Firebird:

A space mission to gather scientific and physical data on the effects of atmospheric deceleration.

Submission Date: 14 November 1997

Team Phoenix:

Kammie Criddle, Mechanical Engineer

Jack Felici, Mechanical Engineer

Rick Rambo, Mechanical Engineer

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Approval:

Roy Gladden, Systems Engineer

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Assisting Engineers:

Shelly Barlow, Harold Bowman-Trayford, Dominic Florin, Corey Gravelle, Chris Wright

Executive Summary:

The **Firebird Project** is a series of four experimental spacecraft designed to further scientific and physical understanding of atmospheric deceleration, also called aerobraking or aerocapture. Whereas the launch cost per kilogram of equipment typically becomes the largest expenditure in most space exploration endeavors, minimizing launch mass is extremely desirable. Spacecraft propellant, particularly for interplanetary missions, usually occupies a large percentage of the overall spacecraft mass. Reduction of the required propellant mass would result in a smaller, less expensive spacecraft design. Effective use of aerobraking techniques can reduce the amount of propellant necessary to complete successful missions involving any planet with an atmosphere. Firebird will provide a scientific and mathematical foundation that will allow future aerobraking missions to use this technique more reliably.

The Firebird Senior Design Project is a preliminary design phase of the Firebird Project. In this project, a spacecraft will be designed to perform and study aerobraking maneuvers at different velocities and altitudes above the earth. The spacecraft will be fully functional in terms of communication, power, and attitude control. The spacecraft bus design must be robust enough to survive the substantial thermal loads that will be generated during this mission, while being simple enough to remain relatively low-cost. All subsystems in the spacecraft are affected by these key requirements, and successful implementation of intelligent spacecraft design will play an integral role in the success of this mission.

The Firebird proposal examines this spacecraft concept and its designated subsystems. The objectives, requirements, and tasks assessed to date by each subsystem are reported and a work breakdown presents the division of labor among Team Phoenix engineers. A project schedule shows the time frame and milestones of the project as it plans to progress toward completion. A budget estimate is also given, both for the design phase of the Firebird Project and for a projected manufacture and first launch. This proposal demonstrates the need for a project like Firebird and begins the process of designing a spacecraft to fulfill that need.

Table of Contents:

1.0 Introduction

In 1994, NASA's Magellan spacecraft neared the end of its mission life and trimmed its orbit to come within 150 kilometers of Venus at closest approach. At this altitude, Magellan began to use an unproven technique called "aerobraking," which is defined as changing the orbital parameters of a space vehicle by using the upper atmosphere of a planet to create drag. This enabled the spacecraft to gather scientific and aerodynamic data on the sparsely explored regions of Venus' upper atmosphere. Magellan's successful use of Venus' atmosphere for orbital maneuvers led to the use of aerobraking on the Mars Global Surveyor. This aerobraking technology provides new possibilities in space exploration.

Traditionally, a spacecraft must use rocket engines and thrusters to lower its orbit, requiring the spacecraft to spend a large portion of its limited mass and size on propellant. With aerobraking, air resistance encountered in the upper atmosphere is used to slow the spacecraft, thus conserving fuel, mass, and cost. However, one of the drawbacks of this innovative orbital maneuvering technique is that scientists have a limited quantity of knowledge on the amount of drag that will be encountered at various depths in the upper atmosphere. (For example, the Mars Global Surveyor is discovering greater thickness in the Martian atmosphere than current scientific models predicted.) The amount of drag will determine the rate of heating the spacecraft experiences. Limiting and controlling this heat build-up is vital to the survival of several spacecraft systems. It is therefore desirable to understand the effects and conditions that aerobraking through an atmosphere will have on a spacecraft and to formulate accurate models that predict these effects.

The Firebird Project is a proposed series of four spacecraft conceived for the purpose of studying the upper atmosphere of earth and gathering information on conditions imposed upon a spacecraft during aerobraking maneuvers. Scientists and engineers would use this information to construct mathematical models for use in the design of earth-orbiting satellites that could employ aerobraking rather than conventional propulsion to make orbital adjustments. In addition, this data would be valuable to designers of interplanetary spacecraft inasmuch as the data gathered could be mathematically extrapolated to describe aerobraking effects for other planetary missions. In the Firebird Senior Design Project, Team Phoenix will lay the foundation for the actual Firebird Project by researching the requirements for such a mission and designing a spacecraft to meet those requirements.

2.0 Objectives

Team Phoenix will design a low cost spacecraft to measure specified aerobraking parameters over a range of reentry velocities to provide a database sufficient to construct and validate mathematical models of such aerobraking mission maneuvers. The Firebird design will focus on a primary atmospheric entry velocity of 10.5 km/s while remaining adaptable to variable reentry velocities.

3.0 Subsystem Breakdown

Firebird is a complex design which is simplified by dividing the spacecraft into several subsystems. Each subsystem will be developed simultaneously but cooperatively through system interaction. This design process is iterative since each subsystem depends on input from the others to satisfy the mission requirements. Below, each subsystem is introduced and the requirements to be met and the tasks to be performed are outlined.

3.1 Systems Engineering

Systems engineering examines the entire spacecraft mission and, in cooperation with Mission Planning and Operations and all other subsystems, determines the feasibility of existing and future mission plans and spacecraft designs. Overall knowledge of every subsystem and key issues provides direction to the design process. Top-level design requirements are provided by systems engineers as the objective toward which all other subsystems design.

Effective integration of the spacecraft requires proper interface of all subsystems. All subsystems must work together to overcome key issues and determine an effective spacecraft design. Systems integration coordinates the design information from every subsystem and interfaces the components by relaying data on the power, control, thermal, and data lines required.

The systems engineer will primarily focus on the following tasks:

- Provide top-level design requirements.
- Assign mass and power budgets to the substems.
- Oversee the design process.
- Ensure proper communication between subsystems.
- Manage the scheduling and effective completion of all project milestones.
- Provide a learning and working design environment.

3.2 Mission Planning and Operations

The Mission Planning and Operations Subsystem lays the foundation for the entire mission. This subsystem selects orbital parameters, determines a suitable ground station location, ascertains communication opportunities, and provides scheduling throughout the mission to ensure all objectives are accomplished. Mission Planning is responsible for selecting a launch vehicle which will fulfill the requirements of the mission and remain cost effective. Proper launch vehicle selection will define spacecraft dimensions and mass restrictions.

Mission Planning and Operations must meet requirements specified by the National Aeronautics and Space Administration and The United States Department of Defense, as follows:

- The spacecraft must perform geocentric aerobraking between altitudes of 130 km and 180 km.
- The primary reentry velocity at the start of an aerobraking maneuver should be approximately 10.5 km/s.
- The total mission cost for one spacecraft, including launch, must not exceed $12 million.
- The total wet launch mass should not exceed 250 kg.
- The spacecraft should fit within a launch vehicle payload envelope of 1.2 m in diameter and 1.0 m in length.

The Mission Planning and Operations Subsystem will complete the following tasks to meet the design requirements:

- Select a launch vehicle, considering both primary and secondary payload opportunities.
- Determine actual launch date, initial orbit, and mass and dimension restrictions due to the choice of launch vehicle.
- Determine desired orbital parameters.
- Estimate the number of passes and geocentric locations of aerobraking maneuvers as required by the payload and calculate the orbit adjustments necessary to achieve each maneuver.
- Estimate total mission life and provide event scheduling throughout the mission.
- Select ground station location(s) and determine communication windows throughout the mission.
- Estimate the required ground support and subsequent cost throughout the mission.
- Support subsystem trade-off studies.

3.3 Payload

The Payload Subsystem consists of the scientific instrumentation required aboard the spacecraft to achieve the mission objectives. Therefore, the primary purpose of the instrumentation package is to determine the scientific and physical effects on the spacecraft during aerobraking. Measurement criteria include decelerations, velocities, electromagnetic emissions, atmospheric parameters, and thermal factors acting on the spacecraft. These measurements will be taken at different stages of each orbit, including all phases of the aerobraking maneuver.

Two ultraviolet spectrometers will determine the frequency spectrum of ultraviolet emissions. The *vacuum ultraviolet spectrometer* takes measurements from within a vacuum while the *ultraviolet spectrometer* operates from within a pressurized one atmosphere container. A *mass spectrometer* will be used to determine the compositional make-up of surrounding particles as found by their emissions. *Proportional counters* will be used to find the proportions of various particles surrounding the craft. An *ionization cell* will count the number of ionized particles that are created as an effect of the aerobraking. A bank of *photometers* will determine the intensity of emissions produced during aerobraking while *near-infrared photometers* take measurements in the near-infrared spectrum.

Accelerometers will sense the deceleration of the spacecraft and verify the accuracy of the experiemntal *micro-accelerometers*. *Pressure sensors* will be used to determine air densities and forces on the spacecraft. *Global Positioning Satellite receivers* and *ground radar* will be used to determine the spacecraft’s velocity as it aerobrakes. A *3-axis magnetometer* will detect the orientation of the craft in the Earth's magnetic field, while *sun sensors* and *Earth sensors* will detect the orientation of the craft with respect to the Sun and the Earth. *Angular rate sensors* will record the angular velocities of the spacecraft.

The scientific and physical parameters of interest dictate the instrumentation as specified. Two critical issues for this subsystem are mass and power consumption. A general listing of instruments with their mass and power consumption is included as Appendix C. The totals calculated in the appendix are derived from projected instrumentation mass and predicted power over an average duty cycle.

The Payload Subsystem will meet scientific and physical objectives by completing the following tasks:

- Finalize the component listing of the science package to be carried aboard the spacecraft.
- Specify the mass, power, and volume needs for the complete science package.
- Determine mounting configuration within the structure.
- Determine vibrational, thermal, and acoustic constraints on the payload.
- Define circuitry, control parameters, instrumentation modes, and data collection methods.

3.4 Structures and Mechanisms

The Structures and Mechanisms Subsystem is responsible for providing the mounting structure for all instruments and components of the Firebird spacecraft. This structure must withstand the launch environment, provide protection for sensitive equipment from all hazardous environments, and offer a configuration that fills the needs of the other subsystems.

The Structures and Mechanisms Subsystem must fulfill the following mission requirements:

- The structure must provide mounting locations for the instruments and spacecraft systems.
- The structure must have the strength necessary to withstand launch forces, accelerations, vibrations, accoustic loads, and depressurization.
- The structure must protect instruments and spacecraft systems from cosmic phenomena, such as radiation and space debris.
- The structure is to furnish sufficient surface area to accommodate solar arrays, provide for thermal dissipation, and allow appropriate fields of view for all instrumentation.
- The structure must protect the spacecraft bus from expected thermal loads, especially those due to aerobraking maneuvers.

The Structures and Mechanisms Subsystem will complete the following tasks in order to meet the design requirements:

- Conceptualize the shape and dimensions of the spacecraft bus.
- Determine the magnitude and spectrum of expected vibrations and accelerations during launch.
- Estimate loading on the spacecraft bus due to instrument position and mass.
- Select a material and configuration for the spacecraft bus.
- Estimate required heat shield properties and select an appropriate material.
- Determine the size and shape of the heat shield.
- Calculate and model the center of gravity, moment of inertia, and product of inertia for the spacecraft.
- Calculate the cost of the materials required to construct the spacecraft.

3.5 Thermal Control

The Thermal Control Subsystem is primarily concerned with the thermal design of the spacecraft. Its objectives are to identify the sources of heat and design ways to regulate and dissipate the heat in order to maintain spacecraft components within their tolerated temperature ranges. Heat transfer can occur by conduction, convection, and radiation. Convection usually plays an insignificant role in a space environment and thus can be ignored in the Firebird analysis. Typical sources of heat include solar radiation, earth radiation, and electrical energy conduction from operating spacecraft components.

One of the most difficult tasks for Thermal Control is determining the heat transfer across component interfaces because contact surface conductance is difficult to model. One approach to this problem is to measure the heat transfer from each component and evaluate the system using spacecraft thermal models. Determination of thermal control elements will depend on dissipation needs, thermal performance, cost, weight, reliability, availability, safety, and durability. The design will attempt to achieve thermal management by passive means, such as radiator panels, paints, and surface conditioning.

The Firebird spacecraft thermal control design must also take into account the effects of aerobraking. Using the Earth's atmosphere to slow the spacecraft will generate an excess amount of heat that the spacecraft must be designed to withstand. The path and time necessary to cool the spacecraft bus after an aerobraking maneuver will also need to be analyzed. The maximum and minimum loads each component can withstand will greatly affect how the spacecraft will function during aerobraking. As a result, the Thermal Control Subsystem will play a major role in this spacecraft design.

Thermal Control must fulfill the following mission requirements:

- The Thermal Control Subsystem must maintain the spacecraft and its components within specified temperature limits.

The Thermal Control Subsystem will complete the following tasks to meet the design requirements:

- Perform trade-off studies on thermal control methods.
- Determine the heat tolerances, dissipation, and temperature limits of spacecraft components.
- Calculate or model the amount of heat generated by solar or earth-reflection radiation.
- Examine techniques of dissipation and control of the intense heat generated by the aerobraking maneuvers.
- Select thermal control components to fulfill the spacecraft's thermal needs.

3.6 Propulsion

The Propulsion Subsystem of a spacecraft has three main purposes. First, the subsystem must lift the launch vehicle and its payload from the earth's surface and put the payload into a low-earth orbit. Second, it must be capable of performing orbital maneuvers. Finally, it must provide the thrust needed for attitude control. It is anticipated that the Firebird mission will use a standard available launch vehicle, and therefore the Propulsion Subsystem will not deal with launch considerations. The subsystem design will focus on performing the orbital maneuvers and making the appropriate attitude corrections.

The type of propellant needed for this mission and the position and size of the thrusters will be determined by several guidelines. First, the spacecraft will have a specific mass budget which imposes a mass constraint on the Propulsion Subsystem. The thrust required for the mission depends on the time frame in which the altitude and orbit adjustments must be accomplished. Once the thrust required is determined, then a comparison between thrust available and mass will decide which type of propellant to use. The amount of fuel required depends on what specific impulse is provided by the selected propellant. Second, the position of the thrusters is determined by the type of maneuvers needed by the mission. In general, a spacecraft has a main thruster for large orbit transfers and corrections and several smaller thrusters for attitude control. Complete three-axis attitude control will be an important parameter when considering the position of the thrusters. The control of the thrusters will be determined by the Guidance, Navigation, and Control (GN&C) Subsystem through the use of computer program subroutines.

Propulsion must fulfill mission requirements, as follows:

- The subsystem must be capable of performing the required orbital maneuvers.
- The Propulsion Subsystem must supply complete three-axis control of the spacecraft.

The Propulsion Subsystem will complete the following tasks to meet the design requirements:

- Estimate the amount of propellant needed for the entire mission.
- Perform a complete trade-off analysis on alternative propulsion mechanisms and available propellant systems, then select an appropriate propulsion system and propellent, if necessary.
- Determine the number of thrusters needed for the mission.
- Determine the positioning of the thrusters.
- Calculate the nominal values for thrust and torque output.
- Determine the size and pressurization necessary for the fuel storage tanks.
- Design the plumbing system.
- Calculate the total subsystem cost.

3.7 Guidance, Navigation, and Control

The Guidance, Navigation, and Control (GN&C) subsystem is responsible for detecting, maintaining, and changing the spacecraft's orientation. Pointing requirements throughout the mission will be determined by instrument needs, communication antenna capabilities, solar panel position, and required heat shield orientation. Aerobraking maneuvers will require an active control system. Knowledge of spacecraft orientation will be obtained on-board using sun and earth sensors. Other position and dynamic information will be obtained with magnetometers, accelerometers, and/or gyros.

GN&C must fulfill the following mission requirements:

- The control system must stabilize the spacecraft orientation.
- The guidance system must orient the spacecraft properly for orbital transfer burns between aerobraking phases; for ground communication, if necessary; for maximum solar power configurations between maneuvers; and for atmospheric entry.
- The navigation system must provide attitude, velocity, and position information for instrument data correlation.
- Quantified point requirements are to be determined.

The GN&C Subsystem will complete the following tasks to meet the design requirements:

- Perform trade studies on the available methods and types of instrumentation to demonstrate optimal system configuration.
- Select a primary attitude control mode.
- Determine the pointing tolerances from data provided by other subsystems.
- Determine the disturbance environment and initiate actions to maintain control, including fuel tank slosh and aerodynamic forces during aerobraking.
- Identify control hardware candidates.
- Select the hardware required to fulfill mission needs.
- Define how the GN&C system will maintain control through use of system components.

3.8 Command and Data Handling

The Command and Data Handling (C&DH) subsystem provides autonomous functions and data storage for the Firebird spacecraft. Data from the various instruments, including science payloads and satellite environmental and control devices, will be collected, compiled, stored, and then transmitted to earth for further processing. The number of inputs and the sampling rate will determine the amount of memory and the type of flight computer required. The overall architecture design will organize computer interactions and prioritize functions to maximize available resources.

The power and capabilities of the main computer are primarily constrained by cost, although mass and volume may be restrictive as well. The spacecraft will only have periodic ground communication so the computer system will be designed with a high degree of autonomy. The C&DH system maintains operations between uplinks, using instrument responses to make adjustments as necessary. Due to its electronic composition, radiation, temperature, and vibration concerns will need to be addressed for the computer system.

The C&DH Subsystem must meet the following mission requirements:

- The computer must transmit data in a format compatible with the communications antenna(e) and ground station configuration.
- The computer and controllers must be durable enough to withstand the vibrational, acoustic, thermal, and radiation loads expected thoughout the mission.
- The computer must be capable of collecting and storing all the data acquired by the various instruments until such time as it can be transmitted to the ground station.
- The capacity and speed requirements of the computer are to be determined.
- The computer must be capable of processing ground commands and initializing all phases of the mission.

The C&DH Subsystem will complete the following tasks to meet the design requirements:

- Determine the total number of spacecraft telemetry points for system operation and data collection.
- Estimate the data size and sample rate required for each of the different sensors.
- Conceptualize the method of gathering and storing data from the sensors.
- Quantify the system's reliability and, if necessary, determine and provide failure modes.
- Determine the needs of the control programs and the demand on the system's resources in order to fulfill mission requirements.
- Perform trade studies on the available controllers to meet established needs.
- Determine the speed and capacity of the processing system.
- Establish the programming and instrumentation necessary to monitor spacecraft status and data handling.
- Provide a functional block diagram of how the system is to be integrated.

3.9 Telemetry, Tracking, and Communications

The Telemetry, Tracking, and Communications (TT&C) Subsystem is responsible for providing a ground station and the ability to communicate with the spacecraft. The spacecraft conveys information on position and system health as well as transmitting collected data. The ground station(s) receives the information and returns commands to update the system and correct for errors. A vital component of this subsystem is the communications antenna(e) mounted on the spacecraft which handles both uplink and downlink functions. There are many types of systems available for consideration with respect to ground station(s), antenna(e), and forms of communication between them. Final selection will be based on performance requirements, system compatibility, durability, and cost.

The TT&C Subsystem must meet the following mission requirements:

- The system must provide a reliable means of communication between the spacecraft and the ground in all orientations.
- The system must provide accurate position knowledge.
- The required link margin requirement is to be determined.

The TT&C Subsystem will complete the following tasks to meet the design requirements:

- Perform thorough trade studies to determine methods of communication.
- Determine antenna(e) type(s) and configurations.
- Investigate antenna mounting options in conjunction with the Structures and Mechanisms Subsystem and determine the optimal antenna(e) location(s) on the spacecraft.
- Estimate the impact of aerobraking on the exposed antenna(e) and develop protection procedures and/or structures, if necessary.
- Obtain ground station information from Mission Planning, including the available communication windows and their time duration.
- Calculate the required data rates using estimates of the necessary amount of data to be transmitted during each downlink.
- Calculate the overall link margin.
- Estimate the power needs of the communications equipment and size appropriately.

3.10 Electrical Power

The Electrical Power Subsystem (EPS) furnishes the power and energy required by the spacecraft. In a high-tech integrated spacecraft design such as Firebird, this subsystem plays a vital and dynamic role. The scope and configuration of the EPS is mainly determined by the number of instruments which require electrical power and the availability of electrical power resources. Essentially every spacecraft subsystem requires power to run its components at various stages throughout the mission. Therefore, the EPS design is highly iterative and depends almost entirely on the requirements of the other subsystems.

In order to provide sufficient power throughout the mission, several energy sources will be investigated. Solar panels, batteries, and fuel systems will be researched as possible means to provide spacecraft power. Alternative power sources, such as natural gas, may also be evaluated in this design. This research will focus on finding the most efficient power source at the lowest cost which will meet mission needs. After an efficient energy source is decided upon, power regulation and distribution methods will be examined.

EPS will meet the following mission requirements:

- Provide sufficient power and regulation to all subsystems during all phases of the mission, including illumination and eclipse.
- Peak and average power requirements are to be determined.

EPS will complete the following tasks to meet the design requirements:

- Determine the specific energy requirements of all instruments on the spacecraft. This includes voltage and current restrictions, peak and average power specifications, etc.
- Perform trade studies on energy source options. Consider solar panels, including various cell efficiencies and mounting styles, batteries for eclipse or peak power phases, and any other new technologies which could fulfill the spacecrafts power needs.
- Select an energy source configuration which will meet spacecraft needs.
- Design the regulatory circuitry which will provide sufficient voltage and power to all instruments.
- Create a complete power schedule in accordance with mission planning to prepare for all expected power expenditures.
- Estimate financial cost, including the cost of solar panels, batteries, power conditioning units, and wires.

4.0 Work Breakdown

During the initial Firebird design phase, Team Phoenix will work collectively on accomplishing the primary tasks of Mission Planning and Operations, Payload, and

Structures and Mechanisms. After laying the foundation of the spacecraft design, team members will expand the project focus to complete tasks within all assigned subsystems.

Mission Planning and Operations
Robert Siu
Harold Bowman-Trayford
Chris Wright

Structures and Mechanisms
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Harold Bowman-Trayford

Payload
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Corey Gravelle

Advisor
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Electrical Power (EPS)
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Systems Engineering
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Propulsion
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Kammie Criddle

Telemetry, Tracking, and Communications (TT&C)
Shelly Barlow
Erin Robinson

Guidance, Navigation, and Control (GN&C)
Erin Robinson
Chris Wright

Figure 4.1: Subsystem Assignments and Subsystem Heads

Team Phoenix subsystem assignments within the Firebird Project are specified in Figure 4.1. The design effort is lead by the systems engineer, and is advised by a professor from Utah State University. Each subsystem is comprised of two or three people, with one person acting as the subsystem head. The subsystem head is responsible to direct the research and design efforts of the given subsystem and also is required to prepare necessary documentation.

Two classes of contributors are present, as indicated on the signature page. The first class is comprised of full-time contributors who are doing this project for Senior Design. The others are aiding in the design effort in exchange for academic credit. All presentations will be made by the full-time contributors; presentation work breakdowns are to be determined.

5.0 Project Schedule

Appendix D contains a complete schedule for the remainder of the Firebird Senior Design portion of this project. Table 5.1 lists the nearest milestones on the schedule. The preliminary subsystem design review will allow each of the team members to gain a more thorough understanding of the entire spacecraft. This will mark the beginning of the iterative process which will culminate with the Final Design Review in May of 1998.

At the completion of the Firebird Senior Design Project, design teams from the Space Dynamics Laboratory at Utah State University will undertake the Firebird Project. The spacecraft design provided by Team Phoenix will be the groundwork for the actual Firebird spacecraft. The first of these spacecraft is expected to launch in the third quarter of the year 2000. Scheduling leading to the manufacture and launch of these spacecraft will be determined by design teams at the Space Dynamics Laboratory.

Table 5.1: Nearest Milestones

Preliminary Subsystem Design Review	25 November, 1997
Preliminary Design Review (PDR) Paper Due	2 December, 1997
PDR	4 December, 1997
PDR Comments	9 December, 1997

6.0 Facilities

As a conceptual design project, Firebird requires the use of computer-aided design models and orbital tracking software. Team Phoenix plans to acquire an account on the Silicon Graphics Workstations at Utah State University for this purpose. Mission Planning and GN&C subsystems will use “Satellite Tool-Kit” for orbital determinations and ground tracking facilitation. Structures and Thermal Control subsystems will use “I-DEAS Solid Modeling” for structural modeling and thermal and vibrational analysis.

7.0 Safety

As a result of this being simply a design phase of the Firebird Project, there are no outstanding safety issues involved at this time. However, the design of these spacecraft is to be conscientious of future design and manufacturing considerations, including outstanding environmental and cultural concerns.

8.0 Budget

The proposed budget for this project is included in Table 8.1. Section 1.0 of the budget is the operational budget for the Firebird Senior Design Project. The additional expenses are the anticipated costs for the actual development and production of the Firebird spacecraft through first launch. All time listed in Section 1.0 is expected to be donated by the participating engineers. The Lab Account is anticipated to be a donation from the Department of Mechanical and Aerospace Engineering at Utah State University.

Table 8.1: Firebird Proposed Budget

1.0 DESIGN	Work Months	Hours/ Week	Cost	Heritage
Senior Design Engineers (5)	9.0	15.0	$ 2,250	USU-MAE Dept.
Design Credit Engineers (5)	9.0	8.0	$ 1,200	USU-MAE Dept.
Lab Account - SGI lab	9.0		$ 60	USU-MAE Dept.
		SUBTOTAL:	**$ 3,510**	
2.0 COMPONENT			Cost	Heritage
Instruments			$ 626,000	SDL-Skipper
Spacecraft Instrument Support Equipment:				
Command & Control Subsystem			$ 326,000	SDL-Skipper
Telemetry Subsystem			$ 263,000	SDL-Skipper
Attitude Contol Subsystem			$ 527,000	SDL-Skipper
Science Section Subsystem			$ 2,228,000	SDL-Skipper
Ground Support Equipment			$ 272,000	SDL-Skipper
		SUBTOTAL:	**$ 4,242,000**	
3.0 MANUFACTURE			Cost	Heritage
Testing & Support			$ 225,000	SDL-Skipper
Data Reduction			$ 13,000	SDL-Skipper
Risk Reduction			$ 145,000	SDL-Skipper
		SUBTOTAL:	**$ 383,000**	
		FIREBIRD TOTAL COSTS:	**$ 4,628,510**	

Appendix A: Resumes

ROY GLADDEN, Mechanical Engineer

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SUBSYSTEMS: **Systems Engineer**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies and small spacecraft design.

EXPERIENCE: **Utah State University - Space Dynamics Laboratory, Mechanical Engineer.** Designed the spacecraft bus for the HOSS Project, a NASA aerobraking experiment.

Lockheed Martin Missiles and Space, Summer Hire - Technical. Performed launch vehicle trade studies and generated systems documentation for commercial and military communication satellites.

Utah State University - College of Engineering, Computer Consultant. Worked in a student computer lab as a consultant for IBM-DOS computers.

Utah State University - Department of Special Education, Computer Consultant. Worked as a troubleshooter for IBM and Macintosh computer systems.

HONORS:
Recipient of Superior Student Scholarship at Utah State University, 1992.
Recipient of National Merit Scholarship, 1992.
Member, Golden Key Honor Society since 1996.
Member, Tau Beta Pi Engineering Fraternity since 1996.

OTHER: Vice President - Student Chapter of the American Institute of Aeronautics and Astronautics at Utah State University.

KAMMIE CRIDDLE, Mechanical Engineer
780 E. 1000 N. #34
Logan, UT 84321
(435) 713-0096
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SUBSYSTEMS: **Thermal Control, Propulsion**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998.

EXPERIENCE: **Utah Medical, Engineering CO-OP,** Engineering Aid. Wrote engineering change requests, performed stress analysis on medical parts, and performed some design on Autocad for medical components.

LORAL Systems, Engineering CO-OP, Engineering Aid. Generated electrical cable analysis documentation and circuit card housing designs on Autocad.

UNISYS, Engineering CO-OP, Engineering Aid. Performed GPS surveying at Langley Air Force Base and performed antenna hardware design and installation.

HONORS:
Recipient of College of Engineering Scholarship, 1994-1996.
Recipient of Don and Melba Corbett Scholarship for Engineering, 1992, 1995.
Recipient of Lamba Delta Sigma Stella Israelson Award, 1994-1995.
Recipient of Richard T. Byrd Scholarship, 1992-1993.

OTHER:
Member - Golden Key National Honor Society.
Treasurer - Student Chapter of the American Institute of Aeronautics and Astronautics at Utah State University.
Member - Society of Women Engineers; Vice President, 1994-1995; Public Relations Office, 1993-1994.
Member - Mortar Board National Honor Society, 1994-1995.

JACK FELICI, Mechanical Engineer

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Logan, UT 84321
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SUBSYSTEMS: **Structures and Mechanisms, Command and Data Handling**

EDUCATION: **<u>Utah State University</u>**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.

EXPERIENCE: **<u>Utah State University</u>, Student.** Performed heat analysis of a sounding rocket. Calculated interplanetary trajectories. Designed a spin control system for an Earth orbiting satellite. Designed a computer program to calculate the flight characteristics of an airfoil.

HONORS:
Recipient - Engineering Scholarship, 1994-1998.
Recipient - Superior Performance Training Ribbon, AFROTC 4-week Field Training Encampment, Tyndall AFB, Fl, Summer 1995.

OTHER:
Member - American Institute of Aeronautics and Astronautics
Member - American Society of Mechanical Engineers
Member - Golden Key National Honor Society.
Member - Mortar Board National Honor Society.

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SUBSYSTEMS: **Payload**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies. Minored in physics.

Brigham Young University, 1990-91, 1993-94. Focused on physics and astronomy. Minored in chemistry and planetary geology.

EXPERIENCE: **Brigham Young University - Physics Department.** Performed astronomical research in developing new techniques to find variable stars.

Utah State University - Get Away Special Program, Design Engineer. Designed science package from concept to flight in microgravity on the Space Shuttle.

Utah State University - Get Away Special Program, Design Engineer. Designed and constructed a small satelilte structure to be used in four satellites contracted by the Jet Propulsion Lab, Pasadena, CA.

Utah State University - Computer Services, Helpdesk Consultant. Assist faculty, staff, and students with networking, software, operating systems, and general computer problems.

HONORS: National Deans List

OTHER: Member - Brigham Young University Astronomical Society.
Vice President - Brigham Young University Astronomical Society.
Member - American Institute of Aeronautics and Astronautics.
Developed deceleration system on Unity IV Hybrid Rocket.
Utah State University chapter treasurer.

ERIN ROBINSON, Mechanical Engineer

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SUBSYSTEMS: **Guidance, Navigation, and Control; Telemetry, Tracking, and Communications**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.

EXPERIENCE: **Utah State University - Space Dynamics Laboratory**, **Computer Specialist.** Created and maintained databases. Created IDEAS models from AutoCAD images. Set-up web server and designed initial web page.

HONORS:
Outstanding Junior, Department of Mechanical and Aerospace Engineering at Utah State University, 1995.
Recipient of Four-Year Presidential Scholarship, 1992.
Honored by Phi Kappa Phi Honor Society for Academic Achievement, 1993.
Recipient of Don and Melba Corbett Scholarship, 1992.

OTHER:
Secretary - Student Chapter of the American Institute of Aeronautics and Astronautics at Utah State University.
Graduate - U.S. Space Academy, Level II, Huntsville, AL, 1990.
Volunteer Guide - Hansen Planetarium, Salt Lake City, UT, 1990.
Member - Tau Beta Pi Engineering Honor Society.
Member - Golden Key National Honor Society.
Member - Society of Women Engineers.
Member - Utah State University Honors Program.
Member - National Space Society.
Member - United States Parachute Association.

ROBERT SIU, Mechanical Engineer

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SUBSYSTEMS:	**Mission Planning and Operations, Electrical Power**
EDUCATION:	**Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.
EXPERIENCE:	**Sports Academy and Racquet Club, Head Swim Coach.**
	Contemporary Services Corporation, Security Officer. Provided security for a variety of special events. Managed a ticket booth.
OTHER:	Member - American Institute of Aeronautics and Astronautics. President and Captain - Utah State University Water Polo Club. Volunteer - Utah State University. Prepared metal samples for a materials class. Volunteer - Utah State University Discovery Center. Taught science concepts to elementary school children. Volunteer Recruiter - Special Olympics at Utah State University. Assisted in coordinating events.

SHELLY BARLOW, Mechanical Engineer

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SUBSYSTEMS: **Telemetry, Tracking, and Communications; Propulsion**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.

EXPERIENCE: **Utah State University - Crop Physiology Laboratory, Laboratory Assistant.** Helped design, build, maintain, and operate a controlled environment growth chamber. Worked with Apogee wheat, soybeans, lettuce, and rice.

Utah State University, Grader. Graded for MAE 211 at Utah State University, Manufacturing Operations Fundamentals.

Reese Ranch, Ranch Hand. Operated equipment, cared for animals, and repaired equipment.

HONORS: Recipient of Four-Year Presidential Scholarship, 1992.

OTHER: Member - American Institute of Aeronautics and Astronautics.
Repaired many automobiles, tractors, and other equipment.

HAROLD BOWMAN-TRAYFORD, Mechanical Engineer

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SUBSYSTEMS: **Mission Planning and Operations, Thermal Control, Structures and Mechanisms**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.

EXPERIENCE: **Frito Lay Incorporated, Packer.** Packed chips into boxes for shipment. Performed sanitation and quality control.

J.P. Services, Apprentice Painter. Performed preparation work for exterior painting, including repair, caulking, and masking.

Woodfabrication, Packaging Clerk. Followed packing instructions for military equipment, including vacuum sealing and construction of wood crates.

Container Design, Packer. Packed styrofoam parts for shipment. Performed some machine operation and deliveries.

HONORS: Recipient of 1-year Honors at Entrance Award.
Recipient of $500 Scholarship from Utah State University's Engineering State.

OTHER: Member - American Institute of Aeronautics and Astronautics.

COREY GRAVELLE, Mechanical Engineer

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SUBSYSTEMS: **Electrical Power, Payload**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.

Ricks College, Associates Degree-Mechanical Engineering, 1995. Minored in computer science.

EXPERIENCE: **Autoliv, ASP., Intern.** Developed production tooling to increase process line productivity. Worked in research and development to improve current airbag component design.

Morton International, Intern. Maintained current production documentation. Solved production line efficiency problems in order to reduce costs while maintaining product quality.

Utah State University - Student Lab Services, Computer Consultant. Worked in a student computer lab as a consultant for IBM-DOS and Macintosh computers.

Taylor Plumbing and Electric, Apprentice Plumber. Installed copper and PVC pipes and all manner of plumbing fixtures in new homes.

HONORS: Recipient of “Consultant of the Month” Award, December 1995.
Recipient of grant from Ricks College for installation and operation of beam analysis engineering software.

OTHER: Tutored college level algebra and calculus at Ricks College.
Member - American Institute of Aeronautics and Astronautics.

DOMINIC FLORIN, Mechanical Engineer

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SUBSYSTEMS: **Command and Data Handling, Electrical Power**

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies and controls.

Salt Lake Community College. 1995-1996.

EXPERIENCE: **Utah State University, Tutor.** Tutored math, physical, and chemistry.

Salt Lake Community College, Tutor. Tutored math, physics, and chemistry.

O'currence, Inc., Telemarketer. Sold products and produced purchase orders.

Crestwood Apartments, Maintenance Worker. Responsible for cleaning, fixing, and showing apartments and taking applications.

HONORS:
Recipient of Kiwanis Scholarship.
Recipient of Deans Departmental Scholarship.
Recipient of Intermountain Electrical Association Scholarship.
Recipient of President's Education Award.

OTHER: Involved in community service organizations.

CHRISTOPHER WRIGHT, Mechanical Engineer

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SUBSYSTEMS: **Propulsion; Guidance, Navigation, and Control; Mission Planning and Operation**s

EDUCATION: **Utah State University**, **BS-Mechanical Engineering,** 1998. Focused on aerospace studies.

Chaffey Community College. 1993-1995.

Brigham Young University. 1993.

EXPERIENCE: **Utah State University - College of Engineering, Lab Assistant.** On flight termination team for the Unity IV Hybrid Rocket project. Programming assistant.

Johnson Brothers Planing Mill, Inc., Sales Manager.

HONORS: Mathematics and Physics Student of the Year, Chaffey College.

OTHER: Member - Tau Beta Pi Engineering Honor Society.
Secretary and Treasurer - Student Section of The American Society of Mechanical Engineers at Utah State University.
Member - American Institute of Aeronautics and Astronautics.

Appendix B: References

Humble, Ronald W., Henry, Gary N., & Larson, Wiley J., Space Propulsion Analysis and Design, McGraw Hill, Inc., New York, 1995.

Pisacane, Vincent L. & Moore, Rober C., Fundamentals of Space Systems, Oxford University Press, Inc., New York, 1994.

SKIPPER Preliminary Design Review, Utah State University Space Dynamics Laboratory, 1993. (Document Number: SDL/93-049, Presented 9-10 September 1993)

SKIPPER Critical Design Review, Utah State University Space Dynamics Laboratory, 1994. (Document Number: SDL/94-054, Presented 11-15 April 1994)

Wertz, James R. & Larson, Wiley J., Space Mission Analysis and Design, Kluwer Academic Publishers, The Netherlands, 1991.

Wertz, James R., Spacecraft Attitude Determination and Control, D. Reidel Publishing Company, Holland, 1978.

Appendix C: Instrument List

Instrument List:

Science Instrument	Number of Units	Expected Mass (kg)	Expected Power (W)
Vacuum Ultraviolet Spectrometer	1	6	19
Ultraviolet Spectrometer	1	6	19
Mass Spectrometer	1	6	15
Proportional Counters	2	0.25	4
Ionization Cells	2	0.25	3
Photometers	2	8.6	39
Near-Infrared Photometers	TBD	TBD	TBD
Accelerometers	TBD	TBD	TBD
Micro-accelerometers	TBD	TBD	TBD
Pressure Sensors	TBD	TBD	TBD
Global Positioning Satellite Receivers	1	2.675	3.64
3-Axis Magnetometer	1	0.35	0.9
Sun Sensors	2	1.3	6.5
Earth Sensors	2	0.76	1.4
Angular Rate Sensors	TBD	TBD	2.4
ESTIMATED TOTAL MASS:		40	