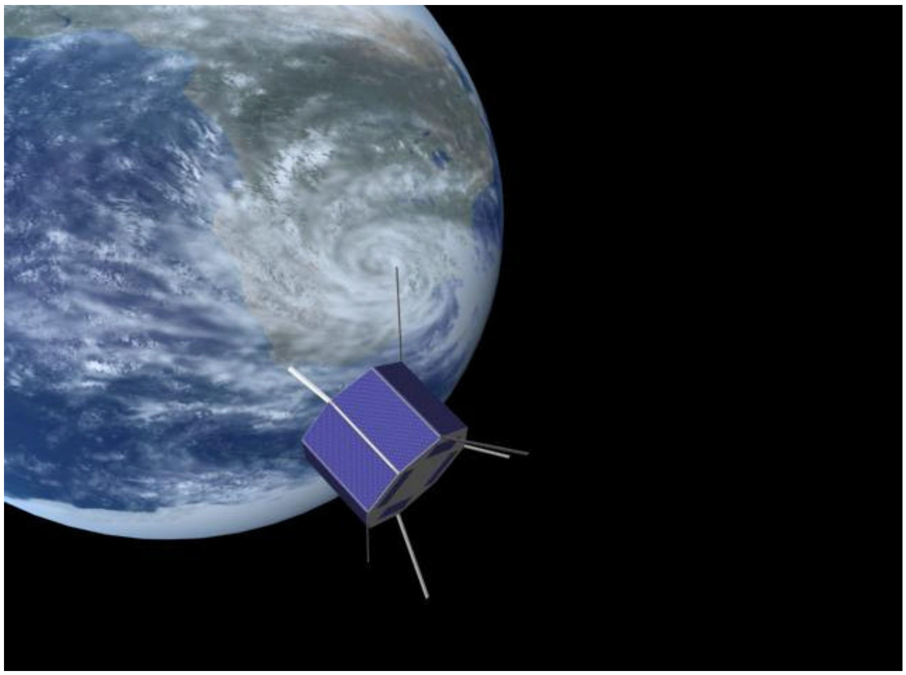
EXECUTIVE SUMMARY



PROJECT SPARTNIK

Microsatellite Design, Construction, Test, Launch,

and Operation at San José State University

Advisor: Dr. Henry J. Pernicka
Email: hank@voyager.engr.sjsu.edu

Spartnik Website: www.engr.sjsu.edu/spartnik

1. <u>EXECUTIVE SUMMARY</u>

1.1 Mission Overview

The purpose of this document is to provide a brief overview of Project Spartnik. This overview of Spartnik includes the mission summary, the specific hardware and software configurations and the operational procedures of each subsystem.

The subsystems that are described here briefly, and in detail in subsequent chapters, are as follows:

- Launch Vehicle and Orbit
- Integration and Manufacturing
  -Cleanroom
  -Launch Vehicle Adapter
- Attitude Determination and Control
- Power
- Payload
- Computer Hardware/Software
- Thermal
- Communications
- Safety Documentation

Included in each subsystem section is a discussion of the design drivers and their purpose, design testing and analysis, construction and assembly, and operations in accordance with the project mission and other subsystem specifications.

Spartnik will be the first satellite built by San José State University (SJSU). The project is named in honor of Sputnik, the Russian built satellite that was first to orbit the Earth, combined with the SJSU mascot, the Spartan. These two terms were combined to create the Spartnik title.

1.2 Mission Statement

The primary goal of this project is to educate students in the design, manufacturing, integration, and operation of a satellite in a real-world setting. Also included is the goal to construct a small, low-cost satellite to be used as a prototype for future government and commercial satellite projects. The prototype is a test-bed. It will demonstrate the way in which a microsatellite can be built quickly and inexpensively with minimal industry support and resources. The multidisciplinary Spartnik team includes the following backgrounds: Aerospace, Mechanical, Electrical and Computer Engineering; Physics and Computer Science. The majority of the team is comprised of students of all experience levels in their undergraduate studies at SJSU. Local industry mentors from Lockheed Martin, Space Systems/Loral and many other companies are donating engineering guidance and/or hardware to assist the progress of the project.

The experimental payload consists of a communications package (which will transmit on the amateur radio frequency band), a color digital camera, and a MicroMeteroite Impact Detector (MMID). All the payloads were selected to demonstrate the usefulness of microsatellites as economical platforms for space related experiments.

1.3 Mission Objectives

The primary objectives are the education of students in spacecraft design and manufacturing and to demonstrate the usefulness of constructing an inexpensive microsatellite. In addition to the primary objectives, the design team has outlined other mission objectives to be accomplished during the course of the project:

- To manufacture and secure the launch of a reliable, low-cost satellite, which may be used for both scientific research and educational purposes;
- To provide practical design experience in a team environment for senior students in preparation for entering into the industry work force;
- To provide hands-on opportunities for undergraduate students in the fields of satellite communication, tracking, maintenance, manufacturing and related technologies;
- To show the feasibility of a cooperative effort between academia and industrial sectors in space vehicle and mission design;
- To demonstrate the ease and low-cost potential of satellite imaging technology and how it can be used in everyday lives;
- To promote Aerospace studies within the Silicon Valley youth community while recruiting and exposing prospective students to the San José State Engineering Program;
- To educate young people about the importance of space exploration and the necessity of space-based research;
- To provide a mobile and versatile platform on which to demonstrate scientific techniques and theory to encourage students and others to become involved in aerospace education and research.

1.4 Mission Requirements and Constraints

The requirements that have been placed on the Spartnik design team are as follows:

- Meet secondary payload constraints for as many launch vehicles as possible;
- Design to multiple orbit configurations, ranging from 300 to 1000 km altitude;
- Inclination must be greater than or equal to 37°;
- Support all payloads; maximize operational life of each in space environment;
- Minimum spacecraft operational life: two years;
- Ease of assembly and disassembly for manufacturing and maintenance;
- Use of as many acceptable non-space rated parts as possible;
- A propulsion system is not needed;

- Use passive and autonomous systems where possible;
- Communications system to use HAM frequencies for uplink and downlink.

Early identification of the design drivers of the satellite helped team members to focus on the priority issues of the design. This has enabled a design process with clear direction and time saving by requiring minimal design iterations of the spacecraft.

Due to the limited budget of project Spartnik, the satellite is expected to be placed into a Low Earth Orbit (LEO) as a secondary payload. Spartnik is seeking a donated launch. The launch vehicle that will carry the spacecraft is still unknown; therefore, the design must meet as many launch vehicle secondary payload constraints as possible. The Spartnik team has focused on a universal design to meet as many secondary payload constraints as possible.

The additional unknown parameters, dependent upon the launch vehicle, are the orbital elements. The satellite is designed to meet all possible orbits. The Spartnik team has designed 12 candidate orbits which fall within the range of 300 to 1000 km altitude and orbit inclinations greater than 37°. These candidate orbits are 300, 500 and 700-km altitudes at 37°, 45°, 60° and 90° inclinations each. These orbits, along with the analysis of each subsystem, give approximate satellite performance in any LEO.

An overall requirement on all subsystems is to support and maintain the payloads. Their goal is to maximize the operating life of the payloads, thus obtaining the maximum amount of data from each payload.

Along with maximizing the life of the payloads, the satellite is designed to have a minimum of two years operational life in orbit. The design team is required to identify all components that would be affected by this time constraint and either modify or design them so they can meet or exceed the minimum operational life.

The spacecraft bus is designed for ease of assembly and disassembly. This improves manufacturing time, ease of maintenance and final integration before attaching to the launch vehicle. In addition, it facilitates the rapid replacement of any components, should the need arise.

The next requirement placed on the project is to use non-space rated components successfully. Although this minimizes costs, it may decrease the reliability of some of the systems. As a result, trade-offs were examined which maximized the reliability of the systems and still maintained the low-cost goal. Components donated to the project by industry were a major factor in minimizing costs. The baseline design takes into consideration the use of non-space rated parts where these donations were not attained.

To reduce the complexity of the spacecraft design, the attitude control system was designed to be exclusively passive with no onboard propulsion systems. Therefore the satellite will not be able to perform station keeping or attitude adjustment burns.

To minimize the power requirements for the satellite, most of the systems have been designed as passive, such as thermal and attitude determination and control. These subsystems used this type of philosophy in their design parameters. The satellite is also designed with an autonomous system on board, which enables the spacecraft to maintain itself with minimal communication from the ground station. This will help in emergency situations, as the spacecraft will be able to identify and perform the necessary tasks autonomously and correct or minimize any problems, should they occur.

The communications subsystem will transmit and receive voice communications on amateur radio frequencies. This requires Spartnik team members to obtain an FCC HAM license for the ground station operation.

1.5 Design Status

The following sections briefly describe each subsystem and its current design status. More detailed discussions on the various subsystems can be found in their respective final design reviews (FDRs).

1.5.1 Launch Vehicle and Orbit

At this time, Spartnik does not have a commitment from an organization for a donated launch opportunity. Research is currently ongoing in to the possibilities of using the following launch systems: Orbital Sciences Corporation, Russian Kosmos, NASA Expendable Launch Vehicle Systems, Ariane IV, Conestoga, Pegasus, Atlas and Lockheed Martin Athena Launch Vehicle. New contacts that have recently been acquired are from Goddard Space Flight Center, the NSA and the Air Force. Due to the size and weight of the spacecraft, the launch vehicle company may classify the satellite as a secondary payload. The mass of the satellite is approximately 37 kg and roughly fits in a square box 50 cm^3.

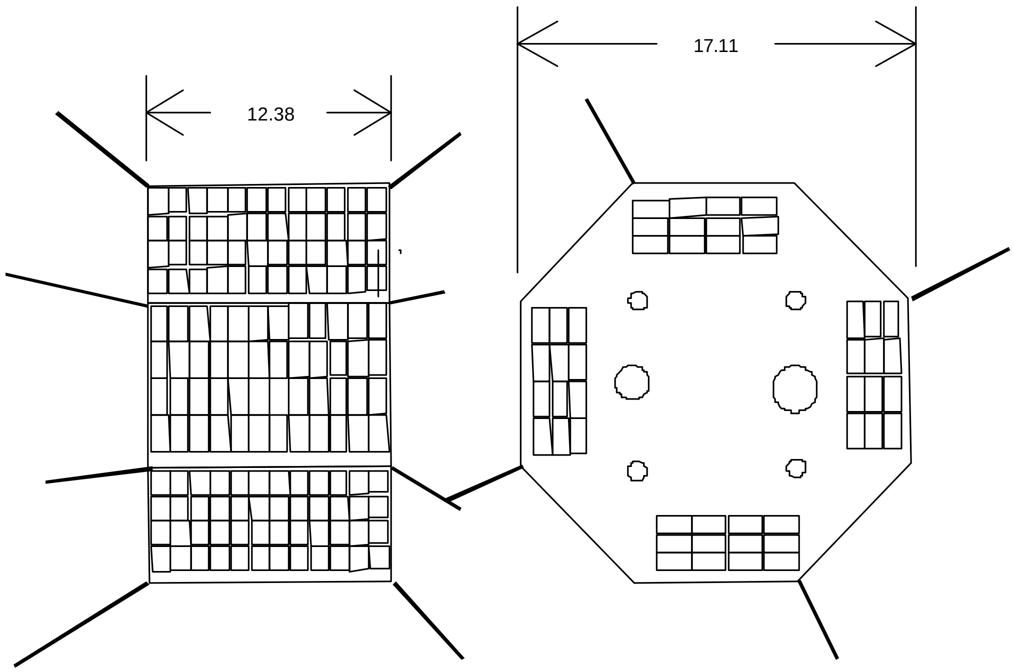
To increase the versatility of the satellite in adapting to possible launch vehicles, the team designed a secondary payload adapter system that can be modified to bolt to most launch vehicles. Modification time of the adapter system is estimated to be no more than one week once the launch vehicle is known. Designing the system to meet various launch vehicles will increase the possibility of receiving a donated or discounted launch as a secondary payload.

The orbital elements are dependent upon the launch vehicle and are critical design parameters that have been carefully examined. The design team used 12 baseline candidate orbits. These selections enabled the team to predict how the satellite will perform in almost any orbit. The 12 candidate orbits are LEOs with altitudes of 300, 500, and 700 km at inclinations of 37°, 45°, 60°, and 90° with an eccentricity of zero. The altitude ranges are specified from the definition of LEO; the design team has planned for an orbit altitude between 700 and 1000 km to increase the orbit lifetime of the satellite. The latitude of the Spartnik ground station that is located in San José, California set the minimum inclination of 37°. For an orbit altitude of 300 km, the ground station would never see the satellite if the orbit inclination was below 37°. Planetary Observer High Precision Orbit Propagation (POHOP) simulations were conducted for each of these candidate orbits. Due to perturbation effects, the design team determined that the minimum altitude for Spartnik should be 450 km to maintain the two-year operational lifetime. POHOP simulations showed excess orbit degradation for orbit altitudes of less than 450 km. In addition, the minimum inclination is changed to 40° to provide a better field of view by the Spartnik ground station.

1.5.2 Integration and Manufacturing

The configuration of Spartnik is an octagon shape with a height of 12.38in (31.351cm), a diameter of 17.11in (43.459cm) and a mass of approximately 37kg. Figure 1-1 illustrates the dimensions and basic exterior layout.

To conform to the requirement of modularity and ease of assembly, subsystem components are mounted to three internal trays. Figure 1-2 illustrates an exploded view of Spartnik. The figure also labels component placement within the spacecraft.



Dimensions are in inches

Figure 1-1 Spartnik Dimensions

The shell, top face, bottom face and trays are machined from 1/2 inch 6061-T6 aluminum honeycomb panels. The spacers and electrical component boxes are constructed from solid 6061-T6 aluminum. The internal trays are equally spaced at 2.9 in distance. Four cylindrical spacers (Figure 1-11) support Tray 1 (the bottom panel) and Tray 2. The aluminum battery boxes support the third tray. The trays are divided between subsystems: Tray 1 contains the computer and communications system; Tray 2 houses the power system components including batteries and junction boxes; Tray 3 is allocated to spacecraft payload and supports the camera module.

For integration purposes, the eight side panels and top panel are assembled into one piece; this forms the Spartnik shell. The three trays are then assembled separately while all internal wiring connections are completed. The trays are then integrated into the spacecraft. The shell is then placed over the trays and bolted to tray 1 at each of the eight vertices. Four threaded steel rods ("through-rods") are then inserted through the structure and bolted on the top and bottom panels. This serves to aid the structural integrity of Spartnik. Figure 1-2 shows this in an exploded view.

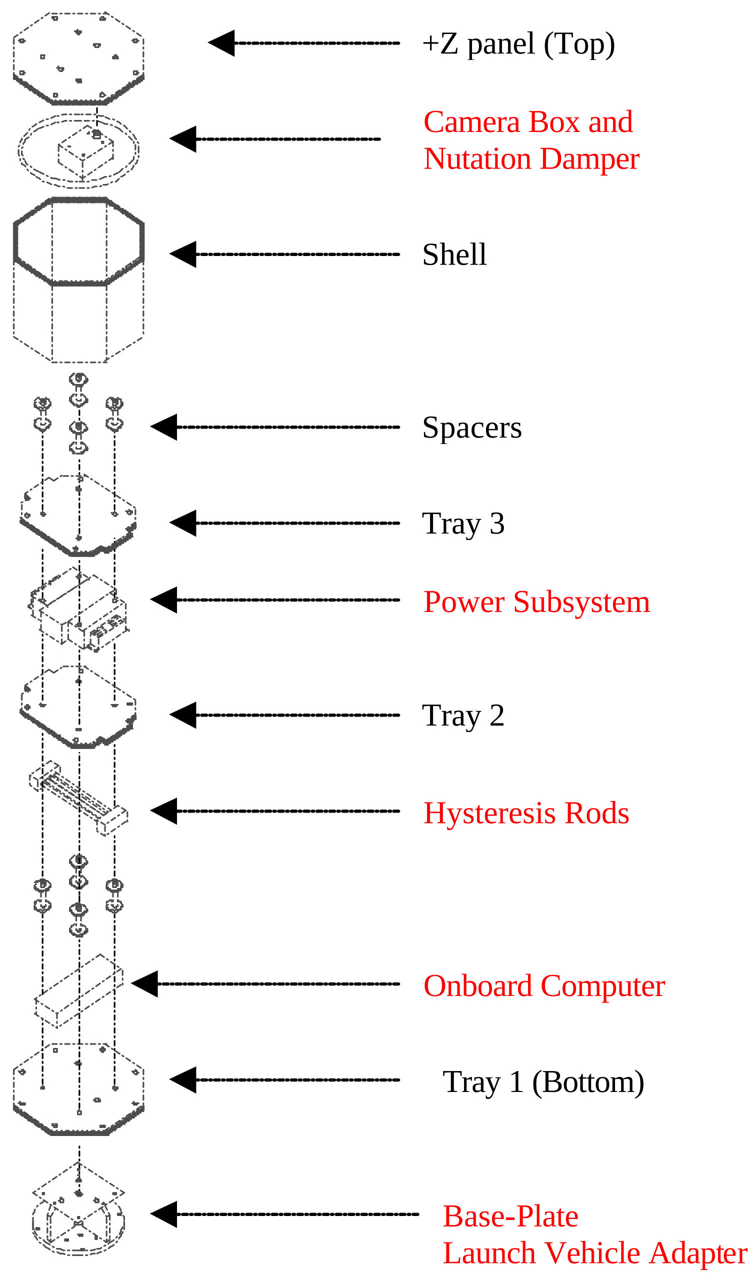


Figure 1-2 Satellite Exploded View with Launch Vehicle Adapter

Several components within the satellite serve a dual purpose. The spacers and bolted through-rods support the structural integrity and also serve as thermal conduction posts. The satellite base-plate, which will stay with the satellite on-orbit, acts as a primary radiator surface. The solar arrays of the satellite are mounted on the outside of the shell and bottom panel. Their function is to provide energy with which to power all subsystems and to provide attitude determination. Attitude determination is done via current versus Sun incidence angle curves using a program developed at San José State University. Dual-purpose components reduce the number of final parts required for spacecraft assembly. This function has greatly reduced design and integration complexity.

Along with meeting the above requirements the structure is designed to withstand the launch environment. There are various launch load contributions. Spartnik is designed to conform to strict mass and volume constraints while still meeting the extreme environment loads. The smaller, sustained loads are generated from thrust and wind buffeting of the launch vehicle during ascent. These loads can range from 2-12 Gs and are often unpredictable. Stronger loads are generated from shock, acoustic vibrations, and quasi-static loads. These loads and their frequencies cannot be changed; rather the satellite design is such that its natural frequencies will not come close to the frequencies at which these loads occur.

To aid in the design, computer modeling of the structure is being done using Pro/MECHANICA, Pro E, NASTRAN, ANSYS, ABACUS, and COSMOS. The results provide preliminary responses of the structure when subjected to environmental loads. To qualify the computer modeling, environmental shake tests have been conducted. Shake table tests were performed at United Technologies Corporation, Chemical Systems Division. The testing was comprised of a Shock Test, Sine Sweep, and Random Vibration Test. These tests correlated well with the computer modeling. Shake and shock testing will be conducted on the flight model upon completion of final integration.

Currently integration procedures are being drafted. They are designed to provide a step-by-step process of how Spartnik needs to be integrated. This documentation will make available to anyone that is qualified in the team explicit instructions for the integration of each component into Spartnik. The integration procedures can also be given to any perspective launch vehicle companies to offer verification that the spacecraft has been integrated to industry standards.

1.5.2.1 Cleanroom

A new aspect of the Structures subsystem is the implementation of the Spartnik cleanroom (Figure 1-2.5). The purpose of the cleanroom is to assemble Spartnik in a near contaminate-free environment. There are four main reasons for integrating Spartnik in a cleanroom. One reason is Spartnik's optical system must remain as contaminate-free as possible. Optical equipment assembly requires a minimum of a class 100 environment. The second reason is that Spartnik must not contaminate the launch vehicle or any other payload aboard the launch vehicle. This will increase the chances for Spartnik of receiving a donated launch. Third, one of Spartnik’s payloads is a color digital camera and it is necessary to keep the optics and mirror clean for clear photographs. Finally, safety issues and documentation is a primary concern of Spartnik.

The cleanroom is designed with three laminar flow High Efficiency Particulate Air (HEPA) filters that are mounted on C-frames. Walls of plastic were built to enclose the exit-flow filters and a working area of approximately 110 square feet. These walls allow six inches of space above the floor. Air from the surrounding room is drawn in through the intake filters where suspended particles are removed, and then exhausted into the enclosed cleanroom. As air enters the cleanroom, air is forced out along the base of the walls. This airflow creates positive-pressure inside the cleanroom, so that no dust particles can enter the cleanroom from the surrounding environment.

While the HEPA filters are on, the plastic walls of the cleanroom bulge outward-proving that there is positive pressure inside the cleanroom. Minimal dust contaminates can enter the cleanroom while the filters are on.

Figure 1-2.5 Two Views of Unfinished Cleanroom

As of this time, hoods have been installed onto the C-frames and power has been provided. The cleanroom has been enclosed using plastic sheets and aluminum frames. Cleanroom rules, supplies, and standardization parameters have also been attained and implemented.

1.5.2.2 Launch Vehicle Adapter

The Launch Vehicle Adapter (LVA) is the interface between the satellite and the launch vehicle. It also contains the release mechanism for the satellite. During launch, the LVA will act as a rigid body, therefore, all loads can be transferred to the satellite without damping or amplification. The LVA design is versatile; it can be attached to a wide range of launch vehicles. A solid circular plate was designed with the capability for mounting holes to be drilled once the launch vehicle is determined, making the LVA a universal design.

The LVA contains a mechanism that releases the satellite with minimal stress. It uses a 28V DC signal that is provided by most launch vehicles. The release bolt receives the signal and activates the mechanism so that separation of the nut occurs. The satellite will be released from the launch vehicle even in the severe case that only half of the nut separates from the bolt. Once released, a spring will push the satellite away from the launch vehicle. Most of the LVA will remain with the launch vehicle except for the satellite base plate and the bolt. The satellite plate will stay on the bottom (–Z) panel and act as a thermal reflector to help keep the satellite within its required temperature range. Figure 1-3 shows the different parts of the LVA and Figure 1-4 indicates which parts stay with the satellite and which parts stay on the launch vehicle.

It is necessary to insure that the satellite and launch vehicle adapter fit into the allowable secondary payload fairings for all possible launch vehicles. The launch vehicle adapter is approximately 6.7 inches (17.08cm) high by 11.5 inches (29.21cm) in diameter. The overall height of the satellite and LVA is approximately 19.08 inches (48.46cm).

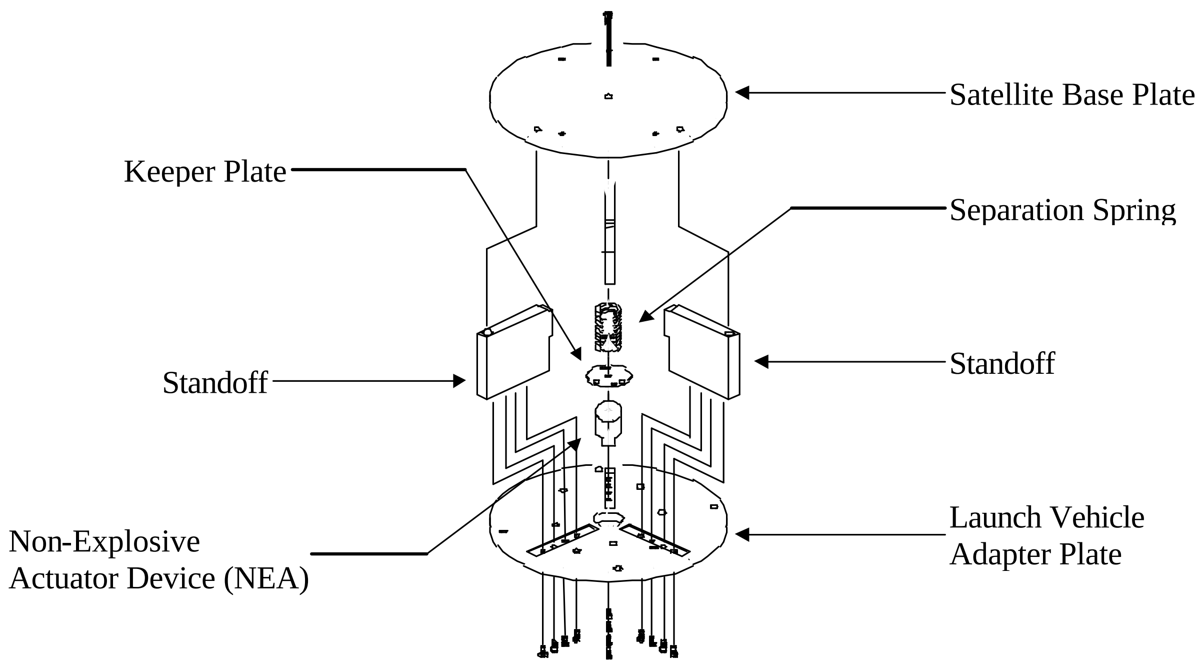


Figure 1-3 Exploded View of Launch Vehicle Adapter

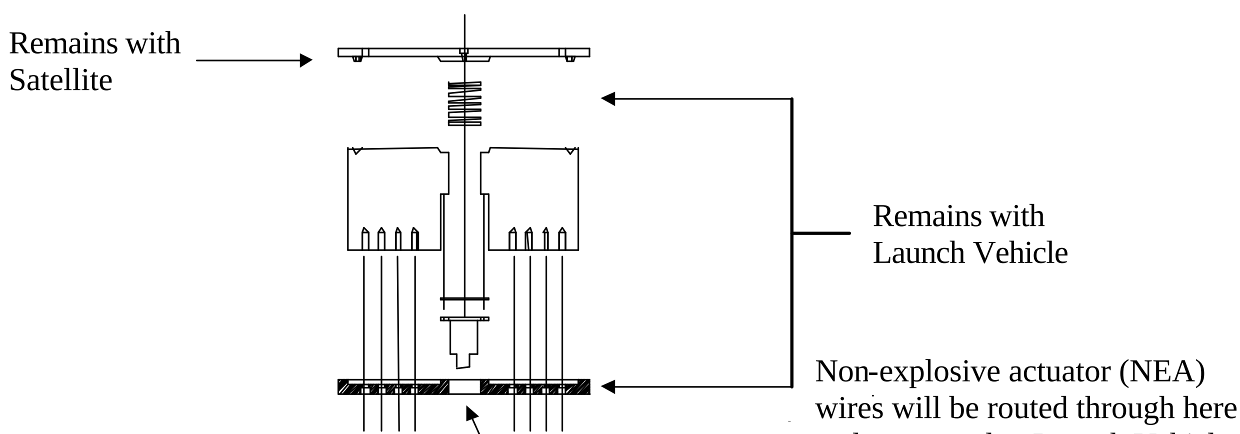


Figure 1- 4 LVA Exploded View

The only connection between Spartnik and the launch vehicle will be through a MIL-Specified DB-9 connector, which is attached to the release mechanism. This connector, along with the release mechanism, will remain with the launch vehicle after separation.

1.5.3 Attitude Determination and Control

The attitude determination and control subsystem is completely passive and uses spin and a controlled tumble to maintain desired orientation. A spin will be induced by solar radiation pressure on the communications antennae. The antennae (created from venetian blind/tape measure material) are coated with highly reflective tape, Aluminum Flexible Optical Solar Reflector (FOSR), on one side and are black anodized on the other. Figure 1-5 is a representation of Spartnik from its side view. It also shows the antennae (the black anodized portion is displayed on the right side of the drawing and the highly reflective coating is displayed on the left). If the Sun vector is perpendicular into the page, the solar-radiation pressure differential between the reflective and the anodized sides will cause the satellite to rotate in a clockwise direction around the +Z axis.

Four soft iron rods are mounted perpendicular to the spacecraft's Z-axis as shown in Figure 1-6. These rods act against the induced spin caused by the antennae and prevent the spacecraft from spinning unboundedly. As the iron rods (hysteresis rods) rotate within Earth's magnetic field, the magnetic dipoles within the rods realign themselves to run in the same direction as Earth's magnetic field lines. This realignment generates eddy currents which generate a torque that counters the spin of the satellite. At each half turn, the current flow in the rods will reverse and cause the poles to switch. Flipping the poles and reversing the current creates heat within the rods. This heat is the result of the conversion of spin energy of the satellite. Thus as heat is radiated from the rods into space, the spin energy is dissipated.

The Spartnik camera is mounted on the +Z-face. The Spartnik attitude control system insures proper positioning for the acquisition of on-orbit photographs and keeps the spacecraft pointed in the desired direction. This is done by inducing a controlled tumble of the spacecraft's Z-axis. Eight bar magnets are placed inside the honeycomb shell (Fig 1-6) with the poles orientated parallel to the satellite's Z-axis. These magnets will interact with the magnetic field of Earth and align the Z-axis of the spacecraft with the local magnetic field lines.
Figure 1-7 shows the approximate attitude of the spacecraft for a quarter of a polar orbit.

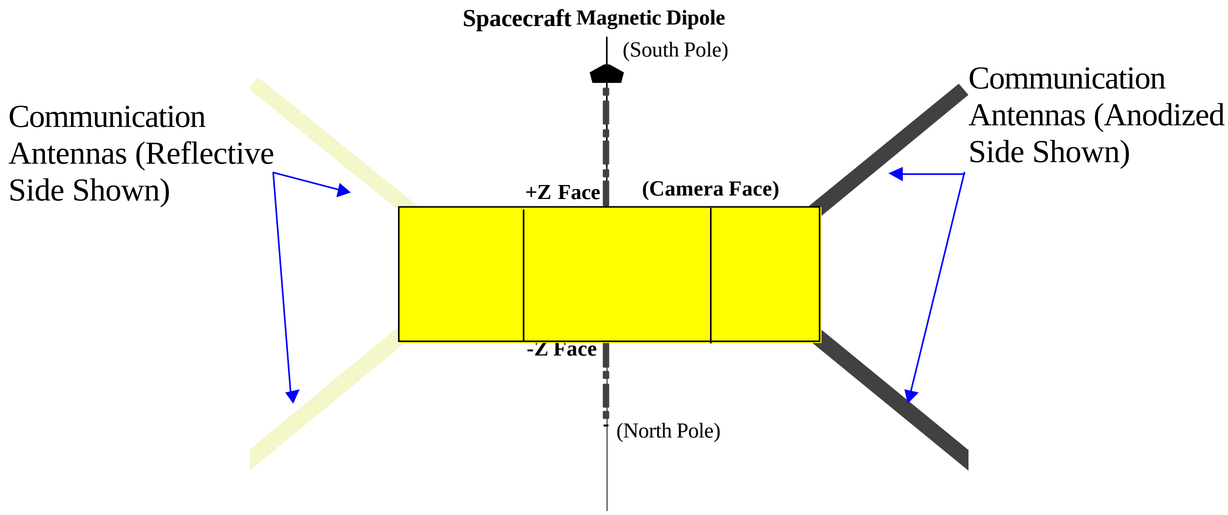


Figure 1-5 Solar Pressure Paddles

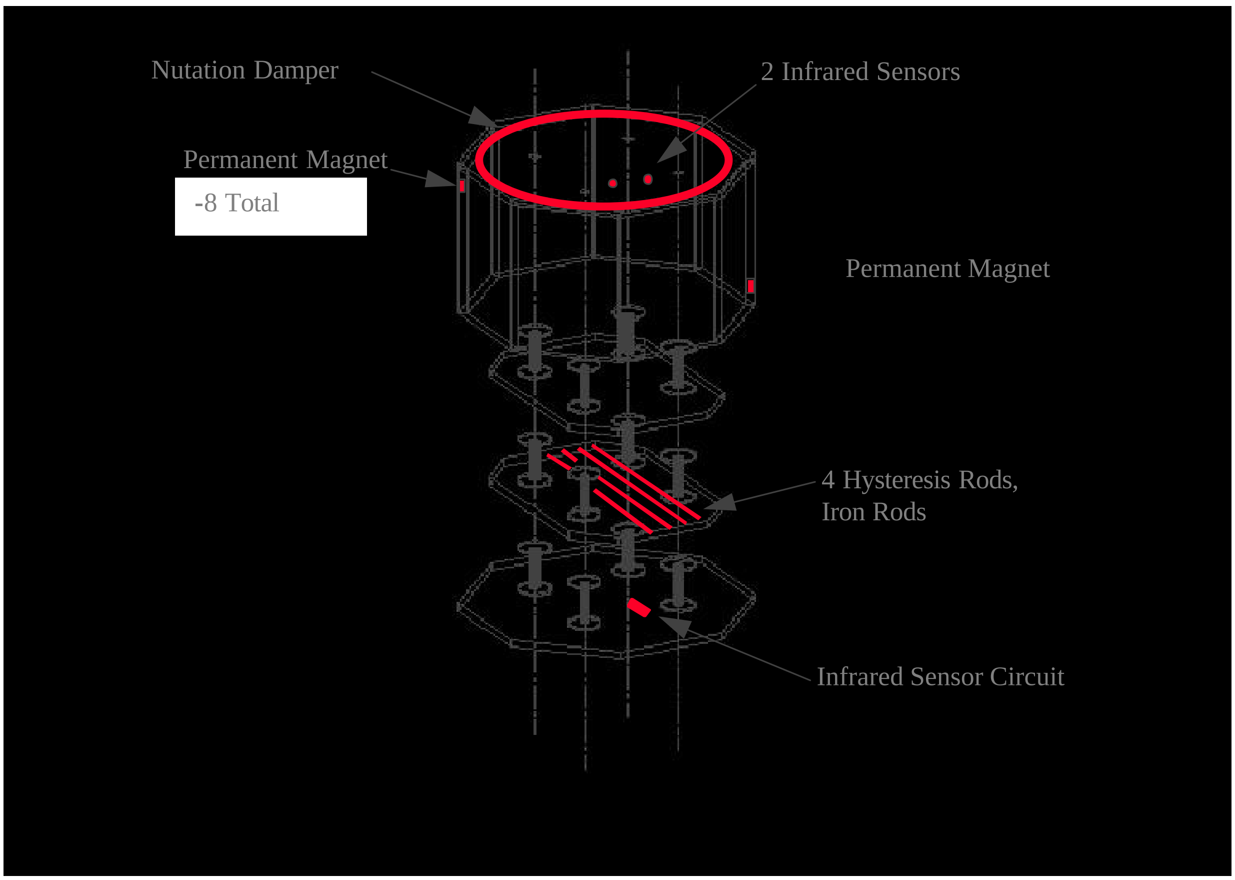


Figure 1-6 Attitude Determination and Control Hardware Locations

The controlled tumble insures that the camera lens will point toward the Earth in the Northern Hemisphere. This motion will also insure that the satellite camera points away from earth in the Southern Hemisphere.

To control nutation about the Z-axis of the spacecraft, a nutation damper hoop is mounted parallel to the xy-plane of the spacecraft. (This is seen in Figure 1-6). The nutation damper is filled with a predetermined amount of synthetic 10W40-weight grade oil. As the spacecraft rotates, the fluid lags behind. This action causes friction, which dampens the nutation of Spartnik until it reaches equilibrium with the satellite (spin about the Z-axis only). If the spacecraft starts to nutate in small angles, waves form on the surface of the fluid. The waves propagate around the hoop and dampen the small nutations. If the satellite experiences large nutations, the viscous fluid will act as a slug to dampen out the unwanted motion.

To verify the passive attitude control system, software was developed by students at SJSU to simulate the attitude dynamics while taking into account the Earth's magnetic field and attitude control hardware.

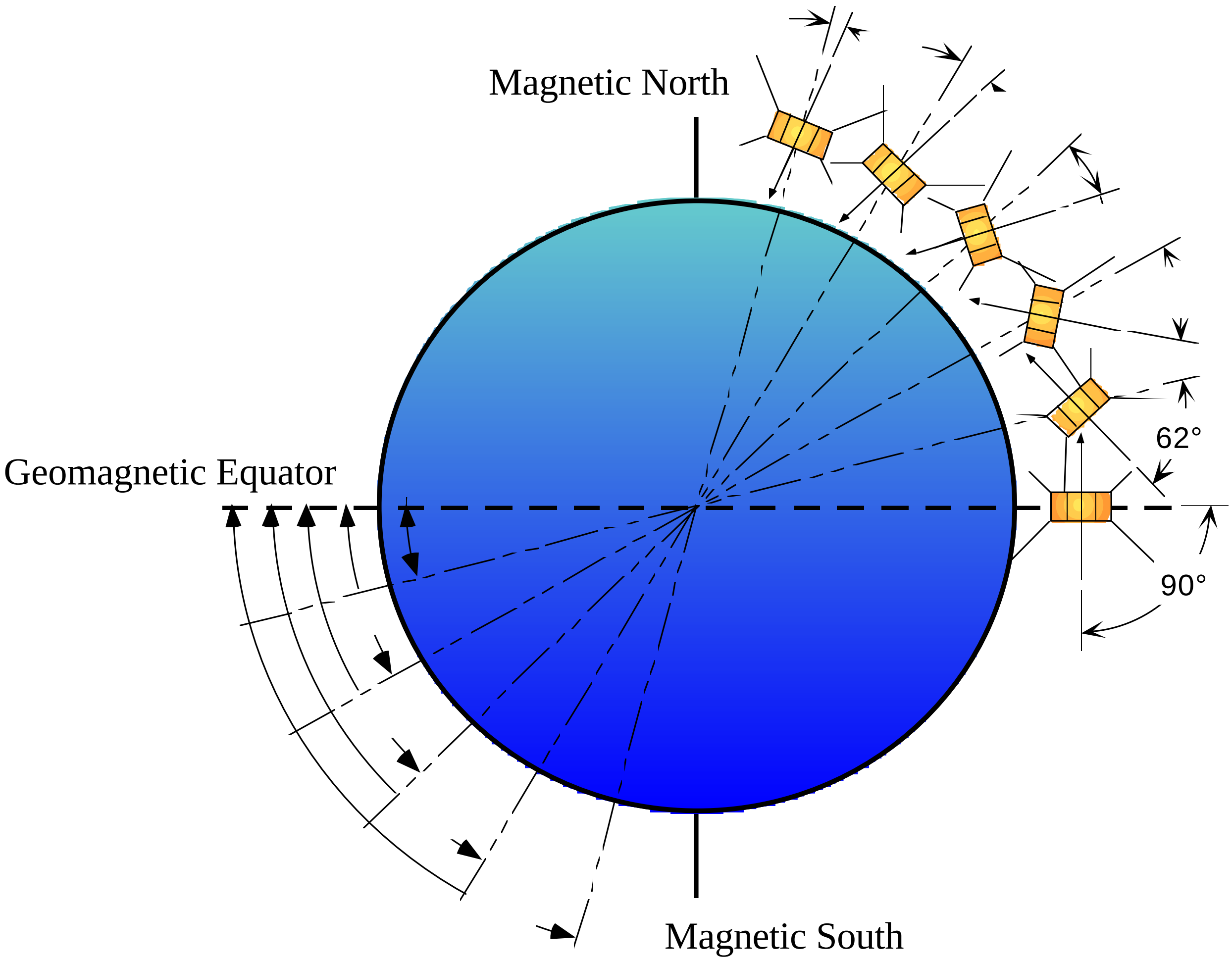


Figure 1-7 Spartnik Orientation for a Quarter Orbit

In order to determine the orientation of the spacecraft, measurements of current will be taken from the solar arrays of the satellite. The angle between the solar vector and the solar string is directly proportional to the current in the string. The onboard computer uses these readings to calculate the orientation of Spartnik relative to its local inertial coordinate system. This allows Spartnik's attitude to be known at all times. Further, the system provides a means of predicting the attitude of the spacecraft at any future time. This allows the team to determine the optimal time for on-orbit photographs of the Earth as well as the Moon and other targets.

To aid the current sensor calculations in determining camera position and spacecraft orientation, two infrared sensors are mounted equidistant on either side of the camera lens. The orientation of the Spartnik camera can then be determined from these values.

1.5.4 Power

The power system is a battery-dominated configuration, where the batteries determine the bus voltage. Originally, Eagle Picher donated the batteries to be used on Spartnik. The batteries that will be used are SAFT rechargeable commercial grade Nickel Cadmium (NiCd) cells. Telemetry will be recorded on the health and performance of the batteries while on orbit, and will help our team determine what kind of batteries should be used on future spacecraft.

A dual battery pack design is used to minimize the depth of discharge (DOD) to approximately 10%, thus increasing the number of possible cycles and operational life of the batteries. Figure 1-8 is a simplified wiring diagram depicting the power system configuration.

The power budget for the onboard systems is summarized in Table 1-1. The satellite will have various operational modes while different systems are in use. The power system is capable of handling all systems simultaneously for a limited time period.

The transponder produces a transient load with a maximum of 5W. This will allow for interference and corrupted signals from the satellite. The system will be able to boost its power to offset any anomalous interference.

The nominal bus voltage is 7.2 V from the battery packs. Each payload will have a Maxim™ step down DC-DC converter to bring the bus voltage to the required voltage of the system. The peak voltage of the batteries is 9.0 V DC. In order for the solar arrays to recharge the batteries to full capacity the array voltage needs to be higher than that of the batteries. The solar array design uses 16% efficient Gallium Arsenide 2x4 cm cells that were donated by Applied Solar Energy Corp. The solar arrays will provide a nominal voltage of 9.76 V and approximately 8 Watts, at end-of-life (2 years). This is acceptable for the recharging of the NiCd batteries, and supplying the required system load. The Solar Power Corporation has manufactured the solar arrays, and Lockheed Martin Missiles and Space (LMMS) has completed attaching them to the shell. Placement of arrays on the +Z and -Z faces has begun. Figure 1-9 shows the solar array surface layout for the side panels.

Table 1-1 System Power Requirements

Systems	Load Requirement (W)
CPU	1
Camera	.001 - 6.1
MMID	.1
Receiver	1

Transponder	0.5 - 5.0
Total	13.2 max.

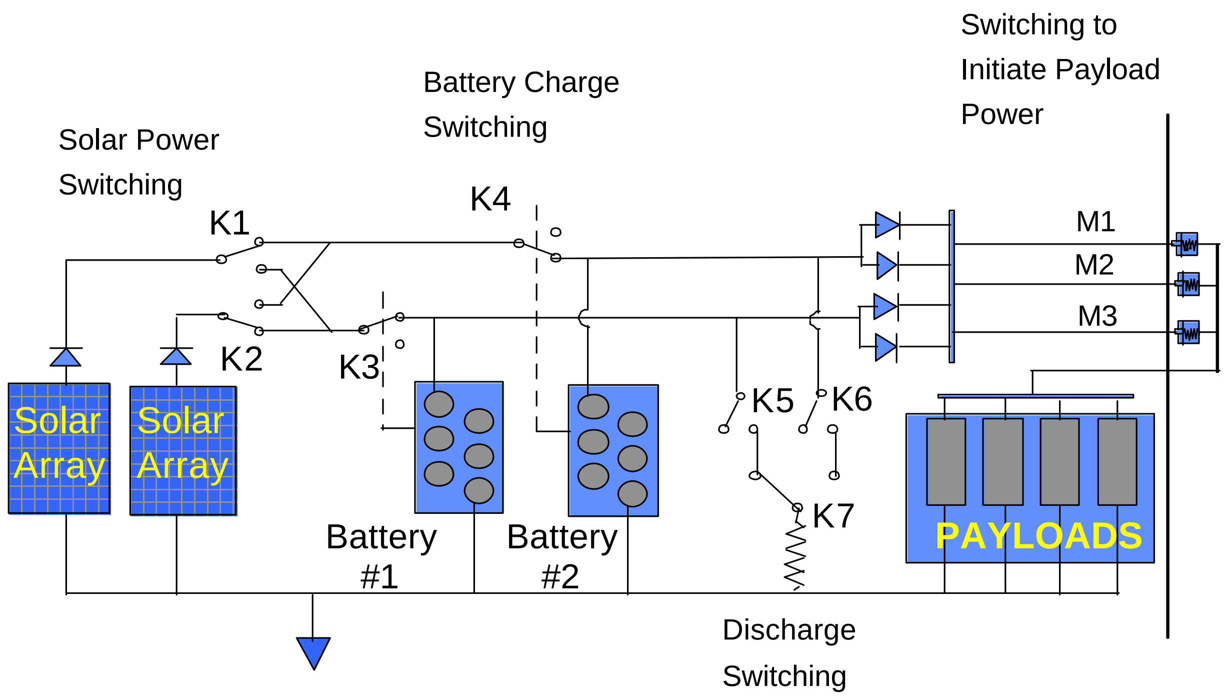


Figure 1-8 Power Wiring Configuration

To ensure that the batteries recharge at the proper rate (a rate slow enough to maximize life, without maintaining a continual state of charge) the solar arrays were split into two systems. Increasing the versatility as the power can have any of the following configurations: two solar arrays switched between the two battery packs; use of both arrays to recharge the batteries; splitting the arrays between the two packs; or removal of one or all arrays from the system until needed. The batteries are being tested by LMMS to determine the voltage-temperature (VT) curves. Based on these VT curves the charge controller will put the system into a state of charge at the proper time. The VT testing will be redone with the new batteries as well. To ensure maximum battery life, each battery pack will be reconditioned every two months.

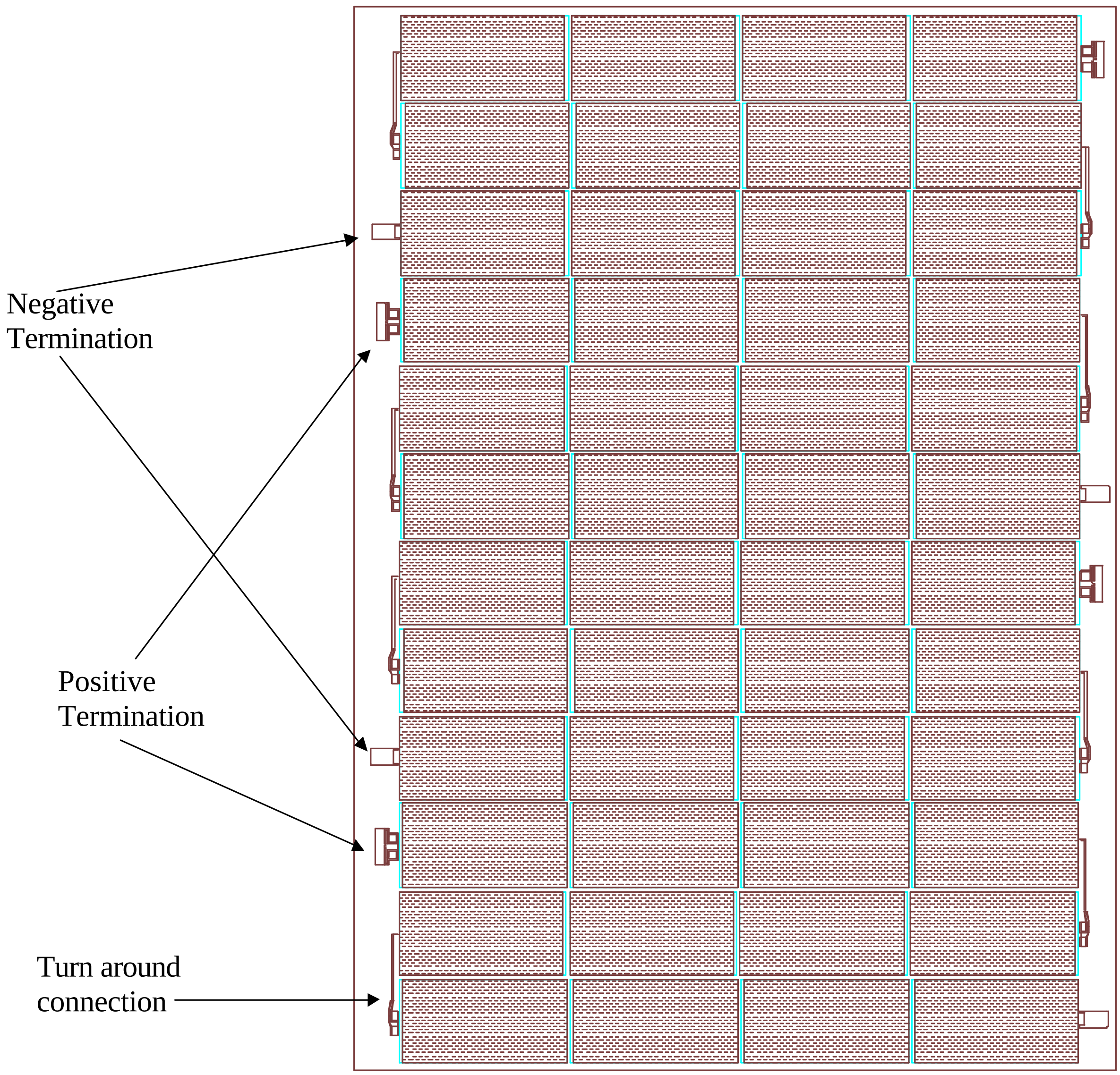


Figure 1-9 Solar Array Surface Layout of Side Panel

1.5.5 Payload

The Spartnik satellite project hopes to prove that an undergraduate senior design class can build a successful microsatellite, which may be used for space-based research by both universities and industry. To demonstrate this concept three payloads are placed onboard: a color digital camera, a MicroMeteroite Impact Detector (MMID) and a communications package. The digital camera and MMID are discussed in this section. (The communications package is described in section 1.5.10).

The first experimental payload is the color digital camera. A Kodak DC40 has four megabytes of Flash RAM for image storage and uses a charge-coupled device (CCD) developed by Eastman Kodak. Modifications to the camera in preparation for the harsh environment of space include the removal of the flash, the liquid crystal display, the plastic components and the placement of conformal coating over the electronics boards. Eastman Kodak Co. did all but the conformal coating.

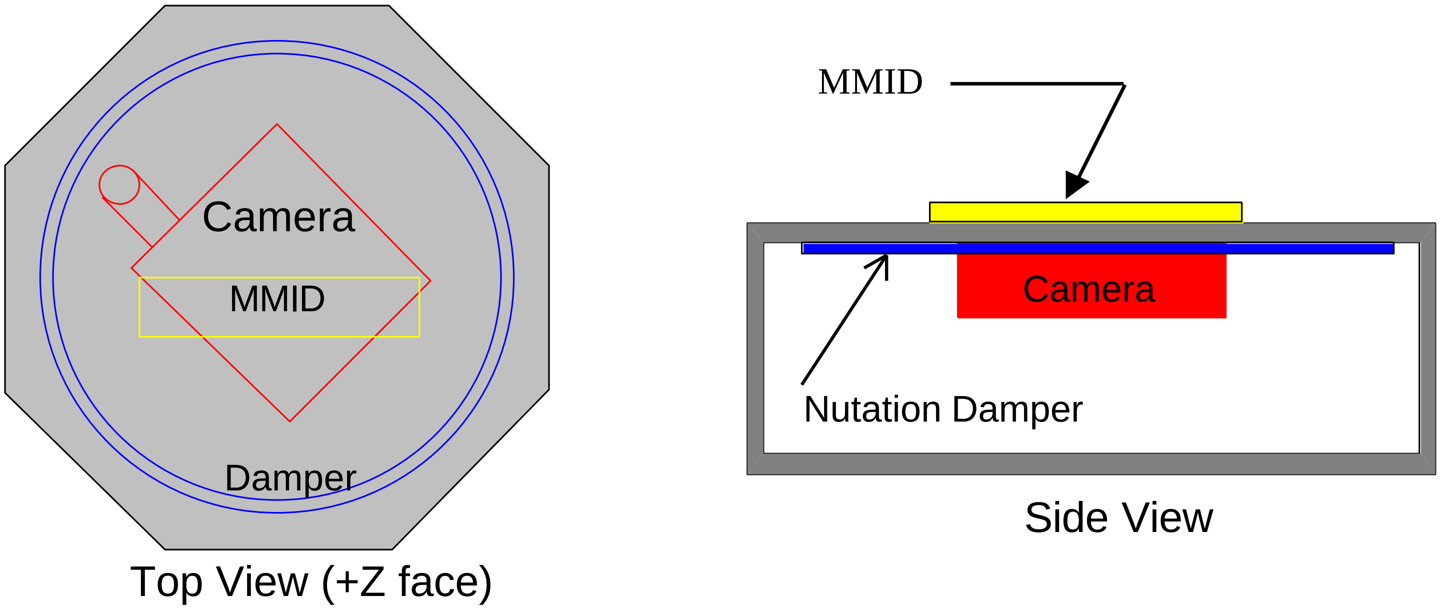


Figure 1-10 Camera and MMID

The camera is mounted to the inside top face of the satellite, as shown in Figure 1-10, and will be nadir pointing when over the Northern Hemisphere due to the nature of the attitude determination and control system. One concern for the camera is the effect of infrared radiation on the Flash RAM. It is unknown if repeated exposure to high radiation levels will adversely affect the quality of the digital images. Flying this camera not only demonstrates that surface imaging from a microsatellite can be done, but it will also qualify Flash RAM operation in the space environment.

The second payload is the MMID, which is similar to the one used on the Webersat satellite. Piezio-electric strips are used to serve this function. An impact on the piezio-electric sensor will cause a hardware interrupt to be generated on the onboard computer. The computer will maintain a count of the number and magnitude of impacts for a given duration of time.

For many reasons, micrometeorites are not evenly distributed about the earth. Since Webersat is in a particular orbit and Spartnik will be launched into a different orbit, the number of impacts will vary. The data collected from the MMID experiment can then be compared with the data from Webersat. Figure 1-10 shows the piezio-electric sensor mounted to the outside of the +Z face (yellow strip). The sensors are connected directly to the onboard computer.

1.5.6 Computer Hardware / Software

The onboard computer main processor, 80C188EC, is based on Intel 386 CMOS technology that has been tested to be reliable in high radiation environments. The main CPU has one 256k EPROM chip that will hold the boot-up code. When the computer completes the boot-up sequence, the operational program will be transferred to main memory. All sensors are routed through the analog to digital converter that consists of two A/D chips. This system allows for 128 sensors. There will be four megabytes of static ram (RAMDISK) available data storage. Because the operational code will be stored in main memory, mission control will have the ability to upload new code at anytime.

To ensure the reliability from radiation single event upsets and transient upsets several contingencies have been implemented. An Error Detection and Correction (EDAC) chip is implemented between the main memory and the processor and a checksum algorithm is used in the communications software.

The function of the onboard CPU is to operate, maintain and troubleshoot the onboard systems. This will be done through an autonomous software program. Housekeeping, telemetry and regular self-tests will be conducted and recorded to ensure optimum operating performance. The onboard computer will manage the communications payload (AX.25), the transfer of telemetry to the ground station, and the uplink of commands. Student ground personnel and/or autonomous control through pre-programmed commands and automatic tracking will maintain this function.

The system design uses no more than one watt of power and a minimal printed circuit board size. The uplink capability is 9,600 BPS and the downlink capability (power permitting) is 57,600 BPS.

1.5.7 Thermal

Many microsatellite and amateur satellite projects of the past have regarded thermal control as an unimportant topic. This is due to the lack of data available and a difference of opinion between microsatellite builders and industry consultants. The Spartnik team comprises of a separate Thermal Control Systems (TCS) team to eliminate the microsatellite thermal operations uncertainty.

Calculations have been performed to characterize Spartnik's orbital thermal environment loading for a range of possible mission orbits. Operating temperatures were then calculated to estimate the thermal properties of the components onboard the spacecraft. This information was used to evaluate the thermal functionality of Spartnik's design.

Surveys of component temperature ranges and maximization of satellite life were considered in the thermal system performance evaluation. Using manufacturer's specifications, the battery packs were found to have the narrowest thermal operational range. For this reason the batteries are the driving factor in Spartnik's thermal design. The batteries restrict Spartnik's thermal target range from 0°C to 10°C for optimal efficiency; however, the batteries will operate between -5°C to 25°C. Due to this constraint, all thermal control is required to meet this temperature range. This is done using passive thermal control techniques.

Spartnik can be assumed isothermal for first order calculations. Subsequent thermal design modifications have been made to better link components together in support of this simplifying assumption. For example, aluminum was required for most structural components for thermal conductivity benefits. Joint fillers are used to minimize thermal resistance between components on main thermal conduction paths. The through-posts, which are essential to spacecraft integration and structural integrity, are one such example. Solid aluminum blocks are implemented to provide adequate thermal mass to "coast" battery temperatures through transient thermal loads. Such thermal loads include the Sun/shadow portions of orbits.

Studies of thermal system performance have been performed with several identified design parameters. These include surface finish and orbit beta angles. Radiators of calculated size and FOSR material are placed on the top (+Z) and bottom (-Z) panels. These components are used to balance Spartnik with its final orbital thermal environment. During operation, the array of temperature sensors mounted throughout the spacecraft will collect battery and other thermal telemetry. Additionally, TCS will implement Pseudo Active Thermal Control System (PATCS) software to provide the computer with thermally intelligent operational code.

TCS is currently engaged in final verification, detailing, and testing of Spartnik's design. The subsystem is using the industry thermal modeling software SINDA (Fig. 1-11) as well as authoring the PATCS software. TCS is expanding its review to all possible environments that Spartnik will encounter, from manufacturing to reentry.

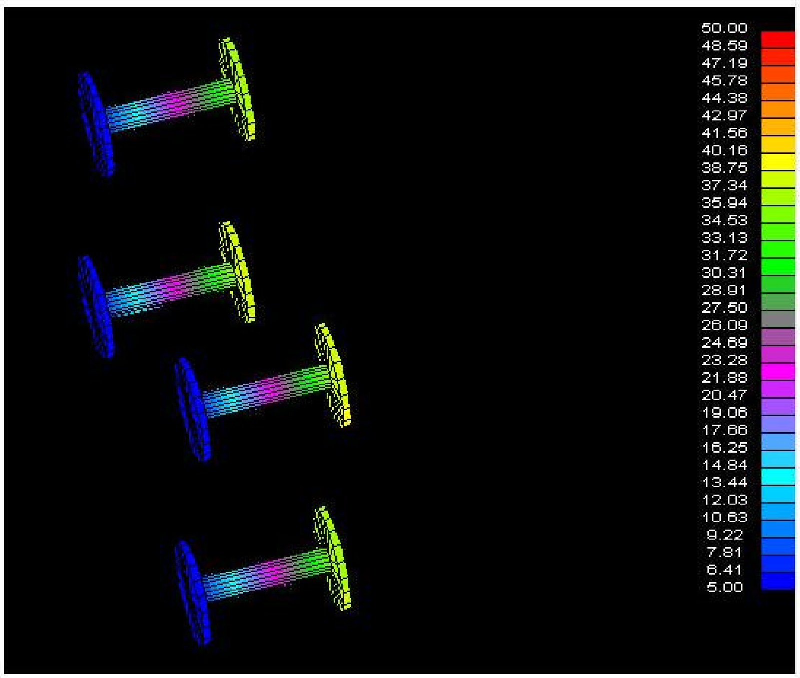


Fig. 1-11 Simulated Heat Load on Spartnik's Spacers

1.5.8 Communications

The onboard electronics require low power and can operate at a variety of frequencies. The system operates on the principle of state of the art direct synthesis. The components are donations from Philips Semiconductors and have been test proven in cellular telephones. Because the system is capable of operation under a wide band of frequency, Spartnik can avoid communications interference with other spacecraft. Spartnik's communication frequency will adhere to the recognized amateur bands of 144 MHz for up-link and 435 MHz for downlink.

The communication electronics is a standard two-layer circuit board measuring approximately 3 inches in length by 3 inches in width and will be electronically shielded from noise. It is located on the bottom panel of the satellite and is connected to the four uplink and four downlink antennas. The up-link and downlink antennae are staggered on the top (+Z) and bottom (-Z) faces of Spartnik. These placements can be seen in Figure 1-12. Both sets of antennae are made of spring steel material similar to that found in venetian blinds. The orientation of the antennae with respect to the ground station-receiving antenna is not pertinent to maintain a communication link. This is due to the proper placement of the spacecraft's antennae.

To simplify the licensing of the satellite, amateur radio bands will be used. This allows most licensed amateur radio operators access to Spartnik. Unlike most amateur satellites, which have standard data rates of 1200 baud, Spartnik will employ high speed downlink data transmission of up to 57.6 kbaud. This will insure that all telemetry data be received by the ground station in a single ground pass.

The packet protocol is currently under development. This routine will use the AX.25 communications software standards. When completed, the packet routine and software will become public domain.

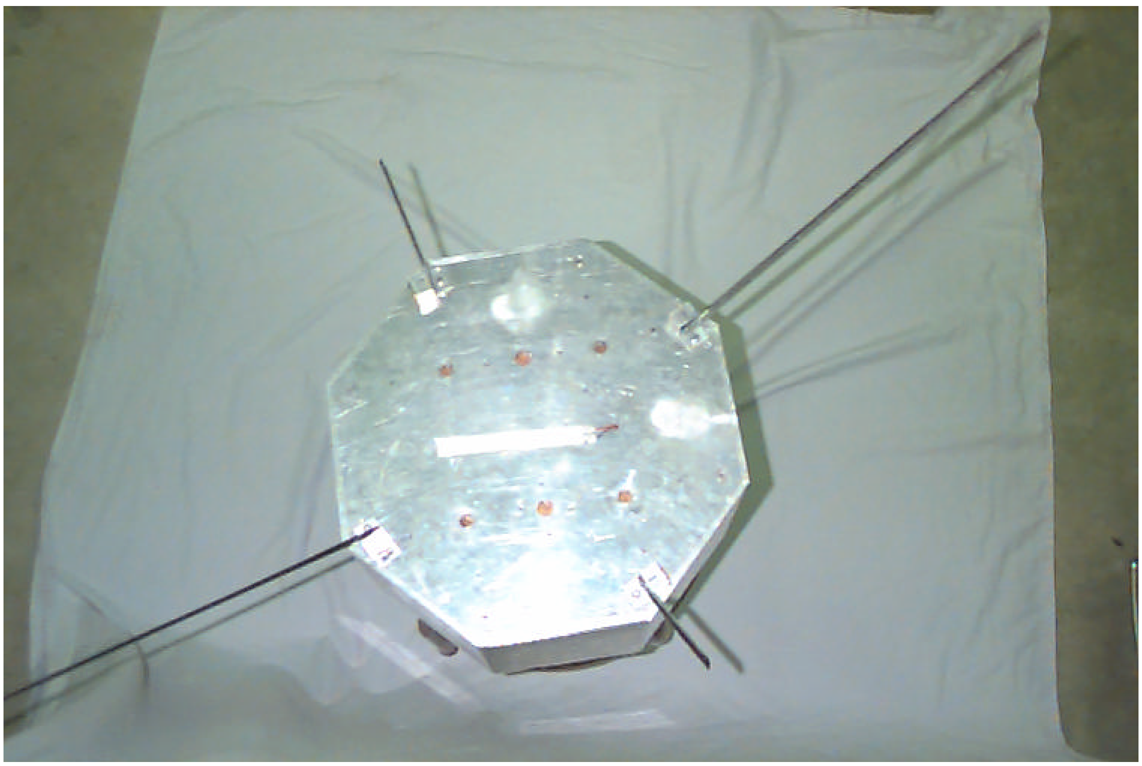


Fig. 1-12 Communication Antennas Placement

The commanding ground station is located in the San José State University Engineering Building and will be operated by HAM licensed students. Currently the ground station and antenna configuration are under development. These components are expected operational by May 2000.

1.5.9 Safety Documentation

The safety subsystem is relatively new and was initiated during the '98-'99 school year. Spartnik team members, as well as the advisor, met with Lockheed Martin engineers to discuss Spartnik's safety documentation. It was determined that such a document will be crucial to the successful completion and launch of the spacecraft. Because this practice is standard for all satellite companies, the document will serve as a tool for success as well as provide invaluable learning and experience. The goal of this document will be to prove to both the launch vehicle company and the primary payload investor that Spartnik is safe, will not cause damage to either the rocket or the primary satellite, and will meet or exceed all requirement standards.

Every subsystem is currently being analyzed and reviewed with painstaking detail. Every possible "worst case scenario" will be presented and means for mitigation of each hazard explained within the safety document. The rough draft will be available in May of 2000. The final draft will be available in August of 2000.

1.6 Conclusion

At this time the Spartnik flight shell (including top and bottom panels) is manufactured and assembled. Lockheed Martin Missiles and Space has installed the spacecraft's solar arrays. An aluminum box has been manufactured for the safe transportation of Spartnik. The flight shell will be brought to SJSU where it will be placed into the Spartnik cleanroom for final testing and integration. Design work is currently being finalized for several components of the satellite including the computer base plate and the periscope. Upon completion of the design process and integration procedures, all spacecraft components will be stringently tested and final integration and testing of Spartnik will be begin. Wiring diagrams of the electrical circuit boards have been finalized. The first revision of the printed circuit board is complete. Environmental testing on the satellite (vibration, shake and shock tests) has been completed. These tests proved that the structure is robust and will withstand the intense loads of transport and operation. An ANSYS and Pro E model are being constructed to verify these results. Manufacturing of the flight model began in August of 1996 and will be completed in the summer of 2000. Software programming of the onboard computer is ongoing and will be completed by spring 2000. The Spartnik team has intensified their search for a donated launch. The team seeks a launch within the time frame of fall 2000 and beyond.

C:/Spartnik Members/FDR's for 98-99/EXECSUM.doc
Spartnik Team-Use Only Section

1-1 Orbit Decay and Selection

Figure (1-1) represents an orbit decay and lifetime analysis for Spartnik vs starting altitude and year of Epoch. The analysis was for Cd=2, i=40, e=0.0018, a varying with starting altitude.

Lifetime 4.0 software was used in the determination of the results below. Other tests were performed to study varying Cd and ballistic coefficient as well as inclination effects on Spartnik lifetime (located in Analysis section listed below)

Location of files used:

Lifetime 4.0:	MAE/Europa/program files/lifetime_ver4/life4 (Runs in DOS)
Analysis:	MAE/Europa/Greg/Orbit Decay/Decay Statistics and Analysis
Documentation:	MAE/CALLSTO/Spartnik/Subsystems/LVnO/Orbit Decay Analysis II

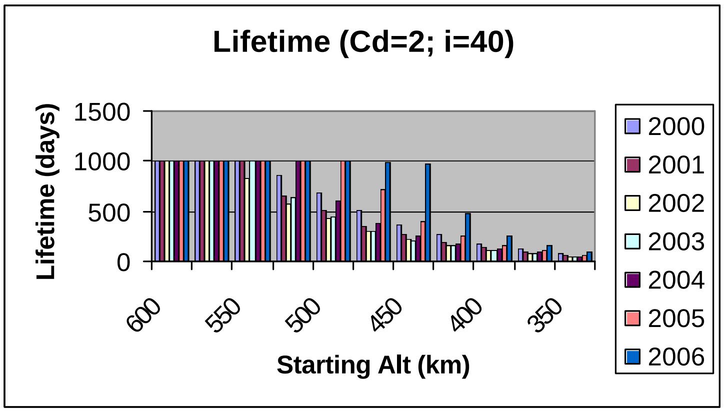


Figure 1-1: Orbital Lifetime vs. Starting altitude and year of Epoch