HASP Student Payload Application for 2008

Payload Title: Magnetic Field Investigation of Luna (MIL)		
Payload Class: (circle one) Small Large	Institution: Virginia Tech	Submit Date: 03/21/08

Project Abstract

Virginia Tech's Magnetic Field Investigation of Luna (MIL) Design Team will determine if photogrammetry is a feasible low cost alternative to other topographical mapping methods for the lunar surface. This will be accomplished by flying five cameras in an enclosed "camera pack" at the end of a fixed mechanical boom. The system will map the topography of the Earth in the same manner as a lunar spacecraft in orbit. The images will be processed post-flight by using photogrammetric analysis to create a three-dimensional map of the surface below the balloon's flight path. The Virginia Tech team plans to fly a data logger and power supply to autonomously collect data from a variety of sensors including: a magnetometer, a GPS receiver, an Inertial Measurement Unit (IMU), and five Canon A520 cameras.

Team Name: Magnetic Field Investigation of Luna (MIL) Design Team		Team or Project Website:
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Project Goals and Objectives

The balloon mission will test the feasibility of including a photogrammetric sensing system on the MIL spacecraft. This will be done by flying a photogrammetry experiment on a high altitude balloon and comparing the results with the known surface features of the Earth. The following outline shows the overall project goals and objectives for the MIL design team:

- Design payload for balloon mission to complement the lunar mission through the following designs:
  - Autonomous imaging system
  - Thermal control system
  - Autonomous power system
  - Electrical control system
  - Structural components to support payload
  - Autonomous data logging system
  - Post-flight attitude algorithms.
- Meet mass, power, and financial budgetary constraints.
- Gain experience through the following:
  - Design
  - Building
  - Operation
  - NASA mission planning process
  - Post-process of data
  - Team building
  - Leadership
  - Lessons Learned
  - Software design
- Document project appropriately for future reference.

Scientific Goals

The scientific goals for the MIL balloon mission are driven by the need to incorporate an inexpensive imaging system on the MIL lunar design and to use attitude information as a way of simplifying the processing of data. These goals are as follows:

- Validate photogrammetry for use in the lunar mission.
- Use information from magnetometer and IMU to produce balloon attitude information.
- Use photogrammetry to create a 3-D map of the Earth's surface.
- Demonstrate low-cost topographic mapping feasibility.

Minimum Criteria for Success

The minimum criteria for the MIL balloon mission to be a success are as follows:

- Design meets NASA requirements such as the Final Mission Plan, Design Review, Mission Readiness Review, and integration.
- The suitcase and payload are delivered within budget constraints.
- The entire system is powered on.
- The payload is recovered and data is acquired on the ground post-flight.

- Data is autonomously acquired in flight from one data logger channel.
- Data is autonomously acquired in flight from all non-redundant data logger channels.
- Data acquired leads to creation of 2-D map of Earth surface.
- Data acquired leads to proof of 3-D photogrammetry feasibility.
- Attitude results are accurate to less than 90 degrees in yaw.
- Photogrammetry data matches known topography data within an elevation of 500 ft.
- Photogrammetric analysis demonstrates feasibility of photogrammetry sensing for use on a lunar satellite.

The mission will be considered comprehensively successful if all the above Minimum Criteria for Success are met. The estimated minimum balloon ascent time required to demonstrate photogrammetry is feasible (Criteria 7 and 8 of the above Minimum Criteria for Success) is 45 minutes; this ascent time is entirely dependent upon wind speed and the travel rate of the balloon itself. This estimate is based upon Virginia Tech's ARTEMIS flight ascent and travel rate, as well as the required 30 degrees of separation between successive photos. ARTEMIS was flown as a piggyback payload on HASP in 2007.

Principle of Operation - Photogrammetry

Photogrammetry is a method of discerning three-dimensional physical distances from multiple images of the same area. The images must be taken from various points of view to enable better mathematical linking of common points. If the images are taken from perspectives differing more than 30 degrees, the images can be successfully linked using a computer program. The cameras used for photogrammetry must be calibrated prior to use. Through calibration, the exact focal lengths and lens distortions may be determined for input into the computer program.

The mechanics behind photogrammetry have been used for remote sensing in the past. A low-cost, student-designed remote sensing system based on photogrammetry has great potential. Testing this system on a high altitude balloon will help determine the feasibility of placing this system on a spacecraft.

Thermal Control System

The components in the MIL balloon experiment must stay within operating temperature ranges through the entire duration of the mission. An initial thermal analysis was used to model how the temperature varies within the suitcase throughout the flight. This model, along with ARTEMIS data, provides a baseline for the design of system thermal control. Thermal control options are then compared and a final thermal testing scheme is developed. This section will detail the temperature ranges of the MIL components the MIL thermal control.

Component Operational Temperature Limits

These are the ranges of temperature in which these devices will remain operational.

Instrument	**Min Operating Degrees**	**Max Operating Degrees**
IMU	-40	85
GPS	-40	85
Cameras	0	40
SD Memory Cards	-25	85
SGVM	-40	50
Data Loggers	0	60
Batteries	-20	60

The thermal control scheme for the MIL mission has been determined based on the data retrieved from the ARTEMIS and Halo balloon missions. These missions show that using only thermal insulation will keep the components in their operating temperature ranges. Thermofoil heaters may be used to heat the cameras if thermal testing shows that insulation alone will not retain an adequate amount of heat. These extremely small and light-weight heaters can provide a large amount of heat to any needed sensor. Connecting them to a DC voltage will create a constant source of heat, and they can be made with an integrated temperature sensor so as to only turn on when a certain temperature is reached. However, they require a large amount of power even though they will be on for a small number of short cycles. If their use is found to be necessary, they will be used at very low power levels for as short a time as possible to minimize their power consumption.

Payload Specification and Requirements

Submitted by:

Jessica Thompson, NASA Wallops Flight Facility
And
Virginia Tech's Magnetic Field Investigation of Luna Design Team

March 21, 2008

Payload Description:

The basis of this experiment is to determine if photogrammetry is a feasible low cost alternative to other topographical mapping methods for the lunar surface. The Virginia Tech team plans to fly a data logger and power supply to autonomously collect data from a variety of sensors including: a magnetometer, a GPS receiver, and an Inertial Measurement Unit (IMU). Five Canon A520 cameras will be flown in an enclosed "camera pack" at the end of a fixed mechanical boom. All remaining components will be enclosed in a suitcase on the gondola. The GPS receiver will be used to track the motion of the system and provide ground coordinates for the corresponding magnetometer data. The IMU will be used to measure the gondola's rotation rate during the balloon flight. All data will be analyzed post-flight. Integration will focus on positioning the fixed boom such that it does not interfere with ground equipment during launch activities.

Payload Specification:

Suitcase dimensions: 18.5 in x 13.4 in x 6.7 in
Mechanical Boom dimensions: 2 in. box beam with ¼ in. thickness, 5 ft length
Weight: 50 lbs maximum
Power: None (autonomous -- lithium batteries)
Telemetry: None (data collection will be autonomous)
Suitcase Orientation: Horizontal with handle to the side

Payload Orientation and Location:

The MIL boom is restricted in its attachment to the gondola. The boom specifications are as follows:

- Boom must be mounted in three locations.
- Bottom edge of boom must be secured no more than 12 inches from the bottom of the gondola.
- Camera housing must be at least 6 inches from the bottom of the gondola.
- Boom must be oriented to be 90° from vertical plane of gondola.
- Three feet of the boom's length must hang freely from the edge of the gondola.

List of contents:

Contained in suitcase:

Persistor CommLogger – CF2 Data logger
DG14 GPS receiver
MotionPak II Inertial Measurement Unit
Battery packs (2)
Science Grade Vector Field Magnetometer Electronics Box

Outside suitcase:

- Fixed mechanical boom
- Camera housing
- Canon A520 cameras (5)
- GPS antenna
- Science Grade Vector Field Magnetometer Sensor Unit

Magnetometer:

Range: ±65536 nT
Dimensions: Sensor unit: 54 x 46 x 33 mm; Electronics box: 106 x 148 x 40 mm
Mass: 1.658 kg

Inertial Measurement Unit:

Range: Rate sensor: ±75°/sec; Accelerometer: ±3g
Dimensions: 4.58 x 4.43 x 5.03 in.
Mass: 1.26 kg

GPS Receiver/Antenna:

Mass: Receiver: 0.12 kg; Antenna: 0.087 kg
Dimensions: 107.5 x 57 mm

Cameras:

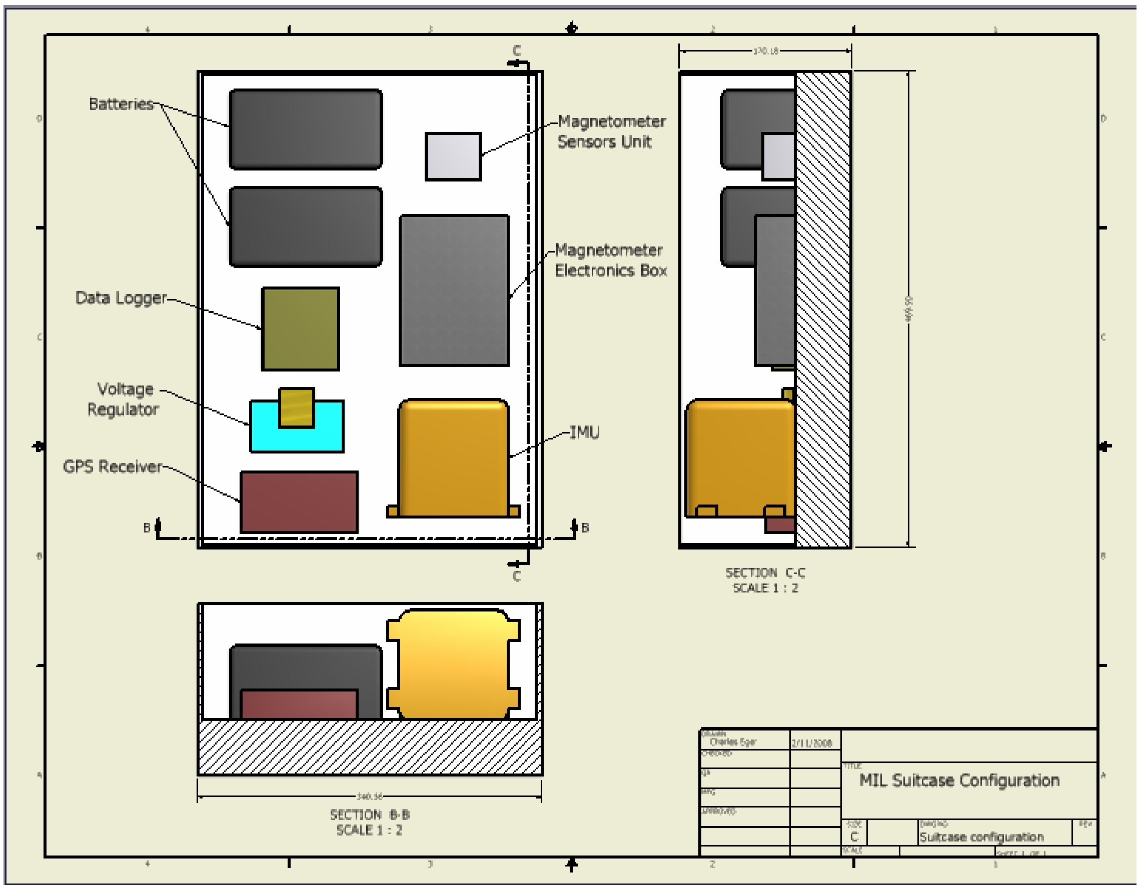
Resolution: 2272 x 1704 pixels
Dimensions: 90.7 x 64 x 38.4 mm
Mass: 0.9 kg for 5 cameras

Hazardous Materials:

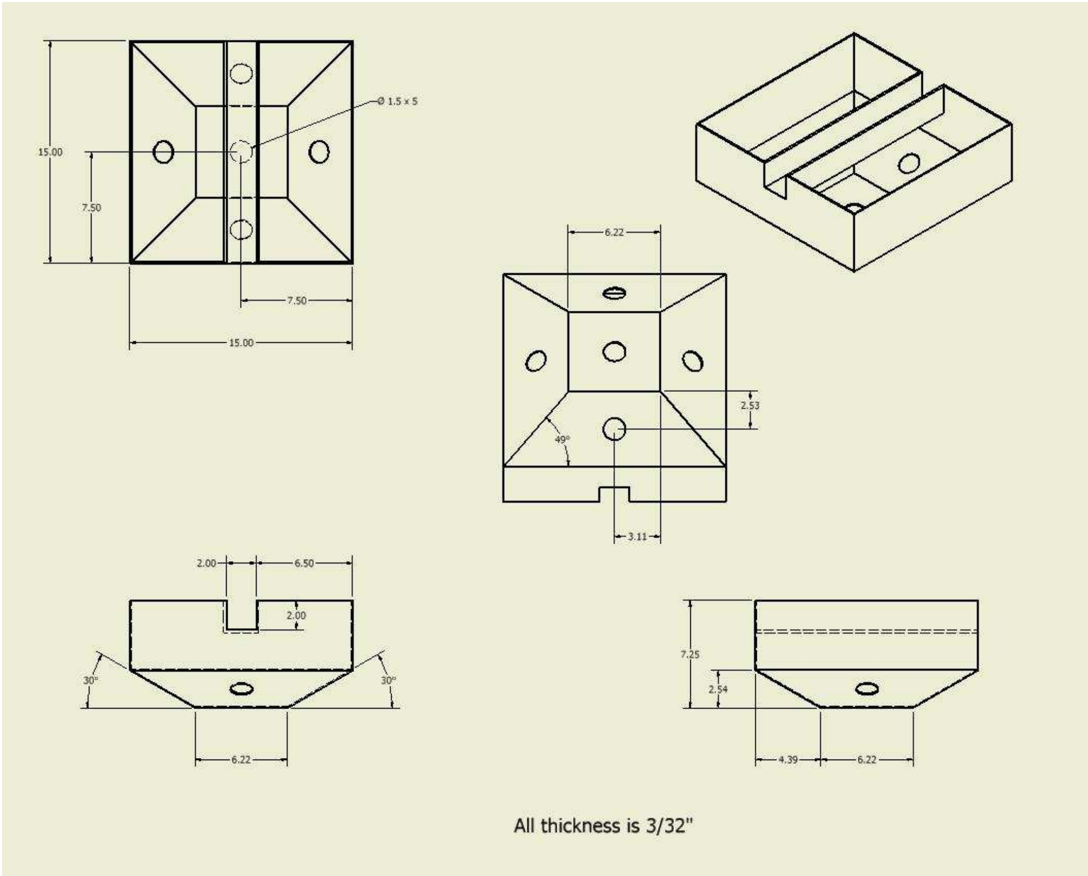
There are NO hazardous materials (such as radioactive or cryogenic materials, lasers, pyrotechnics, toxic gases, pressure vessels, superconducting magnets or high voltage) associated with this payload.

Inside the experiment suitcase there will be two 32 cell lithium ion batteries which are the only potentially hazardous material. Lithium-ion batteries can rupture, ignite, or explode when exposed to high temperature environments. Short circuiting or damage to the cells can also cause the batteries to explode. If the suitcase experiences any significant damage, the batteries should be inspected and possibly disconnected to prevent further damage or possible rupture.

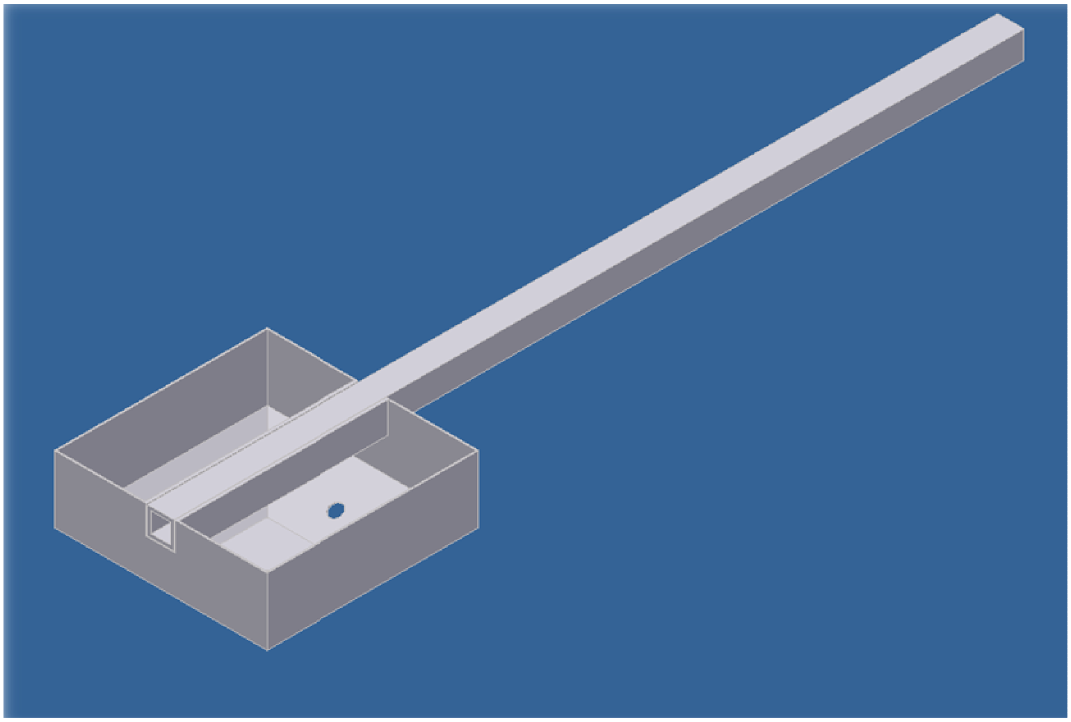
<u>Dimensioned Mechanical Drawings</u>:



MIL Suitcase Configuration



MIL Camera Housing



MIL External Configuration

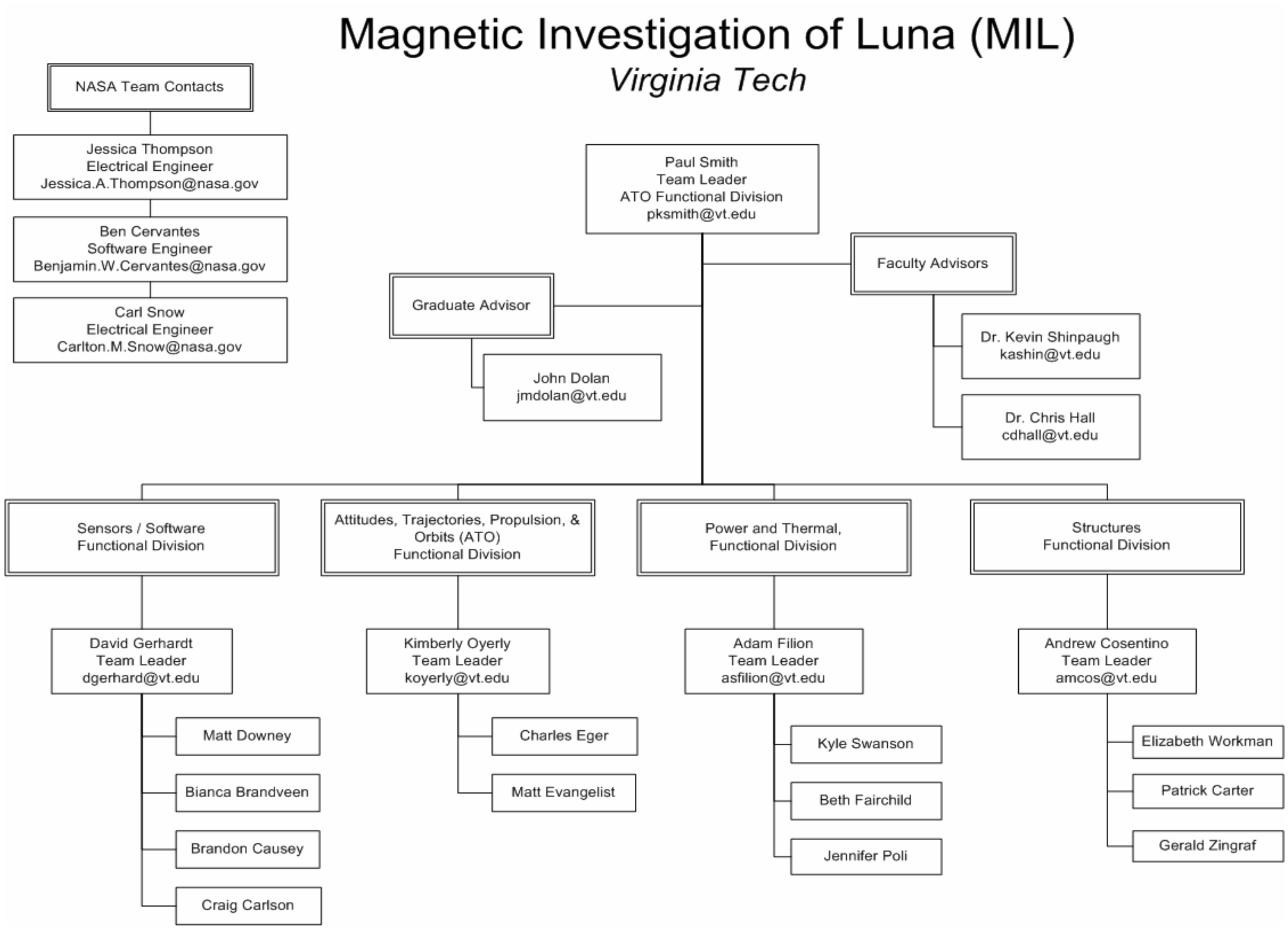
<u>MIL Mass Budget</u>:

Components	Mass (kg)	Uncertainty (kg)
Sensors		
Canon A520 (5)	0.9	0.05
SD Memory Card (5)	0.02	0.005
Magnetometer	1.66	0.05
Data Logger	0.07	0.005
IMU	1.26	0.005
GPS Receiver	0.12	0.005
GPS Antenna	0.087	0.0005
Electrical Accessories	0.5	0.05
Structures		
Boom	1.06	0.25
Camera Housing	3	1
Suitcase	5.75	0.25
Thermal/Power		
Insulation	0.7	0.05
Heaters (5)	0.00385	0.00005
Battery(2)	3.175	0.05
Total:	**18.31**	
Max Total:		**19.53**

<u>MIL Power Budget</u>:

Components	Voltage (V)	Current (mA)	Power (W)	Uncertainty (W)	W-hr	Uncertainty (W-hr)
Cameras (5)	3.3	1,000	3.3	0.5	158.4	182.4
Magnetometer	5	200	1	0.5	48	50.4
Data Logger	12	75	0.9	0.05	43.2	45.6
IMU	12	125	1.5	0.05	72	74.4
GPS Receiver	5	300	1.5	0.05	72	74.4
GPS Antenna	5	50	0.25	0.005	12	12.24
Thermafoil Heaters (5)	15	330	5	0.25	20*	21*
Total:			**13.45**		**425.6**	
Max Total:				**14.41**		**460.5**

*These values are for the heaters running for 4 hours, where all other equipment runs for 48 hours



MIL Organization