HASP Student Payload Application for 2009

Payload Title: Flying InfraRed Experiment for Lunar Investigation (FIREFLI)

Payload Class: (circle one) [✓ Small] Large	Institution: Virginia Polytechnic Institute & State University	Submit Date: 12/16/08

Project Abstract

The Virginia Polytechnic Institute and State University Flying InfraRed Experiment For Lunar Investigation (FIREFLI) team intends to fly an infrared photography experiment using the High Altitude Student Platform (HASP). The experiment will capture images of thermally radiating surfaces through the use of infrared photography as a proof-of-concept for a potential lunar mission. Surfaces observed will be heated by sunlight, and rates of heating and cooling will be monitored with multiple images over a period of time. Due to the differing thermal properties of materials, infrared photography can be used to determine a surface's composition. A 20-hour flight duration will allow observation of heating and cooling rates of the Earth's surface over one day cycle.

Team Name: FIREFLI	Team or Project Website: N/A

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HIGH ALTITUDE STUDENT PLATFORM (HASP)

2009 PAYLOAD FLIGHT APPLICATION

FIREFLI

Flying InfraRed Experiment For Lunar Investigation

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

SUBMITTED ON DECEMBER 16, 2008

Virginia Tech Department of Aerospace and Ocean Engineering
215 Randolph Hall, Blacksburg VA, 24061

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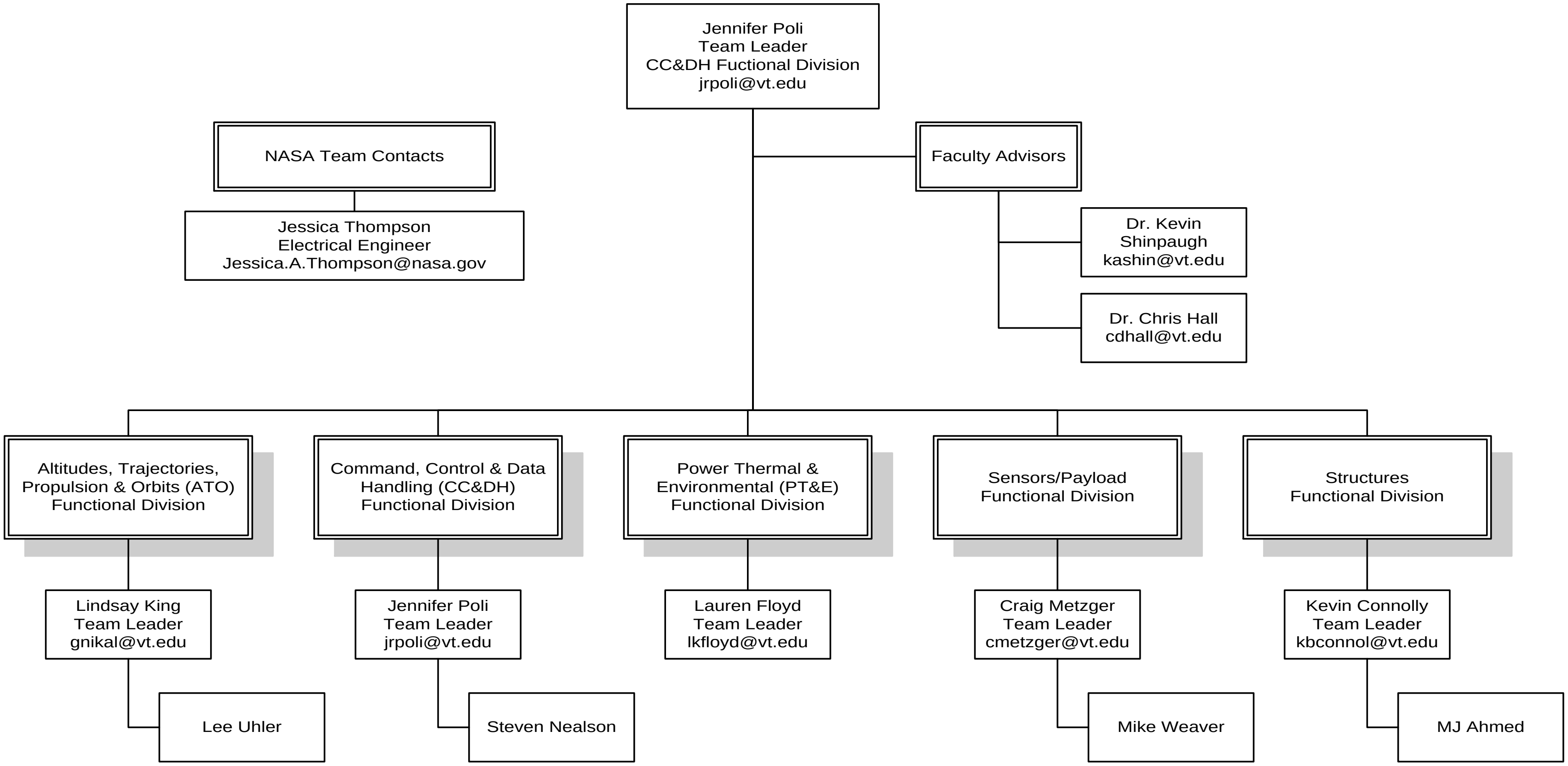
Section I - Project Abstract

The Virginia Polytechnic Institute and State University Flying InfraRed Experiment For Lunar Investigation (FIREFLI) team intends to fly an infrared photography experiment using the High Altitude Student Platform (HASP). The experiment will capture images of thermally radiating surfaces through the use of infrared photography as a proof-of-concept for a potential lunar mission. Surfaces observed will be heated by sunlight, and rates of heating and cooling will be monitored with multiple images over a period of time. Due to the differing thermal properties of materials, infrared photography can be used to determine a surface's composition. A 20-hour flight duration will allow observation of heating and cooling rates of the Earth's surface over one day cycle.

Section II - Payload Size

The FIREFLI group requests to have a spot on the High Altitude Student Platform as a small payload class. The FIREFLI project would be best suited in a small payload location for ground observing purposes. The FIREFLI project could be made more effective if the mass and volume limit were allowed to be increased. This is discussed in more detail in Section VIII.

Section III – Team Structure



Flying InfraRed Experiment For Lunar Investigation (FIREFLI)

Virginia Tech

Figure 1: Team Organization Chart for FIREFLI with Contact Information

Section IV – Interface Requirements

FIREFLI's only required interface will be power from the HASP platform. The power connector will be specified at a later time. The power requirements for this unit will be provided by the HASP power unit, which is 30 volts at 0.5 amps. The equipment in the FIREFLI unit will not need additional inputs provided by HASP. After the experiment has been flown, the project team intends to request the GPS data, and possibly other data, for analysis and correlation with FIREFLI data.

Section V- Payload Description

A. Science Objectives

The purpose of this experiment is to investigate the feasibility of using an infrared imaging system to collect information about the surface composition of the moon. A Sigma SD-14 camera will be converted to record the infrared images, and mounted such that the lens will be pointing towards the Earth. The payload will include temperature, pressure, and humidity sensors located inside and outside the housing to monitor the atmospheric conditions with regards to the health of the infrared system.

Both instantaneous and time-variant infrared emissions can be used to identify surface diversity. If a surface is heated uniformly, objects with different emissivity will contrast on a thermal image. Darker materials tend to be better radiators of thermal energy; these materials will vary in appearance from those with lower emissivity. The thermal conductivity of surface materials will be studied by observing cooling rates indicated on the infrared images. If provided with the long duration flight, the infrared camera will be able to record at least one day to night transition which allows for the monitoring of surface temperatures as it cools.

This experiment will demonstrate as a proof-of-concept how well variations in surface composition can be defined using a thermal imaging system at high altitude. Particular objects will be identified based on the resolution of the thermal imaging data.

B. Payload Details and Principle of System Operation

The desired traits for the infrared imaging system include high ground resolution, fast shutter speeds, and the ability to take photographs in low-light conditions. A 35mm photography equivalent focal length of 500mm is desired to achieve the necessary ground resolution. The shutter speed and low-light capability depend primarily on the aperture size. Lenses with long focal lengths require a trade-off between lens and aperture size. Lenses are first selected to achieve the 500mm focal length requirement because ground resolution is the most critical mission criterion. Given the remaining mass, lenses will be considered based on their aperture size.

A Sigma SD-14 digital single lens reflex (DSLR) camera features a 4.7 Megapixel CMOS Foveon X3 sensor will be flown on FIREFLI. The internal filter preventing infrared (IR) light exposure will be removed. The Foveon X3 sensor provides greater per pixel detail than the Bayer sensor used in comparable cameras. The ability to detect small changes in infrared intensity provided by the Sigma SD-14 is more important than an increased ground resolution for the science mission objectives.

The camera will be paired with a Sigma 28-300mm focal length zoom lens. The lens will be extended to the maximum focal length to provide the best possible ground resolution. The 300mm focal length, combined with the 1.7x crop factor due to the size of the camera sensor, creates an effective focal length of 510mm. A 72mm diameter 093-type infrared glass filter, commonly called a “black” filter, will be used to prevent light in the visible and ultraviolet bands from entering the camera system. This filter allows 0% bypass at a 790mm wavelength and 50% bypass at an 850mm wavelength. An industrial-grade compact flash card with 32GB capacity will be used in the camera for data storage. This card was selected because it ensures the recorded data will survive the temperatures and accelerations associated with the HASP flight plan.

Humidity, pressure, and temperature sensors will be used to monitor the health of the system and provide data at specific intervals throughout the flight. A humidity sensor will be mounted on the outside of the housing, along with a Thermofoil heater to keep it within operating temperature limits. This heater also contains a temperature sensor which will provide exterior temperature data. An additional humidity sensor and a pressure sensor will be mounted on the inside of the housing, along with a Thermofoil heater. Data from all the sensors will be stored on the data logger. Humidity data will help determine if any condensation occurred on the lens and the strength of infrared absorption due to water in the atmosphere. Pressure and temperature data can be used to determine if the payload stays within operating limits.

A series of LED indicator lights, mounted on the outside of the housing, will be used in combination with the HASP CosmoCam to provide information on the health of the payload. LEDs capable of displaying multiple colors will use one color to indicate that each component is within temperature limits and another if the limits are exceeded. Additional LEDs will indicate whether the camera and other sensors are receiving power.

C. Thermal Control Plan

The main area of concern for thermal control is keeping the camera above its lower operating temperature limit of -20°C. The pressure, humidity, and temperature sensors also have lower operating temperature limits of -20°C, -55°C, and -40°C, respectively. In order to stay within these constraints, several thermal control methods will be used. Solid insulation lined with a reflective material, designed to help keep heat inside the housing, will surround the inside of the structure. In addition, foam insulation will be used to fill the remaining space inside. A Minco Thermofoil heater will be used on the inside of the housing to provide additional heat if necessary. A temperature sensor will be mounted on the camera housing and provide real-time data to the data logger, which controls the heater. This configuration will also maintain the operating temperature necessary for the interior pressure and humidity sensor. A Minco Thermofoil heater and temperature sensor combination will also be used on the outside of the housing where an additional humidity sensor will be located.

Section VI – Timeline to Integration

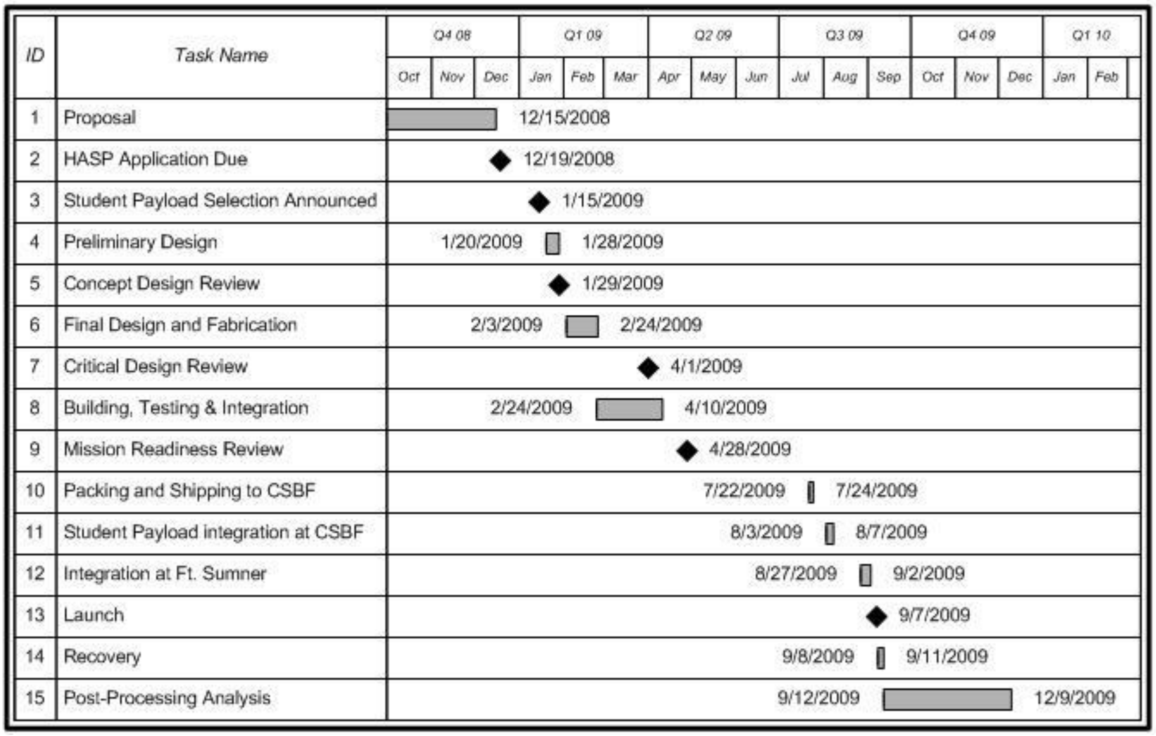


Figure 2: FIREFLI Project Gantt Chart

Section VII – Desired Launch Date

A September Fort Sumner launch is preferred for the FIREFLI mission because of the extended observation period. Since the experiment focuses on determining the surface composition through infrared image sensing, it is imperative that a complete sunrise to sunset day-cycle is observed in order to obtain applicable data. The extended flight time also allows for more images to be captured, which increases the probability of detecting changes in the surface temperature for a specified region.

Section VIII – Payload Specifications

A. Project Budgets

Table 1: Payload Budget.

												Temperature Ranges (°C)	
	Number	Mass (kg)	Uncertainty	Voltage (V)	Current (mA)	Power (W)	Uncertainty	Time Used (hr)	Whr (no +/-)	Whr (with uncertainty)	Cost ($)	Low	High
Sensors (Power by HASP)													
Compact Flash Card (32GB)	1	0.02	0.005	-	-	-	-	-	-	-	300.00	-25	85
Persistor CommLogger-CF2 Data Logger	1	0.001658	0.05	5	200	1	0.05	48	48	50.4	550.00	0	60
Electrical Accessories	1	0.2	0.05	-	-	-	-	-	-	-	400.00	-	-
Sigma SD14 Digital Single Lense Reflex Cammera (SLR)	1	1.3	0.05	7.4	93.75	0.69375	0.1	48	33.3	38.1	380.00	0	20
Temperature	1	1.88979E-05	0.000000005	5	5.00E-02	2.50E-04	5.00E-05	48	0.012	0.0144	2.47	-55	85
Pressure	1	0.0025	0.0005	5	6.00E+00	3.00E-02	5.00E-03	48	1.44	1.68	25.90	-20	105
Humitidy	2	0.0005	0.0001	5	2.00E-01	1.00E-03	5.00E-04	48	0.048	0.072	26.24	-40	55
Sigma 28-300 mm Zoom Lense	1	0.64	0.05	-	-	-	-	-	-	-	250.00	0	20
Infared Filter 72 diameter 093-type infared glass filter	1	0.02	0.01	-	-	-	-	-	-	-	144.50	0	20
LED Indicating Lights	10	0.01	0.0005										
Thermofoil Heaters	6	0.06	0.005										
Structues													
Housing	1	0.382	0.01	-	-	-	-	-	-	-	8.70	-	-
Camera Support	1	0.12	0.005	-	-	-	-	-	-	-	20.00	-	-
Thermal / Power													
Insulation (inside)	1	0.15	0.05	-	-	-	-	-	-	-	50.00	-	-
Post Processing													
Poster	1	-	-	-	-	-	-	-	-	-	-	-	-
Failure Report for HASP	1	-	-	-	-	-	-	-	-	-	-	-	-
Total		**2.906676898**	**0.286100005**								**2157.81**		

Table 2: Travel Budget.

Travel Budget	Cost ($)
To Wallops (9 people)	
Renting Van	1636.00
Food	204.00
Housing	300.00
To Integration (Texas) (3 people)	
Flight	2100.00
Lodging	450.00
Food	200.00
To Launch (New Mexico) (3 people)	
Flight	1200.00
Lodging	500.00
Food	200.00
Total	**6790.00**

B. Mounting Plate Footprints

The FIREFLI team will construct the housing for the instrument mounting plate. The nylon walls of the housing will be connected to the PVC mounting plate with chemical bonding or mechanical attachment. A circular viewing window will be cut out of the PVC board for the camera. Figure 3 shows the footprint of the PVC plate.

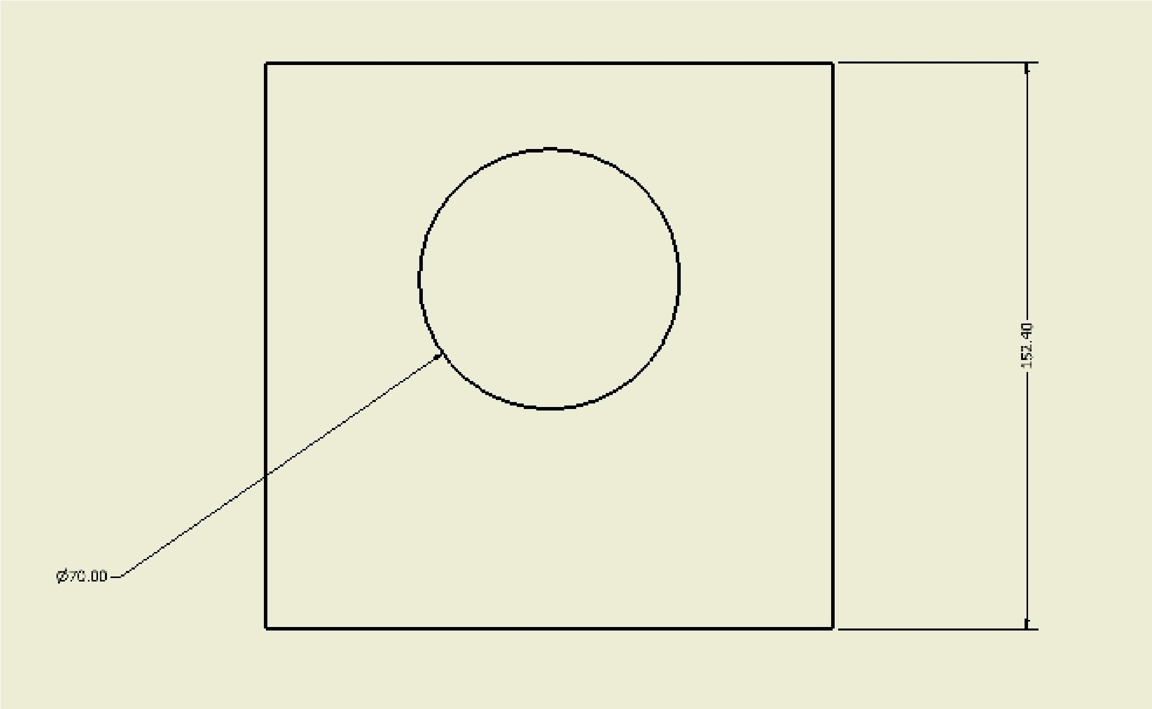


Figure 3: Footprint of the PVC mounting plate [mm].

C. Integration Procedures for HASP

a. Date and Time of your arrival for integration:

We plan on arriving on August 27. The time of our arrival is still to be determined, but it is flexible.

b. Approximate amount of time required for integration:

Approximately 2 hours.

c. Name of the integration team leader:

Integration team leader is not currently known. Our current team leader is Jennifer Poli.

d. Email address of the integration team leader:

jrpoli@vt.edu.

e. List ALL integration participants (first and last names) who will be present for integration with their email addresses:

Lindsay King- gnikal@vt.edu.

Michael Weaver- mdweaver@vt.edu

Steven Nelson- sgnelson@vt.edu

f. Define a successful integration of your payload:

Payload is secure and all components are receiving power, which will be indicated by LEDs located on the top of the payload.

g. List all expected integration steps:

i. Secure payload to HASP platform
ii. Attach power leads from payload to HASP power supply.

h. List all checks that will determine a successful integration:

i. Ensure payload is secure and will not rotate.
ii. Check to make sure camera view is unobstructed.
iii. Check power indication lights on top of payload.

i. List any additional LSU personnel support needed for a successful integration other than directly related to the HASP integration (i.e. lifting, moving equipment, hotel information/arrangements, any special delivery needs…):

i. Hotel information/arrangements
ii. Delivery confirmation of payload package to integration location

j. List any LSU supplied equipment that may be needed for a successful integration:

None

Section IX – Preliminary Drawings

Figure 4 shows the preliminary drawing of the FIREFLI pay load assembly. All dimensions provided on the figures are in mm. The dimensions of the temperature, humidity, and pressure sensors are not shown in the drawing but they are available in Table 3. The space between the walls the equipments is filled with insulation which is also not shown in the drawing.

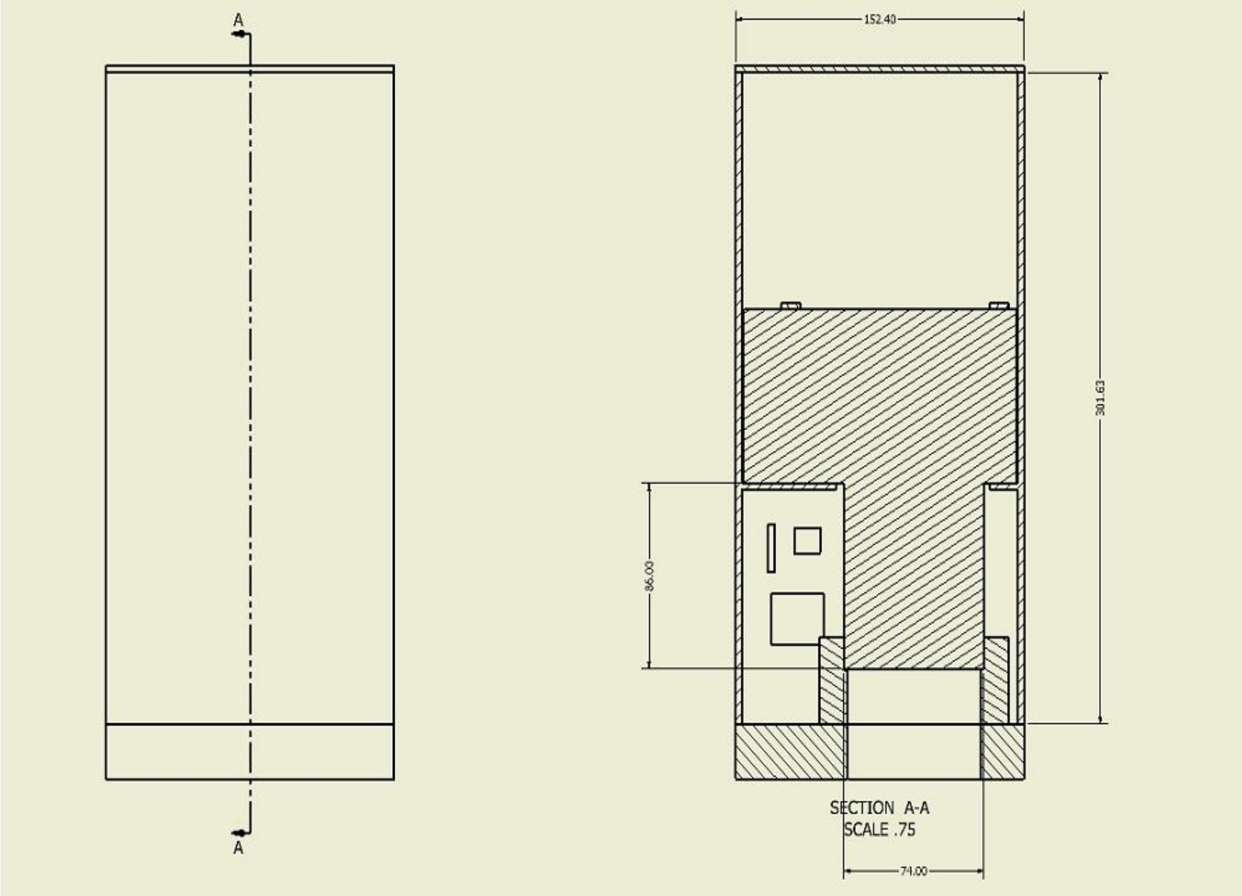


Figure 4: Sectional View of Payload Assembly

Table 3: Sensor Dimensions.

Component	Model	Length (mm)	Width (mm)	Height (mm)
Humidity sensor	Honeywell HIH-4000-003	22.17	4.27	2.03
Pressure sensor	Honeywell ASDX015A24R	16.89	13.97	11.89
Temperature sensor	Texas Instruments TMP123AIDBVT	3.05	3.00	1.45
IR Camera	Sigma SD-14 DSLR	144	107.3	80.5
Lens	Sigma 28-300mm Zoom Lens	74	74	86

Section X – Special Request

The mass and size constraints specified for the small payload limit the feasibility of obtaining the high resolution images needed to distinguish and identify surface features for the FIREFLI mission. Given the experiment operates on the principle of optics, a longer and heavier lens significantly improves the obtainable image resolution from the long ranges associated with high-altitude flight. A large payload was considered; however, it was deemed inadequate because large payloads do not have a ground field of view.

The FIREFLI team requests an additional 1.5 kilograms of mass and an additional 6 inches of vertical space. This would bring the final dimensions of the payload to be 6x6x18 inches with a total mass of 4.5 kilograms. These additions would increase the performance and data acquisition capabilities of the infrared system and would significantly enhance the ground resolution. With this increased resolution, the team is confident that surface cooling rates will be more precisely observed and detected by the infrared sensors. The additional image detail will allow for more accurate data reduction and determination of surface characteristics.