CO^3 Hermes CubeSat FCC Experimental License Application Narrative

SYS116.03

Revision	**Date**	**Authored By**	**Description**
Initial Release	3-2-2008	Philip Zanin Holtzman	Additional Information for FCC Experimental Application
Revision 1	11-20-2008	David A. Ferguson	Revision and additional info for FCC Experimental reapplication
Revision 2	11-24-08	David A. Ferguson	Ground Station Update and Aircraft Collision Mitigation Added
Revision 3	12-03-08	David A. Ferguson	Ground Station Update and Location Change

Question 6: The proposed radio station will be essential to a research project

The Colorado Space Grant Consortium, in affiliation with the University of Colorado at Boulder, is currently developing a single-unit (1U) CubeSat named Hermes. It follows the dimension and mass requirements as outlined by California Polytechnic Institute in the CubeSat Design Specification (Rev. 10). Hermes will be the University of Colorado's first fully developed CubeSat.

Outlined in more detail below, the mission goals and objectives of the Hermes project are the creation of an extensible bus capable of supporting future missions and payloads, the on-orbit testing and verification of a high-speed communication system, the collection and characterization of external and internal environmental data, and the provision of hands-on engineering experience to undergraduate students.

The estimated satellite hardware cost is US$10,600. This includes the expense of the physical hardware as well as hardware development and testing costs. Launch costs and labor costs are provided from other sources are not accounted for in the US$10,600 budget for the project. As a result of the limited budget for the project, a large emphasis has been placed on the utilization of commercial off-the-shelf (COTS) components. While not designed for space applications, COTS components offer significant monetary savings and if implemented properly, can function successfully in spacecraft.

Hermes has passed the Critical Design Review (CDR) phase and the team is finishing development of flight hardware. Individual subsystem testing is well under way and intersystem Flight Hardware testing has begun on many fronts. The hardware completion date of the project is set at December 12th, 2008, at which point the satellite hardware will be ready followed by the completion of software soon therafter.

After analyzing possible launch opportunities, the following mission parameters were chosen as the optimal flight conditions. Hermes is designed for a nearly circular, 640km orbit with an inclination of 98 degrees; these orbital conditions are based upon the launch profile of a potential launch opportunity from Vandenberg Air Force base. Hermes is capable of operating at any altitude from 400km to 800km and virtually any inclination greater than 40 degrees.

From a program perspective, the most important mission goal for Hermes is the development and successful implementation of an easily extensible satellite bus that will be used on future CubeSat missions. This means that not only will the design succeed for this mission, but that it can easily be modified for larger or slightly different applications for future missions. This will allow future projects to focus on more complex scientific endeavors without having to reengineer many of the subsystems.

The second mission goal is the implementation and characterization of a high data-rate CubeSat-scale communication system. This communication system operates at 2.4GHz in the S-band frequencies and has been estimated to produce about 50 times the data rate of many traditional UHF/VHF communications systems. The intent is to demonstrate that this system is capable of replacing a standard UHF/VHF system on a CubeSat, providing higher data rates and allowing more mass, volume, and power for science missions. A handful of other universities are utilizing the same system in their satellites and knowledge gained from the Hermes mission will be shared

openly with the CubeSat and small satellite communities for further advancement of the scientific community.
A third mission goal is the collection of environmental and system performance data. This is accomplished through the use of a 3-axis magnetometer for the measurement of the Earth's magnetic field, temperature sensors throughout the satellite for measuring the effectiveness of the thermal system, and current sensors within the power system for characterizing power system efficiencies and solar input power.

Finally, as with any student-run university program, this project has a large emphasis on education. The project has been managed and developed by undergraduate engineering students from multiple engineering disciplines including: computer science, electrical, electrical and computer, mechanical, and aerospace. Mentoring and direction is provided by faculty and industry advisors allowing a large degree of freedom to student-based project development. It is the intent of Space Grant to continue this type of project dynamic where students are in charge of their project and seek outside help when necessary.

Question 6: Scientific Merit-Current facilities are inadequate for research.

In support of the third mission goal specified above, Hermes will be carrying a suite of sensors to record the environment of low-earth orbital flight. Current and voltage sensors will monitor and record the input power into the satellite via the solar panels. Other voltage and current sensors will be located throughout the satellite's power distribution system to monitor the efficiencies of the power subsystem from collection to distribution. These sensors will also show the degradation of the solar panels from beginning of life to end of life and help characterize what to expect from solar cells in on-orbit conditions.

Magnetometer readings will also be taken to determine the spacecraft attitude relative to the earth's magnetic field. Thermal data will be collected through temperature sensors distributed throughout the satellite to validate the spacecraft's thermal design and verify that temperatures remain within specified temperature ranges. S-Band (HSCOM) and UHF (PCOM) communication system performance data will be collected through analysis following communication passes. Currently there are no S-Band facilities available for use with this project as necessary. The approval of this station will allow for the rapid advancement of satellite payloads in the Space Grant community, specifically Colorado Space Grant institutions. In addition, detailed analysis of onboard data storage efficiency as well as the frequency of dropped data packets will also be evaluated and reported to the scientific community.

Upon collection of the data at the proposed ground station in Boulder, Colorado it will travel via TCP-IP to a system at the University of Colorado at Boulder. The data stream will then be analyzed via GUI packages created with the software package InControl.

The magnetometer data will be used to model the satellite's attitude and response to torques in orbit. This will help verify the passive attitude control subsystem's performance. The temperature data collected will be used to verify the thermal model used for the satellite as well as validate the thermal system.

Sensor data is also used in real-time to autonomously monitor the system performance and take emergency action in case of off-nominal behavior. One example of this scenario is if the Command and Data Handling system detects a current surge on a sensor, it can immediately shut down that part of the circuit to prevent permanent damage to the spacecraft.

A large portion of the data collected on this mission will be made publicly available in accordance with amateur radio regulations. Some interesting flight data and analysis will be tabulated on the Space Grant website: (http://spacegrant.colorado.edu/co3sat/) and subsequently, will be provided to the CubeSat community.

Question 6: Show the communication facilities requested are necessary for the project

For the S-band communications system to operate, a link margin of 10 dB is required as specified by the manufacturer of the MHX 2420 modem. In order to obtain this amount of link margin, it is necessary to both transmit at 1W on both the satellite and ground station sides of the link, as well as use a high-gain antenna on the ground. With a 1W output, any dish gain of 6 dB or greater puts the Effective Isotropic Radiated Power (EIRP) at over 36 dBi, violating FCC regulations, and thus necessitating an Experimental Application.

The CubeSat ground station is a 3 meter dish located in Boulder, Colorado, (40.136335,-105.212602) converted via NAD 83 to **40.225833N Latitude and 105.357222W Longitude**. The dish has a gain of 35bB and operates with a modem capable of transmitting at 1W. The dish has an erp of 34.3DBW and is mounted on a remote mount that is capable of swiveling 360 degrees azimuth and reaching an elevation range of 180 degrees. The station has a 5-meter obstruction clearance in all directions.

The proposed station, located in Boulder, Colorado at 40.225833N Latitude and 105.357222W Longitude shows minimal safety hazard to any nearby operating aircraft. The station does not exceed 5 m in height, and is fixed. Although the dish has the ability to swivel 360 degrees and incline up to 180 degrees, it has a clearance of 5 m on all sides. The tallest nearby object is the Table Mountain at an elevation of 1707 m (MSL). The proposed station sits atop a hill 3 km to the east of the mesa at a lower elevation (1585m MSL).

The closest nearby frequent operation of aircraft is Vance Brand airport, ICAO: KLMO, which is approximately 5 km to the east of the proposed radio station. KLMO has frequent general aviation activity coupled with skydiving operations, however commercial flight activity at KLMO is nearly nonexistent.

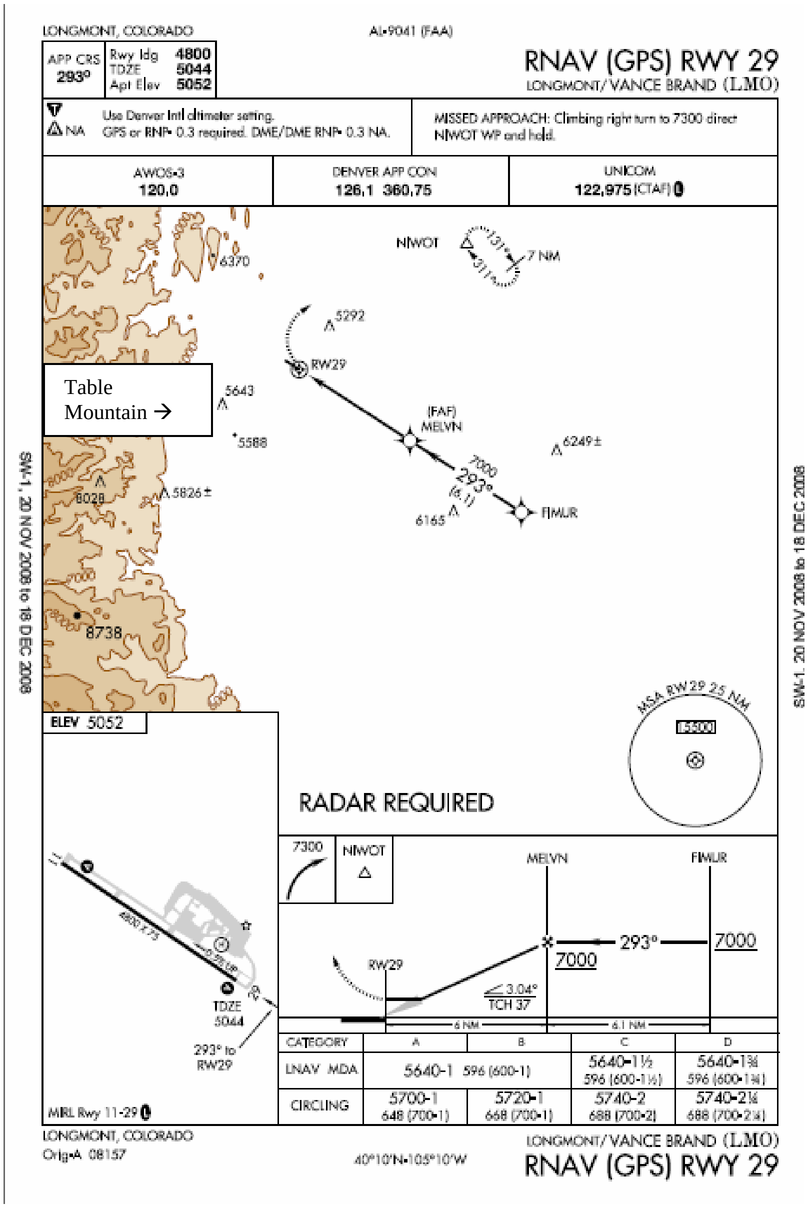

Figure 1: RNAV GPS Approach Procedure KLMO RWY 29

The majority of aircraft operating at KLMO follow the right-hand traffic pattern for runway 29. In addition, the traffic pattern is at 7000ft MSL, which is 1500 ft AGL. The proposed ground station is at 5400 ft MSL, which provides significant vertical clearance from operating aircraft. Furthermore, the ground station is not the tallest object of proximity of the airport as table mesa is located in figure 2 at 5643 ft MSL.

Question 7: Describe in Detail the Purpose of Experiment

CO^3 Hermes: Communications

The primary communications (PCOM) system, operating with the AX.25 protocol at 435MHz in the UHF frequency range, uses a COTS Yaesu VX-3R transceiver and an Atmega AVR microcontroller based terminal node controller (TNC) developed in-house. Frequency coordination with the International Amateur Radio Union (IARU) was obtained in July of 2007, securing a specific frequency for Hermes use. To comply with FCC regulations against interfering transmissions, the system will pause occasionally during any communications in order to receive a shutdown command from a ground station.

The High Speed communications (HSCOM) system, operating in the S-band frequency range at 2.4GHz, utilizes the MicroHard MHX2420 modem. One modem will be onboard the satellite and an identical modem will be a part of the ground station. The MHX2420 utilizes frequency-hopping to achieve data transmission rates over 50kbaud.

Both communications subsystems have deployable, quarter wave monopole antennas and transmit at 1 Watt of power.

Space Grant has developed a Ground Tracking station with two Yagi antennas at the University of Colorado for UHF and VHF systems. A separate team is currently in charge of verifying the tracking abilities of the proposed ground station at Pueblo to ensure its accuracy and precision.

The PCOM system has completed full scale testing of the TNC, with antenna testing to be completed. The antenna modeling has been completed, lacking only the verification of antenna testing to conclude its complete validity.

The HSCOM system has undergone extensive antenna modeling as well as preliminary antenna testing. The modem has flown twice on high altitude balloon missions with encouraging results, leading to a good understanding of the operation modes of the modem.

A ground software team is also currently at work to ensure the success of the ground station and data flow from satellite to usable format on the ground. For example, one focus of ground software is the creation of the software required for the attitude determination algorithm with magnetometer and solar panel current sensor data. With the assistance of InControl, a software client, this is made possible via the extensive use of GUI (Graphic User Interfaces) for the rapid analysis of streaming data.

Question 14: Denied License Narrative

The application denoted 0121-EX-PL-2008 was dismissed without prejudice for failure to submit an orbital debris study. In compliance with the request an orbital debris analysis, a separate document has been prepared.