such, there are a variety of tasks that both NASA and TSGC expect the team to complete during the course of the project. These tasks are divided into levels that must be completed by specified dates. The first level is the Base Level which only requires the submission of an online design brief which was completed at the beginning of this semester. Once the design brief was completed the team moved on to Level I which requires weekly updates of our progress along with this project proposal.

The next level the team will work on completing is Level II which includes a variety of tasks including designing a team patch, taking a field trip to NASA, continuing weekly updates, and submitting a midterm design review. The midterm design review focuses on the progress made by the team with a special emphasis on concept generation. Finally, at Level III, all of the accomplishments and findings throughout the project are presented in the Final Showcase and recorded in a final report. The Final Showcase presentation takes place at NASA and is presented to the teams mentor, other design teams, and other NASA engineers. The final report should be a stand-alone representation of the team's work on the project and should include: design objectives; specifications, requirements and constraints; design concepts, plans, challenges and methodologies used; safety and risk analysis; drawings and schematics; a project timeline with design cost; key accomplishments and future plans.

5 CONCLUSIONS

The Altair Lunar Lander will play a central role in expanding space exploration efforts. With the plan to extend missions on the moon surface there will be an increase in the number of moon walks, which leads to numerous excursions from the lander airlock to the lunar surface. The team, with support from a faculty advisor and a mentor from NASA, will develop a safe and reliable method to transport astronauts and equipment to and from the lunar surface. To accomplish this task, the design team will apply multiple techniques to generate an innovative, useful and safe design within the specifications and constraints supplied by our sponsor. While meeting these specifications and constraints the team plans to exceed the expectations of NASA and the Design Projects Program at the University of Texas.

References

1. *Constellation Program*. (2008, November 26). Retrieved January 30, 2009, from NASA: http://www.nasa.gov/mission_pages/constellation/ares/aresV/index.html

2. *What does NASA Do?* (2008, March 9). Retrieved January 30, 2009, from NASA: http://www.nasa.gov/about/highlights/what_does_nasa_do.html

3. NASA. (2008), *Artist concept of Ares V.* http://www.nasa.gov/mission_pages/ constellation/ares/aresV/index.html, Accessed: Feb. 10, 2009

4. *Constellation Program:America's Spacecraft for a New Generation of Explorers*. (2006, September). Retrieved February 14, 2009, from NASA: www.nasa.gov/centers/johnson/pdf/289914main_fs_altair_lunar_lander.pdf

5. *About Us JSC History*. (2008). Retrieved February 1, 2009, from Space Center Houston: http://www.spacecenter.org/AboutUsJSCHistory.html

6. Patterson, R. (2008, October). *Snapshots of the DAC-2 Altair CAD Model*. Houston TX: NASA,JSC-ES5.

7. Mullins, D. (2009, Spring). *Design of a Crew Elevation Device for a Lunar Lander.* TX: University of Texas at Austin, Mechanical Engineering, Senior Design

8. Conference Call with John Zipay, Engineer, NASA-JSC-ES2, January 30, 2009.

9. Otto, K., & Wood, K. (2001). *Product Design* (PP. 130-217 and PP. 411-534). Upper Saddle River, New Jersey : Prentice Hall, Inc.

10. Boyle, R., Howard, R., Patterson, R., Powell, K., Radke, C., Rust, R., Thomas, S., et al. (2008, December). *Lunar Lander "Porch and Ladder" Conceptual Design*. Houston TX: NASA/JSC.

11. NASA. (2005, September), *NASA's Exploration Architecture.* Houston TX: NASA/JSC

12. *Moon Fact Sheet.* (2006, February 10). Retrieved February 4, 2009, from NASA: http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html

13. Pendleton, Y.S., Worden, S.P., Bicay, M., Heldman, J.L., *Dust Analysis At The Moon*, NASA Ames Research Center, Moffett Field, California

14. Taylor, L.A., Schmitt, H.H., Carrier, D.W., Nakagawa, M. (2005), "The Lunar Dust Problem: From Liability to Asset," Proceedings of the 1st Space Exploration Conference, American Institute of Aeronautics and Astronautics, Orlando, Florida

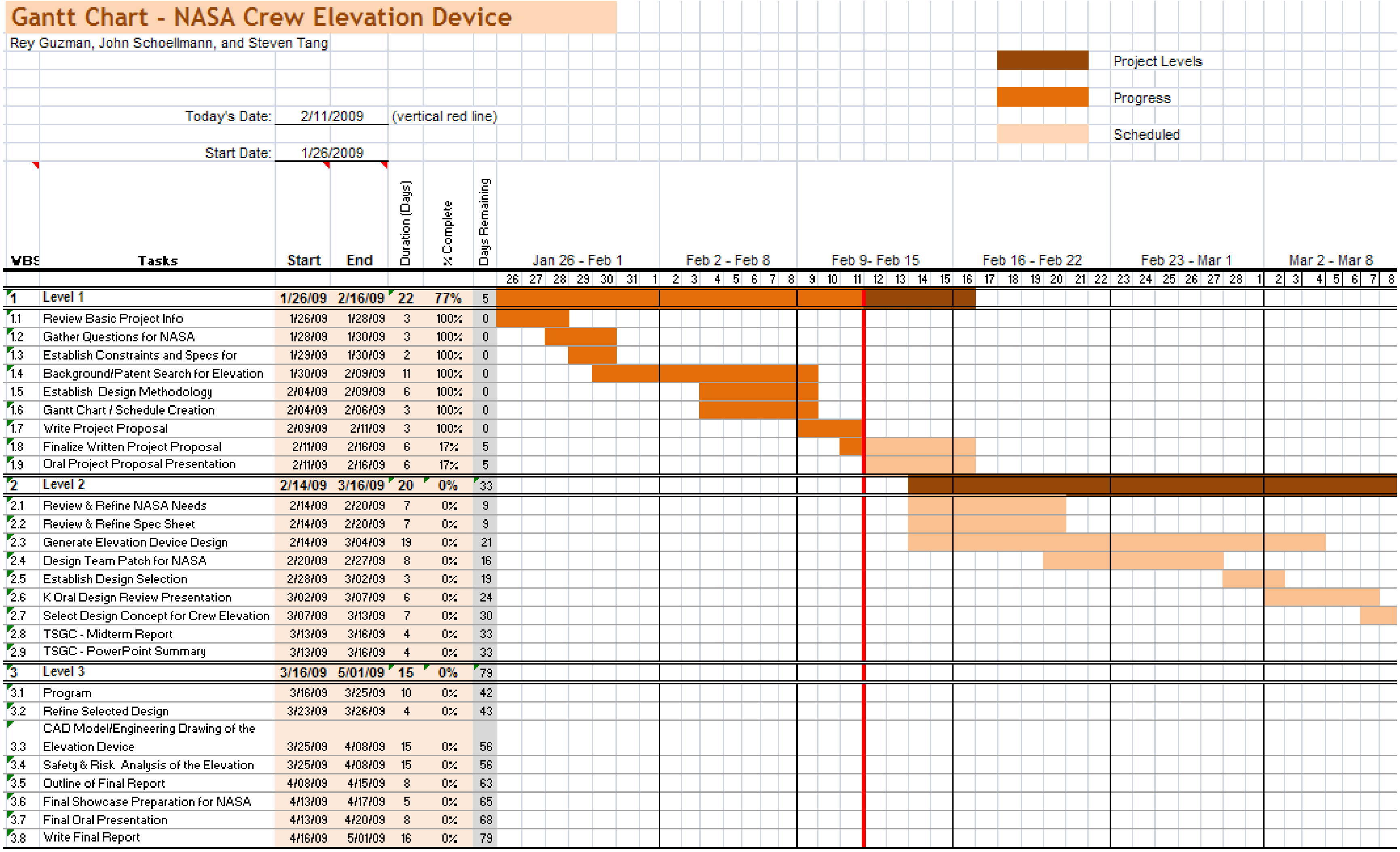
15. Kiraly, J.J., "Elevating Device," US 7,281,607 B1, October 16, 2007.

16. Trujillo, T.A., "Track System for Airplane Serving Carts," US 6,477,962 B2, November 12, 2002.

17. *Mechanical Engineering Design Projects, ME 266K, Course Manual.* (2009, Spring) TX: University of Texas at Austin, Mechanical Engineering Department, Design Projects Program.

18*. Design Team Notebook.* (2009, Spring) TX: NASA, Texas Space Grant Consortium. Retrieved February 10, 2009 from TSGC: http://www.tsgc.utexas.edu/challenge/ teaminfo.html

APPENDIX A: GANTT CHART



Gantt Chart - NASA Crew Elevation Device

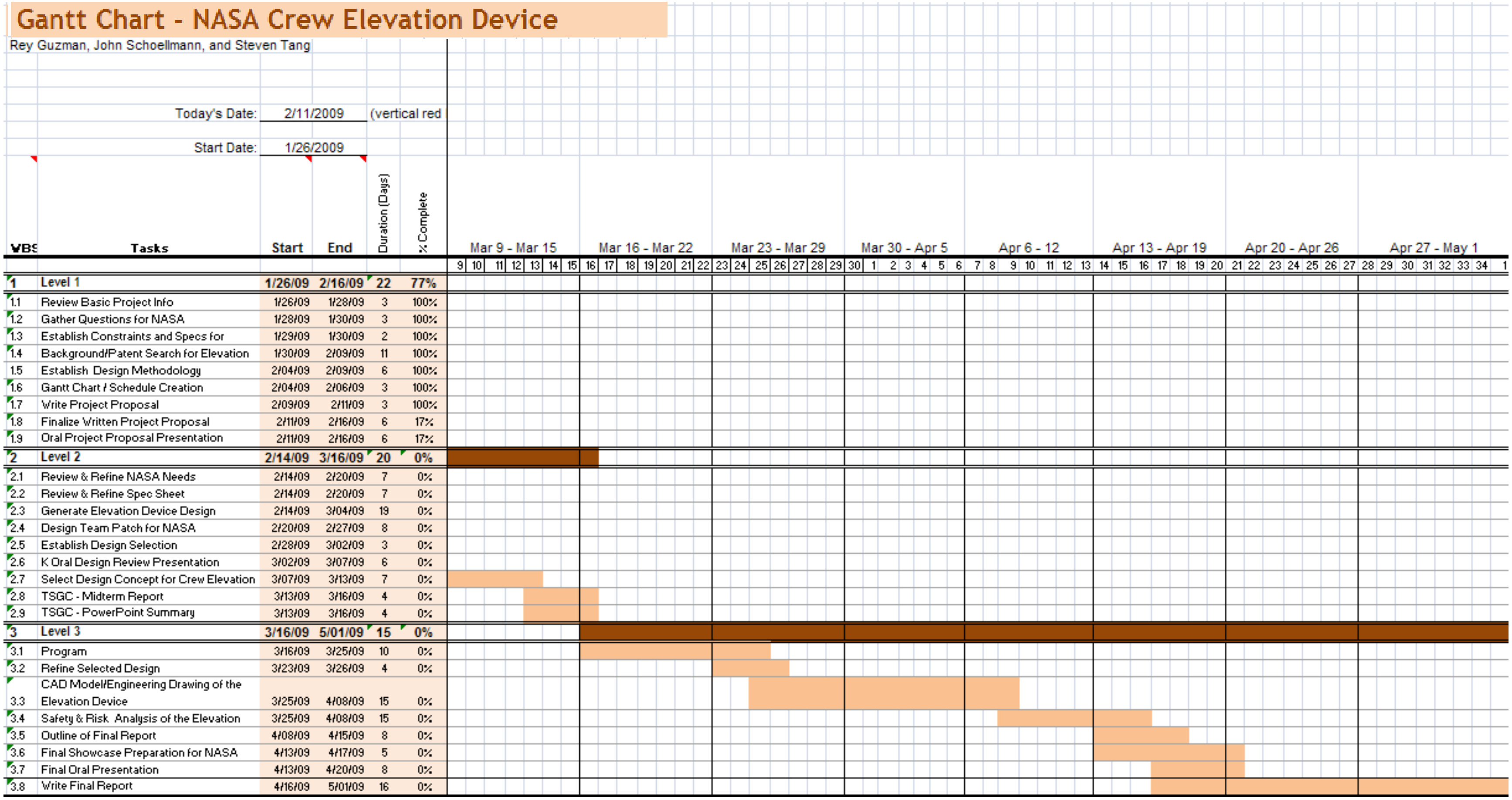
Rey Guzman, John Schoellmann, and Steven Tang

Today's Date: 2/11/2009 (vertical red line)

Start Date: 1/26/2009

WBS	Tasks	Start	End	Duration (Days)	% Complete	Days Remaining
1	Level 1	1/26/09	2/16/09	22	77%	5
1.1	Review Basic Project Info	1/26/09	1/28/09	3	100%	0
1.2	Gather Questions for NASA	1/28/09	1/30/09	3	100%	0
1.3	Establish Constraints and Specs for	1/29/09	1/30/09	2	100%	0
1.4	Background/Patent Search for Elevation	1/30/09	2/09/09	11	100%	0
1.5	Establish Design Methodology	2/04/09	2/09/09	6	100%	0
1.6	Gantt Chart / Schedule Creation	2/04/09	2/06/09	3	100%	0
1.7	Write Project Proposal	2/09/09	2/11/09	3	100%	0
1.8	Finalize Written Project Proposal	2/11/09	2/16/09	6	17%	5
1.9	Oral Project Proposal Presentation	2/11/09	2/16/09	6	17%	5
2	Level 2	2/14/09	3/16/09	20	0%	33
2.1	Review & Refine NASA Needs	2/14/09	2/20/09	7	0%	9
2.2	Review & Refine Spec Sheet	2/14/09	2/20/09	7	0%	9
2.3	Generate Elevation Device Design	2/14/09	3/04/09	19	0%	21
2.4	Design Team Patch for NASA	2/20/09	2/27/09	8	0%	16
2.5	Establish Design Selection	2/28/09	3/02/09	3	0%	19
2.6	K Oral Design Review Presentation	3/02/09	3/07/09	6	0%	24
2.7	Select Design Concept for Crew Elevation	3/07/09	3/13/09	7	0%	30
2.8	TSGC - Midterm Report	3/13/09	3/16/09	4	0%	33
2.9	TSGC - PowerPoint Summary	3/13/09	3/16/09	4	0%	33
3	Level 3	3/16/09	5/01/09	15	0%	79
3.1	Program	3/16/09	3/25/09	10	0%	42
3.2	Refine Selected Design	3/23/09	3/26/09	4	0%	43
3.3	CAD Model/Engineering Drawing of the Elevation Device	3/25/09	4/08/09	15	0%	56
3.4	Safety & Risk Analysis of the Elevation	3/25/09	4/08/09	15	0%	56
3.5	Outline of Final Report	4/08/09	4/15/09	8	0%	63
3.6	Final Showcase Preparation for NASA	4/13/09	4/17/09	5	0%	65
3.7	Final Oral Presentation	4/13/09	4/20/09	8	0%	68
3.8	Write Final Report	4/16/09	5/01/09	16	0%	79

Figure A.1. Gantt Chart 01/26-03/08 [11, 12]



Gantt Chart - NASA Crew Elevation Device

Rey Guzman, John Schoellmann, and Steven Tang

Today's Date: 2/11/2009 (vertical red

Start Date: 1/26/2009

VBS	Tasks	Start	End	Duration (Days)	% Complete
1	Level 1	1/26/09	2/16/09	22	77%
1.1	Review Basic Project Info	1/26/09	1/28/09	3	100%
1.2	Gather Questions for NASA	1/28/09	1/30/09	3	100%
1.3	Establish Constraints and Specs for	1/29/09	1/30/09	2	100%
1.4	Background/Patent Search for Elevation	1/30/09	2/09/09	11	100%
1.5	Establish Design Methodology	2/04/09	2/09/09	6	100%
1.6	Gantt Chart / Schedule Creation	2/04/09	2/06/09	3	100%
1.7	Write Project Proposal	2/09/09	2/11/09	3	100%
1.8	Finalize Written Project Proposal	2/11/09	2/16/09	6	17%
1.9	Oral Project Proposal Presentation	2/11/09	2/16/09	6	17%
2	Level 2	2/14/09	3/16/09	20	0%
2.1	Review & Refine NASA Needs	2/14/09	2/20/09	7	0%
2.2	Review & Refine Spec Sheet	2/14/09	2/20/09	7	0%
2.3	Generate Elevation Device Design	2/14/09	3/04/09	19	0%
2.4	Design Team Patch for NASA	2/20/09	2/27/09	8	0%
2.5	Establish Design Selection	2/28/09	3/02/09	3	0%
2.6	K Oral Design Review Presentation	3/02/09	3/07/09	6	0%
2.7	Select Design Concept for Crew Elevation	3/07/09	3/13/09	7	0%
2.8	TSGC - Midterm Report	3/13/09	3/16/09	4	0%
2.9	TSGC - PowerPoint Summary	3/13/09	3/16/09	4	0%
3	Level 3	3/16/09	5/01/09	15	0%
3.1	Program	3/16/09	3/25/09	10	0%
3.2	Refine Selected Design	3/23/09	3/26/09	4	0%
3.3	CAD Model/Engineering Drawing of the Elevation Device	3/25/09	4/08/09	15	0%
3.4	Safety & Risk Analysis of the Elevation	3/25/09	4/08/09	15	0%
3.5	Outline of Final Report	4/08/09	4/15/09	8	0%
3.6	Final Showcase Preparation for NASA	4/13/09	4/17/09	5	0%
3.7	Final Oral Presentation	4/13/09	4/20/09	8	0%
3.8	Write Final Report	4/16/09	5/01/09	16	0%

Figure A.2. Gantt Chart 03/09-05/01 [11, 12]

APPENDIX B: TEAM BUDGET REPORT

TEXAS SPACE GRANT CONSORTIUM
DESIGN CHALLENGE

DESIGN TEAM BUDGET REPORT FORM

SPRING 2009

INST	**University of Texas at Austin**			**TEAM NAME**	**NASA Elevator**
LEVEL	☒ **I**	☐ **II**	☐ **III**		

Teams are required to provide a Budget Report as an Appendix to each of the required reports for Levels I, II and III. The Budget Report will provide an overview of team expenditures for the time period preceding report submission. Ideally, it will help the team keep its budget in check.

COMPLETED	LEVELS ☒ I ☐ II ☐ III	OPTION AREAS ☐ I ☐ II ☐ III	GRANT APPLICATIONS ☐ SEM II ☐ TRVL I ☐ TRVL II

TEAM EARNINGS TO DATE	**$0.00**	TEAM EXPENSES TO DATE	**$0.00**
		FUNDS REMAINING	**$0.00**

REPORT TIME PERIOD COVERED: ☒ I:Proposal /SOW ☐ II:Mid-term/SOW ☐ III:Final Rpt

ITEM NAME	**USE**	**RECPT?**	**COST**
N/A	N/A	☐	**$**$0.00
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		☐	**$**
		TOTAL FOR THIS REPORT	**$**0.00

Was funding adequate/available to cover team's project needs during this period?	☒ YES ☐ NO