# HASP Student Payload Application for 2016

Payload Title: High Altitude Robot Servo Motor Test

| Payload Class: (check one) | Institution: | Submit Date: |
|---|---|---|
| ☐ Small X Large | University of Bridgeport | December 18, 2015 |

Project Abstract

Our proposal focuses on the testing of critical components of the next phase of a high altitude robotic puppet that will be used on Near Space balloon missions to engage younger students (K-6). The prototype robotic puppet has been under the development at the University of Bridgeport (UB) supported by a Connecticut Space Grant College Consortium (CSGCC) Faculty Seed Money Grant awarded to Dr. Neal Lewis (PI) and Dr. Jani Pallis (Co-PI). A multidisciplinary team of undergraduate and graduate students at the University of Bridgeport developed the robot and its existing housing and already have experience with the initial prototype robot.

The scientific objectives of the HASP experiment are to test and ensure that the robot will function at high altitude and temperature for longer periods of time (in particular to test the longevity and continued functionality of the multiple servo motors used in the robot in the harsh environment of Near Space). There is concern regarding survivability/failure at low temperature and pressure, as well as continued power output at the proper level for the robot's gestures and the continued functionality of the lubricants used within the motors under Near Space conditions.

| Team Name: | Team or Project Website: |
|---|---|
| University of Bridgeport | None at this time |

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|---|---|---|
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## 1. Payload Description

Our proposal focuses on the testing of critical components of the next phase of a high altitude robotic puppet that will be used on Near Space balloon missions to engage younger students (K-6). The prototype robotic puppet has been under the development at the University of Bridgeport (UB) supported by a Connecticut Space Grant College Consortium (CSGCC) Faculty Seed Money Grant awarded to Dr. Neal Lewis (PI) and Dr. Jani Pallis (Co-PI). A multidisciplinary team of undergraduate and graduate students at the University of Bridgeport developed the robot and its existing housing and already has experience with the initial prototype robot.

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We are requesting a "large" experiment seat based on volume but not on weight, which is less than 6 pounds. The puppet looks like an upper body of a chimpanzee and has a head and arms that move. The robot's motions with the greatest ranges of motion are the "wave" and "clap" and a larger space is needed for these gestures.

Potentiometers will be used to monitor the output of the servos and our objective is to collect that information and report that information in real time. We would like to also include a small camera directed at the robot as a "backup" to later visually review the robot's performance.

Because the robotic monkey will be used in high altitude balloon (HAB) flights routinely, testing the robustness of the developed system, and monitoring of the servos in the extreme environment are critical to the outcome of the overall project.

If the overall project is successful the team hopes to take the next step and apply for additional funding from the Department of Education which has supported projects where "puppets" are used to teach STEM subjects. [1, 2]

### 1.1 Background

The University of Bridgeport works with a local children's museum (the Discovery Museum and Planetarium in Bridgeport, CT), which has a Challenger Center. The two groups are working together on a NASA small satellite/rocketry project, a CubeSat, and ballooning projects. For example, UB students developed software that runs on the museum's Challenger Center computers that serve as a real "mission control" for balloon flights (with a mission director, and different science stations). Middle and high school students may participate in real missions in mission control. In Figure 1 we have included a photo of mission control for a “simulated balloon mission” (Montana Space Grant provided footage and data for this pilot test during software development).

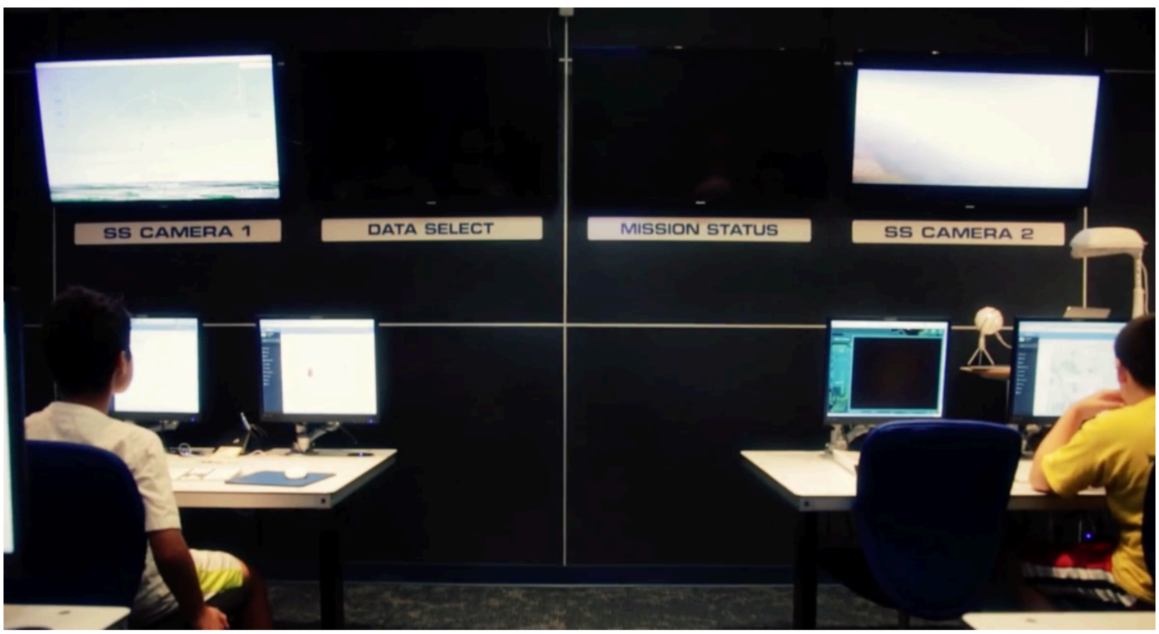


Figure 1 - Middle school students pilot new UB software used to operate and monitor actual balloon missions

However from working with children we know the view from a high altitude balloon may not (unfortunately) enthrall a younger student [grades Pre-K – 6] for very long. And the thought was (as unusual as it may sound), "What if the children had a little friend onboard the HAB that they could interact with?"

The "friend" has become a robotic monkey (reminiscent of the early American space program), and the robot is named after the actual chimpanzee that travelled into space, "HAM". However, this "HAM" stands for "High Altitude Monkey". The project has been student designed and the prototype is almost completed. We see a rich educational curriculum in mission control, life sciences, Earth observation, remote sensing and history of space flight around HAM and the HAM HAB flights. The actually HAM HAB flights will be conducted several times per year as an outreach activity through the museum. Figure 2 shows a picture of the real chimpanzee HAM and Figure 3 is one of the animal models being used to create the robotic puppet's outer body. Figure 4 is the arm and head servos of the robot (without a "puppet covering")

Figure 2 - HAM

Figure 3 – One of the animal models used to create the robots outer body.

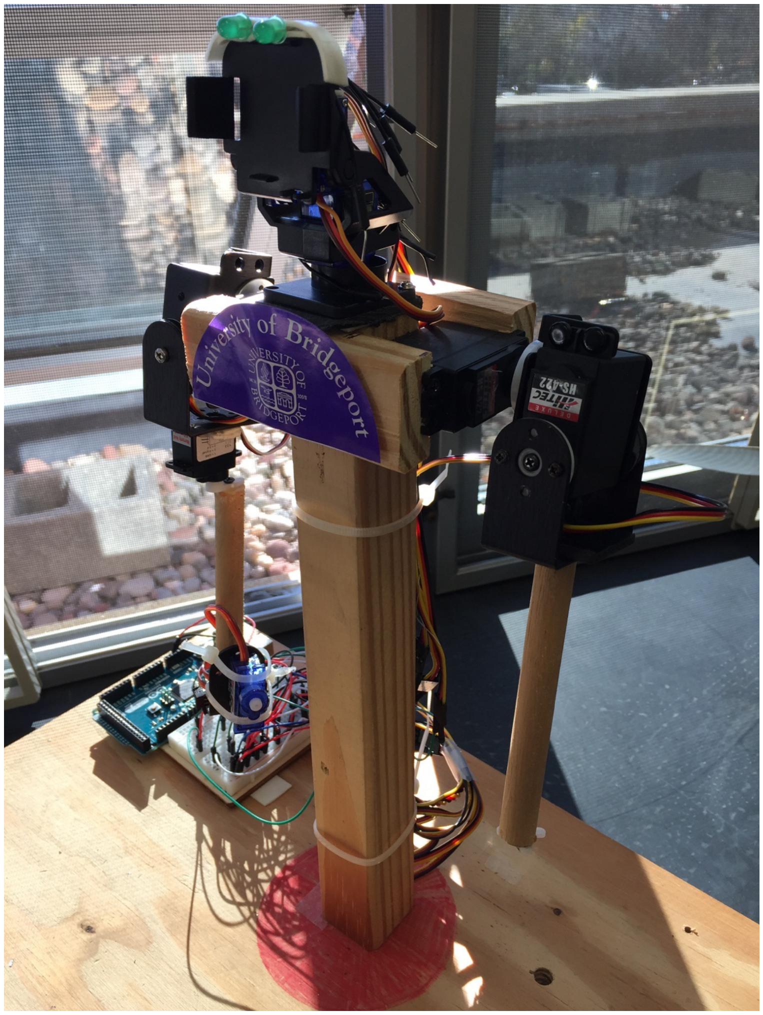


**Figure 4** – HAM's neck and shoulder servomotors

**1.2 Technical Challenge**

As stated in Section 1, we are requesting a "large" experiment seat based on volume but not on weight. The robotic puppet looks like an upper body of a chimpanzee and has a head and arms that move. The robot's motions with the greatest ranges of motion are the "wave" and "clap" and a larger space than the small payload can provide is needed for these gestures. The other gestures are "yes", "no", "thumb up", thumb down", "press a button (control panel)", "touch heart".

The existing "A" model of HAM is physically too big for either the large or small HASP payload. As well the manner in which instructions are sent to the robot will need to be modified for the HASP flight. Thus, the team will fabricate a smaller HAM robot for the HASP test and conform to the power, size and other communication constraints but utilize the same servomotors. The team feels that they have identified the modifications that need to be made to fabricate a smaller robot that will test the functionality of the servos at low temperature and low pressure.

The scientific objectives of the HASP experiment are to test and ensure that the robot will function at high altitude and temperature for longer periods of time (in particular to test the longevity and continued functionality of the multiple servo motors used in the robot in the harsh environment of Near Space). There is concern regarding survivability/failure at low temperature and pressure, as well as continued power output at the proper level for the robot's gestures and the continued functionality of the lubricants used within the motors under Near Space conditions.

### 1.3 Payload Systems and Principle of Operation

A compact camera will be used.  There will be a frame with the servomotors on it.  There will be an Arduino that will control the gestures.  Pressure, temperature and a GPS will be installed.  The team will conform to all of the suggestion data downlink, command uplink, command format, GPS time and position data formats described in the HASP Student Interface Manual.

### 1.4 Payload

We have included photos of components that were planned for an 800-gram balloon test on Dec. 6, 2015 planned for 80,000 ft. to test the servos.  Unfortunately, we were not able to fly that day.  (It was also the start of finals week with our student team leaving.)  This servo test will be the first balloon test conducted in Spring 2016.  While we intent on creating a small frame for the servos to actually conduct gestures, we wanted to show the evaluators that the student created payloads exist.

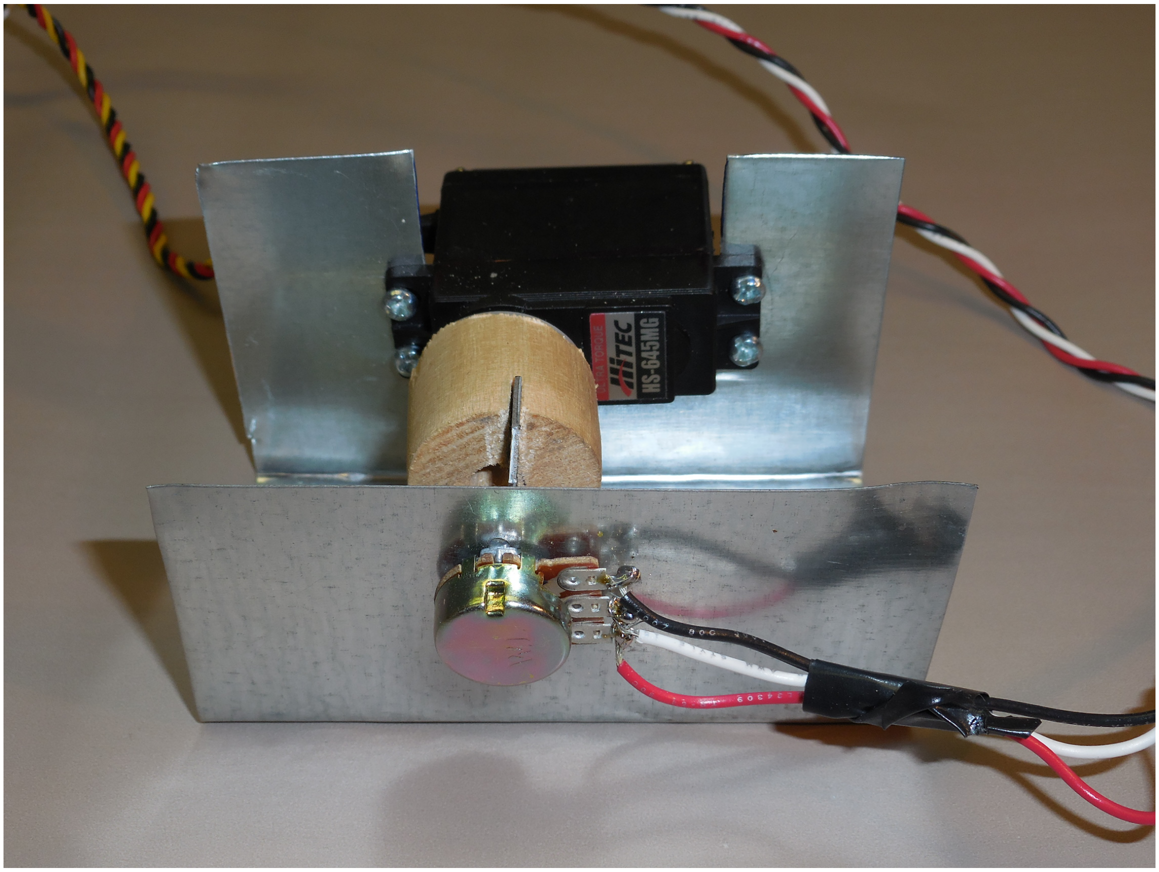


**Figure 5:** Mounting of single high-torque servo driving potentiometer to measure servo position.

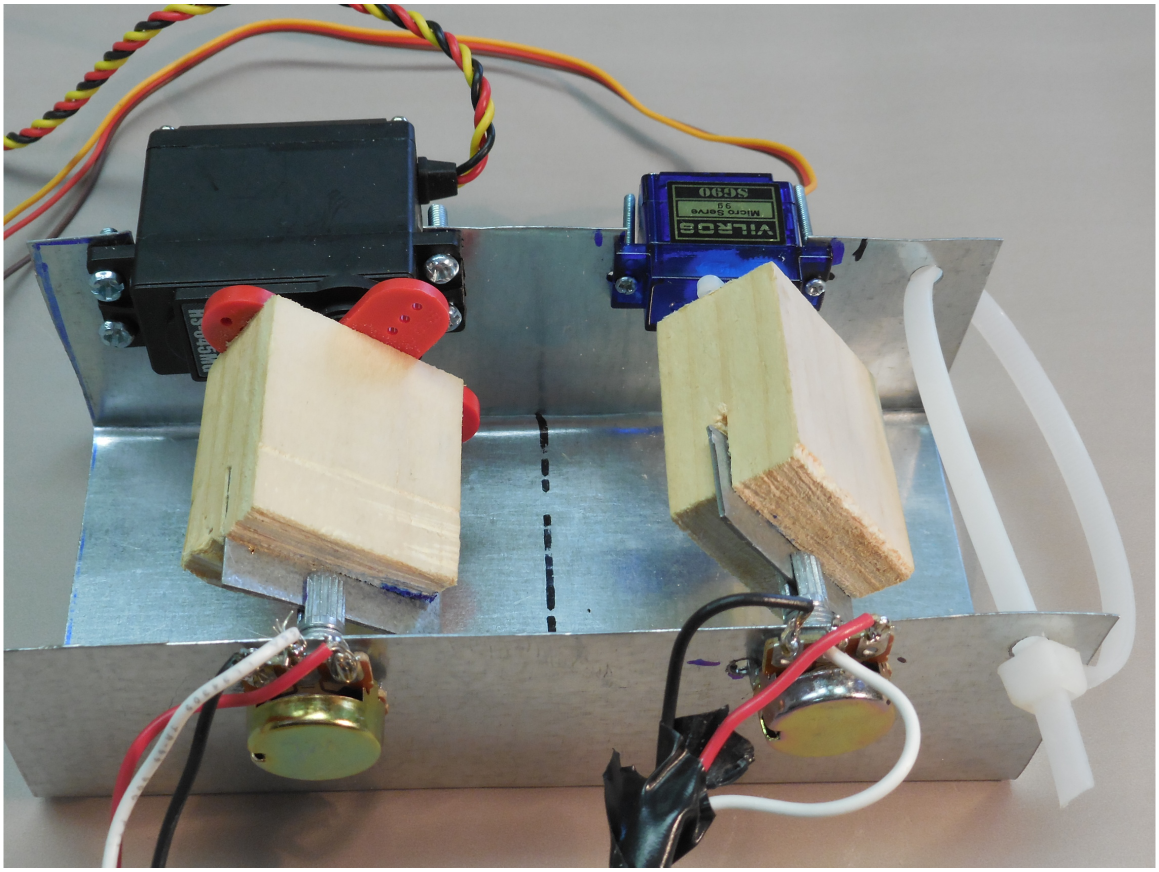

**Figure 6:** Mounting of dual (high-torque and low-torque) servos driving potentiometers to measure the position of each servo.  Our plan is to mount this "inside" the container, and try to keep the temperature above -30 degrees F.

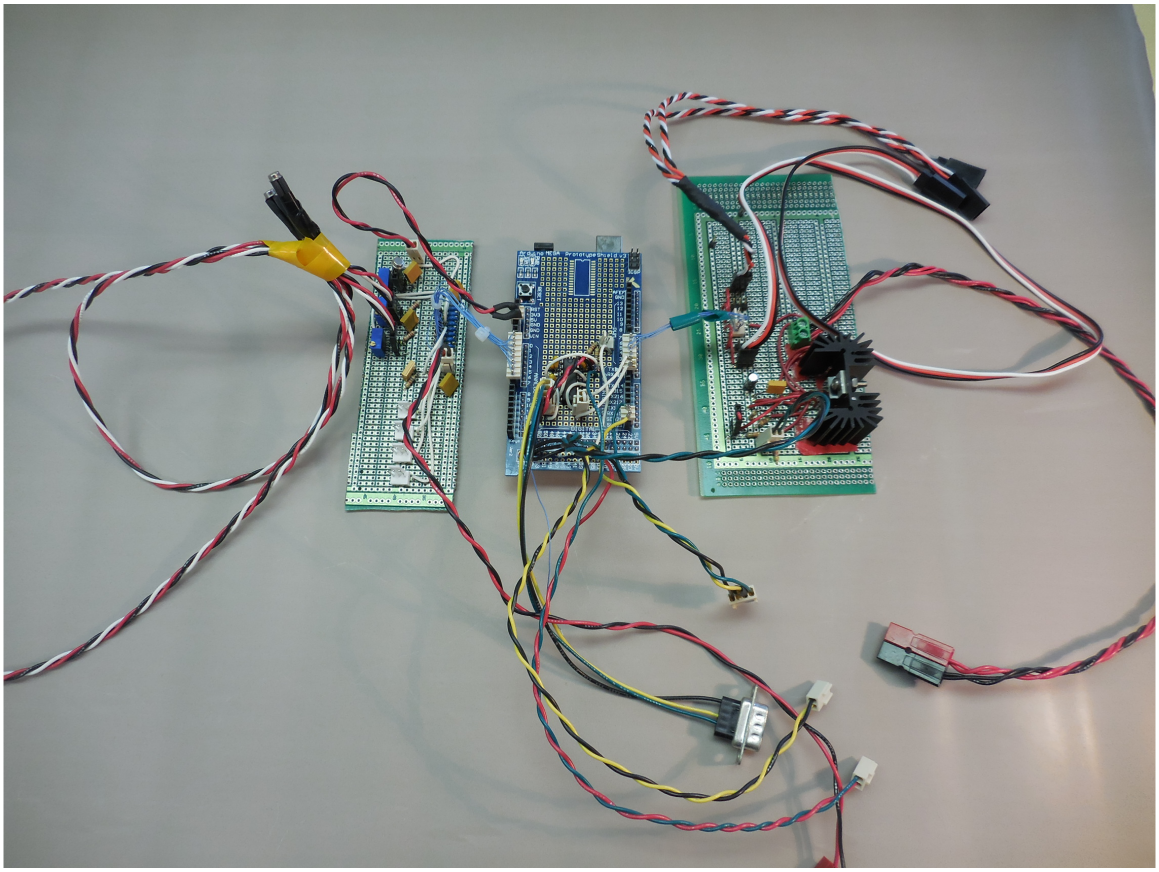

**Figure 7:** left-to-right: The sensor input board, the Arduino Processor with interface shield, and the Servo Drive Board.

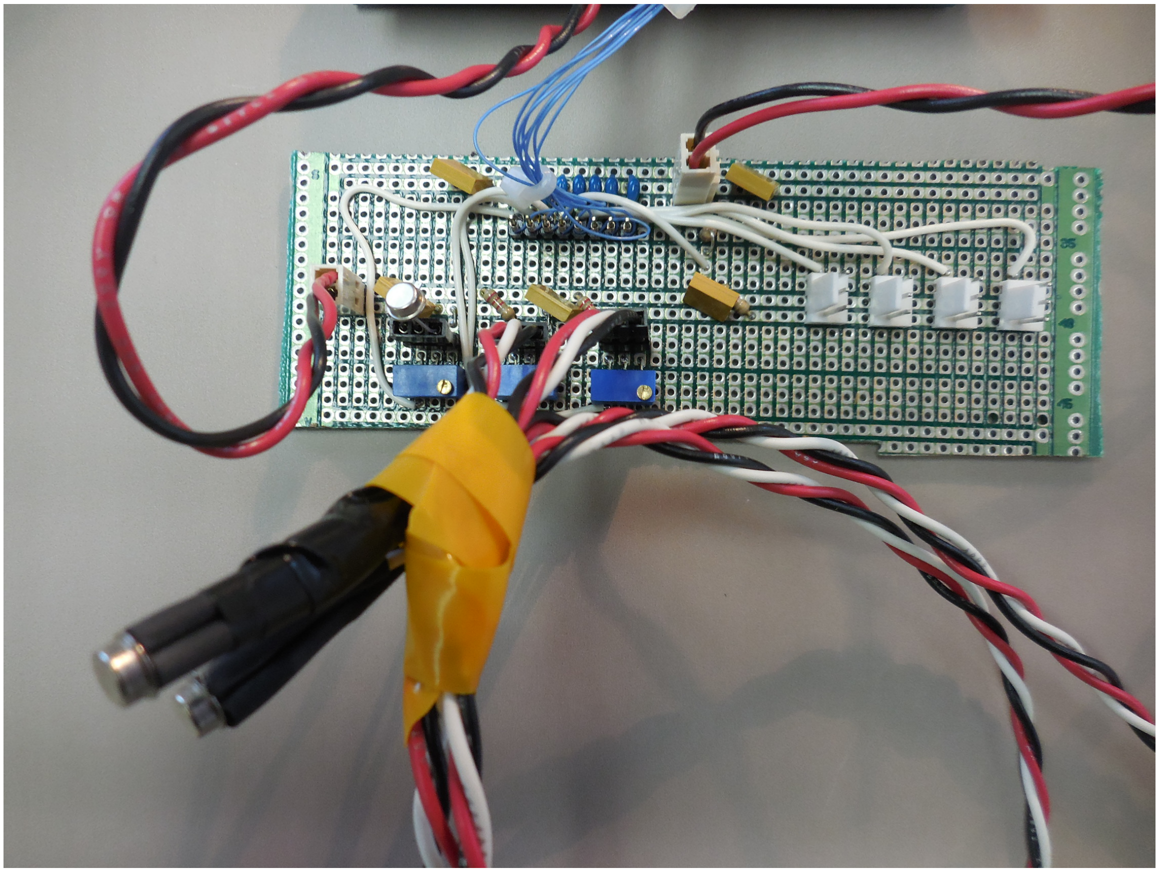

**Figure 8:** The sensor input board, showing one local and 2 remote LM-135H Temperature Sensors on the left, and headers for four potentiometer inputs on the right.

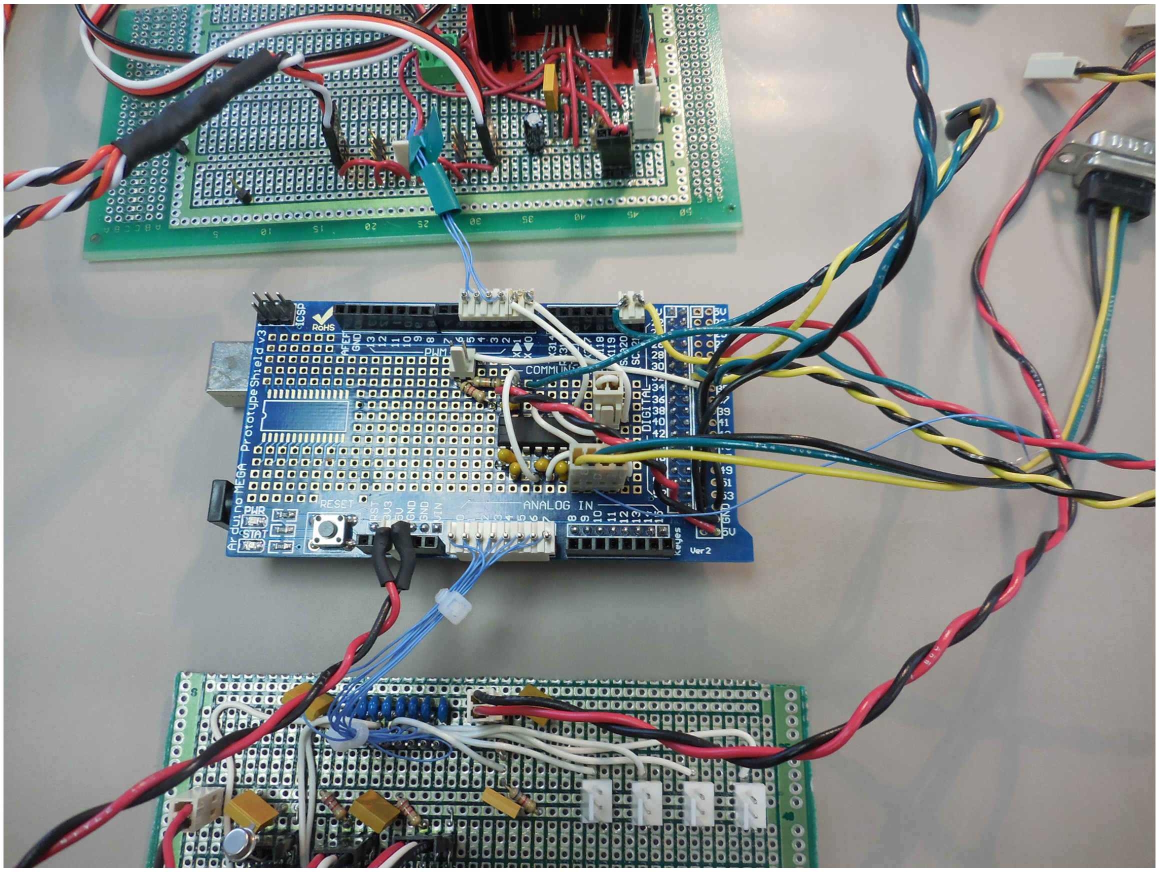


Figure 9: Arduino Processor with Interface shield daughtercard.

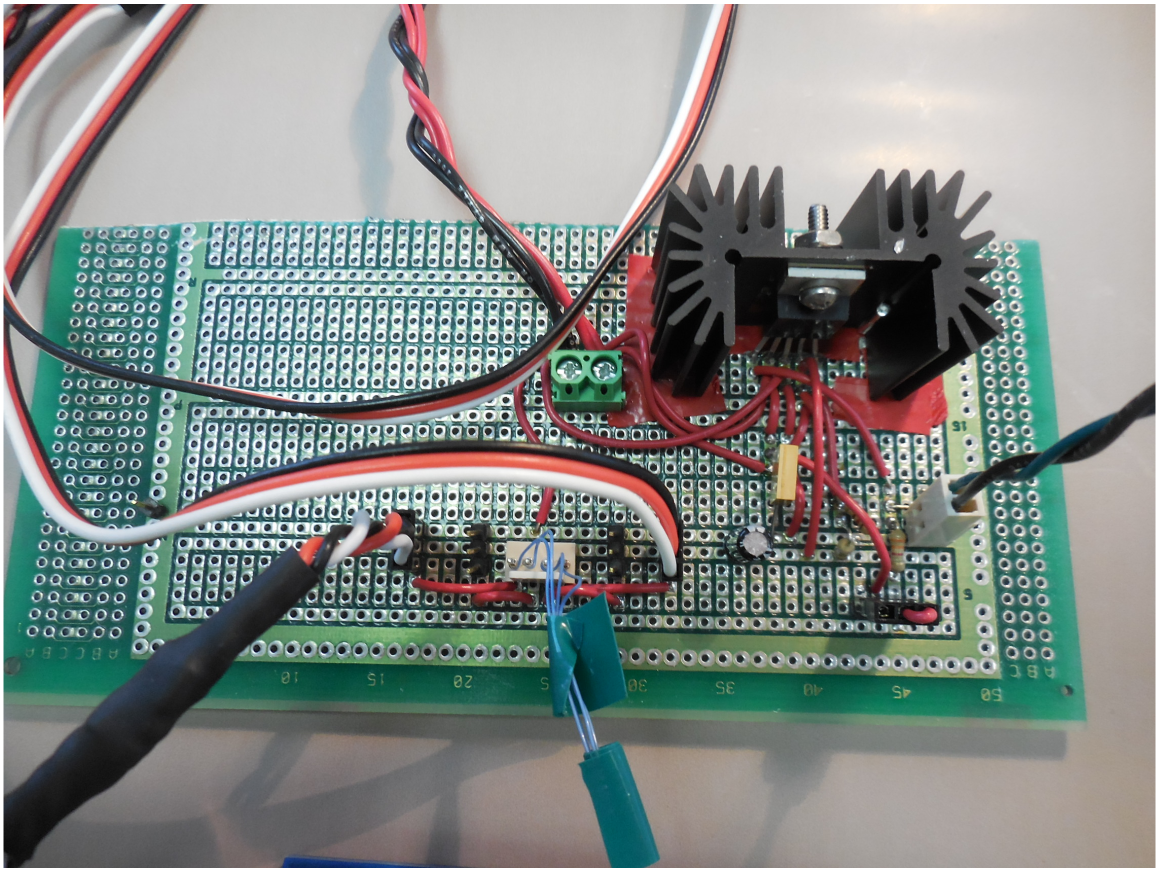

Figure 10: The Servo Drive Board contains a linear 6V regulator for the servos, and connectors for the drive signals from the Arduino.

**1.4.2 Computer and Data Logger**

An Arduino Mega will run flight code written in C++. A template of the flight code has been used in small satellite and other balloon missions. Pressure, temperature, potentiometer readings will be taken.

The team will conform to all of the suggestion data downlink, command uplink, command format, GPS time and position data formats described in the HASP Student Interface Manual.

**1.4.3 System Operation**

Once HASP operations begin, power will be provided to the HAM model. The Arduino will be programmed to trigger a sequence of gestures. Since in the outreach project the robotic puppet interacts with the young students in short duration, the robot's motions are definitely not continuous. Several combinations of gestures will be programmed and will be pre-timed to be repeated throughout the flight (if possible from accent, at altitude over the 5-20 hour period, and during the descent.) There will be a final shutdown command to turn off the robot’s gestures during the descent period, although other data will continue to be logged (pressure, temperature, altitude). The team will conform to all of the suggestion data downlink, command uplink, command format, GPS time and position data formats described in the HASP Student Interface Manual.

**2. Team Structure and Operation**

The students and faculty team have all worked together on different but related projects. The HAM servo test payload system will be constructed by a student team managed by Bashar Alhafni.  Bashar has served on two CanSat (small satellite competition) teams, has served in leadership roles (president and treasurer) and is one of the founder’s of UB’s Aerospace Club. Bashar will be responsible for team management, monthly report submission, teleconferences, and hardware and material procurement. Bashar’s technical responsibilities will be related to the data logging.

Graduate student Rishi Warokar has been the key person in programming HAM’s gestures and will be responsible for the programming of the Arduino to generate the gesture sequences for the test.  Rishi has also been responsible for the electronics and power for HAM and will continue in this role.

Undergraduate industrial design student Phil Carroll has been responsible for the animations of HAM’s motions and will work closely with Rishi to define the sequences of gestures, timing of gestures throughout the HASP flight, and the range of motion bearing in mind the size restrictions of the housing.

Undergraduate computer science major Paul Alfaro who has been responsible for the flight computer data logging for two CanSat teams will be responsible for the flight computer and camera.

Graduate mechanical engineering student Maheshwari Kumar Rakkappan will be responsible for the fabrication of the payload structure, structural integrity and thermal control.  Maheshwari has experience in small satellite design and high altitude ballooning. Due to her background, she will also to responsible for sensor monitoring (thermal, pressure) and the camera system.

Dr. Jani Macari Pallis teaches satellite design, is the faculty advisor to UB’s CanSat teams and coordinates UB’s ballooning activities.  Dr. Neal Lewis is the PI for the CT Space Grant HAM project and will work with the students on project management, schedules, budgets and procurement.  Dr. Sarosh Patel will support the students in areas related to computer science and computer engineering. The UB student and faculty team regularly (monthly) meets with the staff and volunteer from the Discovery Museum and Planetarium in Bridgeport, CT. The two groups work as one team for all balloon flights. We also must give credit to David Mestre, Director of Space Science Education, for the concept of the robotic monkey to interact with younger children.

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Table 1. Mailing addresses, affiliations and contact information of key personnel.

The preliminary plan is:

January – April 2016 Monthly status reports and teleconferences
January 2016: Finalize frame and range of notion for HASP large payload size.

| | |
|---|---|
| | Determine sequence and timing of gestures for the HASP flight. |
| January-Mar. 2016: | Program the Arduino (control of the gestures) and flight computer. Develop and fabricate the structure. |
| February 2016: | Acquire any additional supplies. (We believe that we have all supplies in-house already.) |
| February – May, 2016 | Full system integration and flight software development. |
| April 22, 2016 | Preliminary PSIP document due |
| May – August | Monthly status reports and teleconferences |
| June, 2016 | Final assembly and testing of payload. |
| June 24, 2016 | Final PSIP document due |
| July 28 | Final FLOP document due |
| August 1 – 5, 2016 | Student payload integration at CSBF |
| August, 2016 | Correct any issues determined during payload integration/ |
| August 27 – Sept 1 | HASP flight preparation. |
| September, 2016 | Launch |
| September 6-9 | Recovery, packing and return shipping |
| Sept. – Nov., 2016 | Monthly status report and teleconferences |
| Sept. – October, 2016 | Analyze results and prepare science report |
| November, 2016 | Complete data analysis and final report. |
| December 9, 2016 | Final Flight/Science Report Due |

## 3. Payload Specifications

The payload dimensions will conform to the large payload classification. There will be one uplink to command the robot's gestures to start and another to end the gestures. Downlink bandwidth will be needed for system status monitoring. The serial link will be connected at 4800 baud as described in the HASP Student Payload Interface.

### 3.1 Payload Mass and Power Budget

The payload will use the EDAC 516 connector to provide power to all systems. Table 4 lists the preliminary power and mass budgets for the payload components. There will be 5 low-torque and 3 high-torque servos. A camera has been included. The structural components include the payload walls and mounting hardware.

We would like to test as similar a payload and configuration of the robot to what will actually be used in the outreach project. However, we will continue to work on simplification of our HASP payload. Alternative scenarios that will be considered include a) only include one arm (including shoulder, elbow, and wrist), and not the neck and head; b) if only one arm is included then outer body materials will be secured within the housing (to determine any high altitude issues with them) but will not serve as an outer covering over the servos.

While this is a preliminary design and the payload sizing and arrangement may change, the mass and power specifications will remain within the limits of +30 VDC at 2.5 amps and 20 kg for the large payload.

| **Component** | **Mass (g)** | **Mass uncertainty (g)** | **Power (W)** | **Power uncertainty(W)** |
|---|---|---|---|---|
| GPS Module | 84 | 5 | 0.2 | 0.02 |
| Camera | 190 | 10 | 5.0 | 0.2 |
| Arduino Mega 2560 | 37 | 5 | 0.25 | 0.025 |
| Structure | 1000 | 40 | - | - |
| Arduino Extension Shield | 15 | 2 | 1.0 | 0.1 |
| Servo Low Torque | 45 | 5 | 5.0 | 0.5 |
| High Torque Servo | 231 | 15 | 3.0 | 0.3 |
| **TOTAL** | **1602** | **82** | **14.45** | **1.135** |

**Table 2.** Preliminary mass and power budget

**3.2 Payload Location and Orientation**

Our experimental objectives are independent of the physical payload location and orientation on the HASP gondola. While we have selected a location on Figure XX, the selection was arbitrary and any of the four large payload locations are suitable.

**4. Preliminary Drawings**

Drawings for a possible location, a possible alternate frame system for the servomotors, and mounting plate are provided.

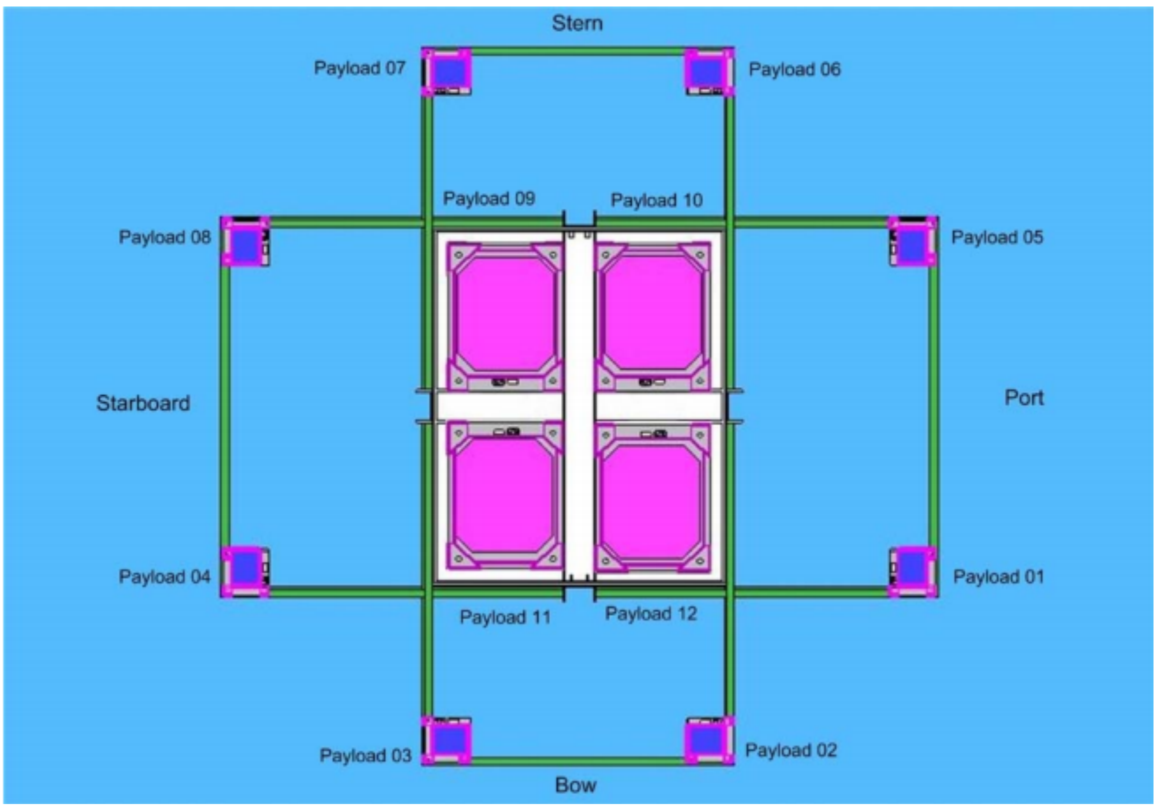



Figure 11: Possible location

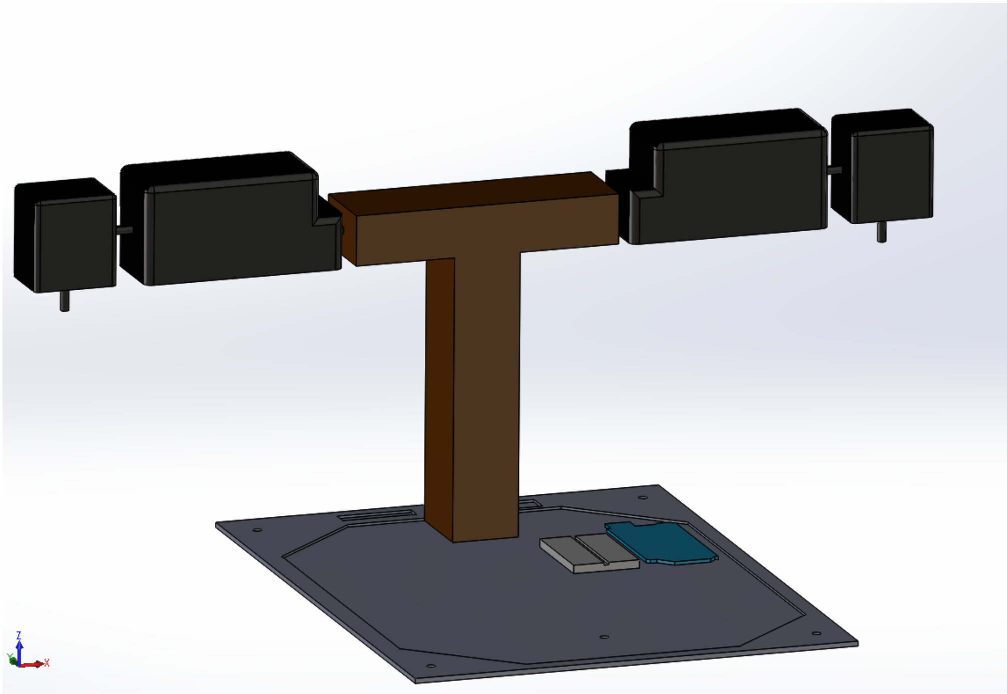


**Figure 12:** Possible smaller frame for servos

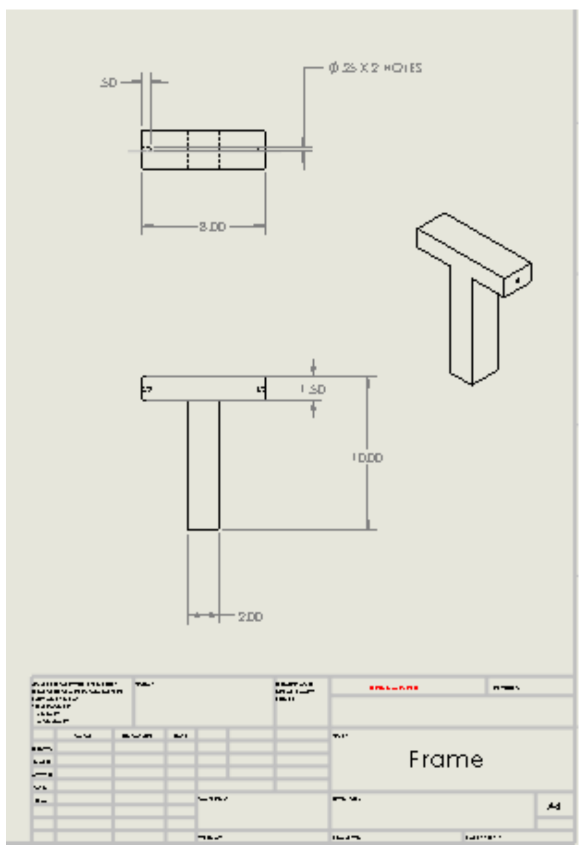



**Figure 13 Frame schematic**

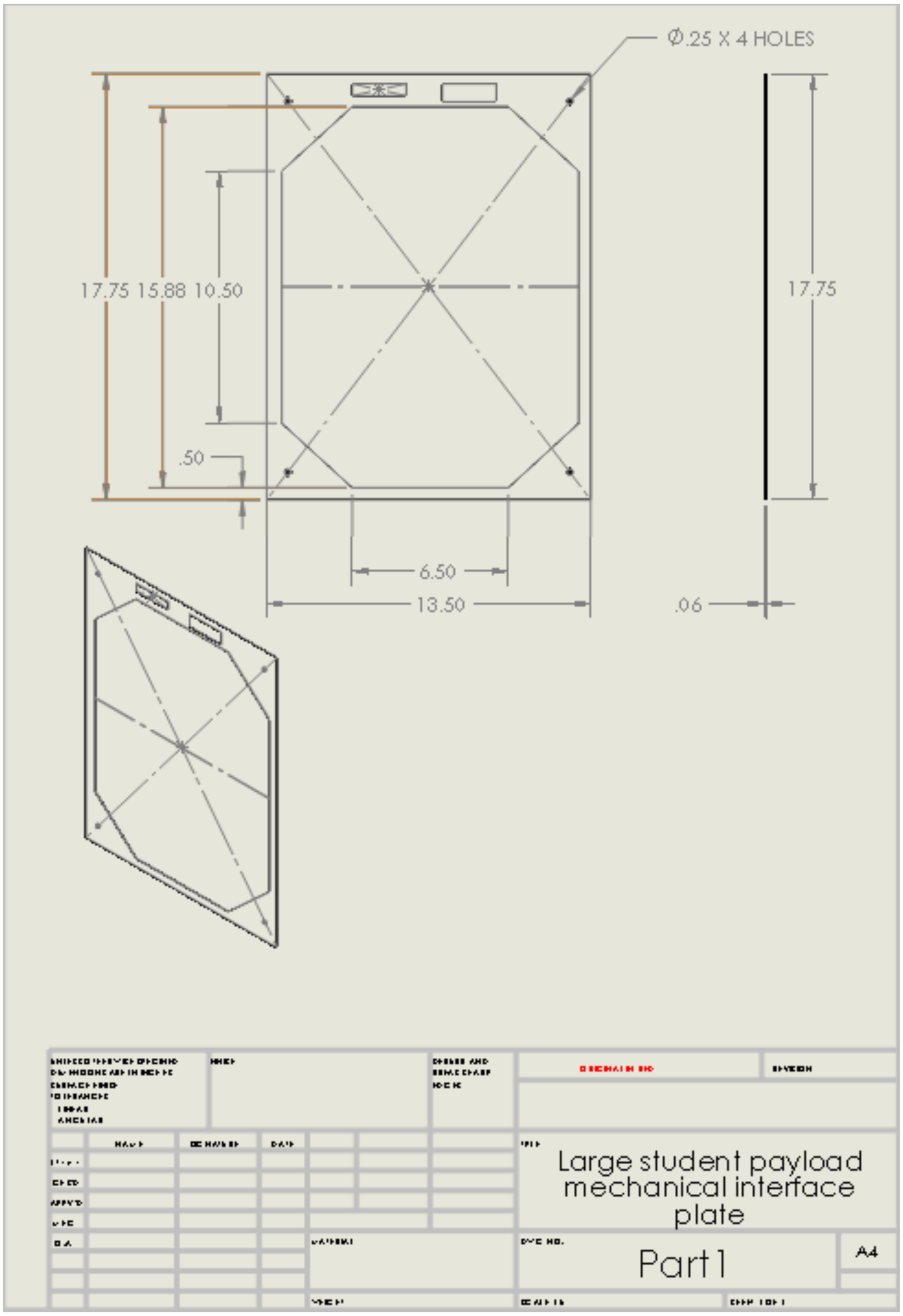
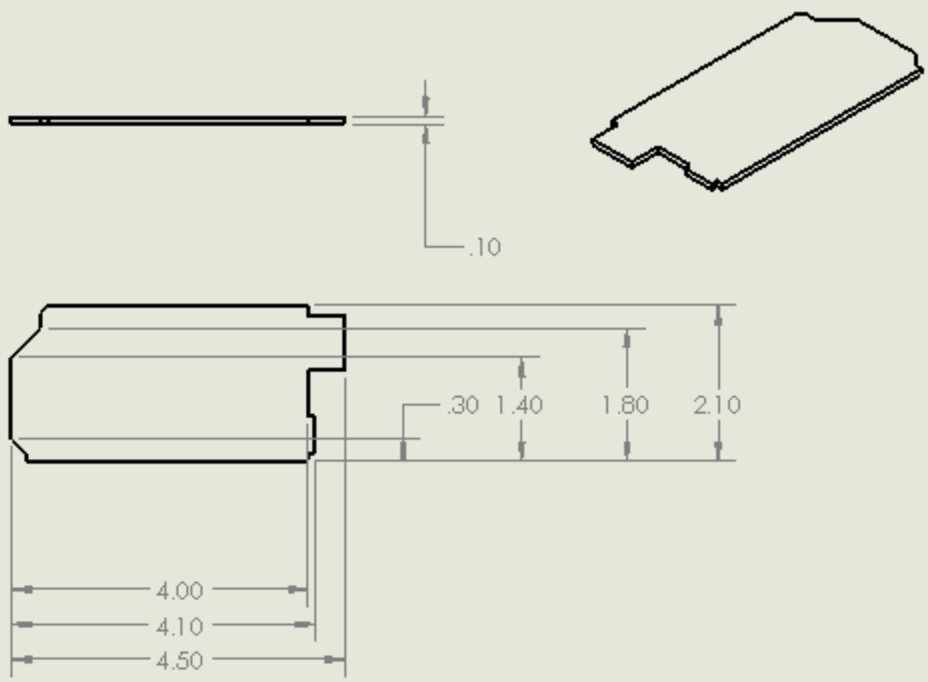



**Figure 14:** Plate for large payload

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| | | | DRAWING TO SCALE | | | |
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| MFG | | | | | | |
| Q.A | | | | MATERIAL: | DWG NO. Arduino | A4 |
| | | | | WEIGHT: | SCALE:1:2 | SHEET 1 OF 1 |

**References**

**References**

1. Department of Education, Arts in Education program, http://www2.ed.gov/programs/artsedmodel/index.html

2. Wolftrap Foundation, Puppets in STEM, http://articles.chicagotribune.com/2014-05-19/news/ct-stem-kids-district-15-tl-nw-20140518_1_math-and-science-concepts-arts-program-kids