University of Bridgeport HASP Servo-Motor Testbed

INTRODUCTION

The University of Bridgeport HASP Servo-Motor Testbed project focuses on the testing of critical components for the next phase of a high altitude robotic puppet that will be used on Near Space balloon missions to engage young 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).

The purpose of this flight has been to test hobby grade electronics and servo-motors in a Near Space environment. There are seven servo-motors of different sizes and manufacturers. These servos activated, measuring the speed of movement and energy required. There was concern that lubricant could leak or freeze or that the servo-motor gear boxes could rupture in the vacuum of Near Space.

This testbed tested the effect of low temperature on the servos, and determined at what point they might fail. The HASP flight also tested an Arduino Mega 2560 processor, a Byonics high-altitude GPS, an Adafruit 16- channel 12-bit PWM driver board, and analog and digital temperature sensors.

The inside of the flight package contained nichrome wire heaters, and part of the experiment was to determine how much energy is needed to maintain a variety of temperatures. Servos are tested one at a time, once per minute. Each servo is commanded to its maximum position, and as it moves the current it uses from the 6V supply is measure 100 times per second until it stops after about 0.5 seconds. Commands were developed to operate and control the servos function well at the low temperature.

The test has helped the team understand and select the specific servo-motors to use in the full-scale robot and understand the temperature requirements for the future flight operations.

The results will assist us in creating the prototype for our future High Altitude Monkey (HAM) robot project. The future robotic puppet will interact with young students during high altitude balloon flights at the Discovery Museum and Planetarium. While the robot itself is up in Near Space “collecting data”, Museum educators will actually control it on the ground.

PAYLOAD PERFORMANCE

Seven servo-motors were placed in two arrangements – four in a tray and three on the robotic arm. There was concern that lubricant could leak or freeze or that the servo-motor gear boxes could rupture in the vacuum of Near Space.

Lubricant leakage: At Fort Sumner, the team reopened the HASP container and checked for any lubricant leakage. None was found on any of the seven servo-motors.

The nichrome heating system operated as planned – we were very pleased.

One of the mentors had suggested a "verbose" feedback system. This was very helpful in determining and isolating problems.

Since we might only be able to execute a commend once every 12 minutes, the team programmed the Arduino to handle most functions.

As we mention in Problems Encountered Servos 1, 2, 3 failed during the test as the temperature dropped, but restarted as the temperature became warmer.

PROBLEMS ENCOUNTERED

1. Technically, we observed issues with Servos 1, 2 and 3 during the thermal/vacuum test. As the temperature became colder those servos stopped operating. However, as the temperature heated up, they began to function normally again. However, this was what we sought to learn – so we considered this a successful test. We attributed this to the cold temperature versus gearbox rupture, since if the gearboxes had ruptured we would not anticipate the servos returning to full operation – which is what they did.

2. There was an unexpected issue; a key project faculty member resigned from the university two weeks before the Fort Sumner launch. Unexpected expenses were incurred for travel. The faculty member was anticipated to rent a car with his grant funding, but without him travelling those funds were no longer available. Connecticut Space Grant was able to allocate some additional funds to cover a student car rental (more expensive). Workloads had to be shuffled at the last minute and another university faculty members was not able to attend.

3. There was a difference of opinion between one of the team mentors and the university PI regarding modification of the four tray servo-motors while in Fort Sumner. The mentor modified the electronics without permission and unfortunately the modified configuration was not operational. When contacted the PI asked that the four servos on the tray be shut down, and to operate the flight test on the remaining servo-motors on the robotic arm. Everyone agreed that it was more important to have a flight experience, than to have all seven servos functional. While the overall test results were successful, frank conversations were conducted when the team returned between the Museum director and UB staff.

4. No other problems were encountered. Students, faculty and mentors all understood that many times the original design may not work, and team members were perseverant. We had a great team – great performers – folks got along.

LESSONS LEARNED

On documentation: the team learned not to vary from the specific sample template instructions. 3D CAD drawings were not required but 2D drawings with clear dimensions and notations are. We need a repository for all documents so that students involved in HASP in the future can have access to these documents and "lessons learned". Dr. Pallis is working to determine if CANVAS

can be used and create a “HASP” class. The PDR should be continually updated – having to document all changes would have saved the team money in that we would have planned more and spend less.

Technically: the students working in thermal control had limited experience with nichrome wire, so it was a great learning experience. More computer science and electrical engineering students should be on the team.

SCIENCE TECHNICAL RESULTS

The three servo-motors on the robotic arm (Servos 5-7) were operational during both the thermal/vacuum test in Palestine and the fight test in Fort Sumner. The four servo-motors in the trays (Servos 1 – 4) were only operational during the two thermal/vacuum tests in Palestine and were not operational (intentionally) during the flight test in Fort Sumner (see Problems Encountered).

Both sets of data – Palestine and Fort Sumner were very useful.

During the Palestine tests servo-motors in the tray began to fail as the temperature dropped. These were the less expensive motors.

In the testbed tray were one of each: Servo 1: HS-485HB Servo Motor (Hitec); Servo 2: S3004 Standard Ball Bearing Servo (Futaba); Servo 3: HS-645MG High-Torque 2BB Metal Gear Servo (Hitec); Servo 4: HS 82MG 17G Metal Gear Micro Servo (HiTec).

On the robotic arm were: Servo 6 and 7: 2 Batan S1213 Servos and a Servo 5: Batan B2122 1.8kg ball bearing servo. The charts show the “swing” of the servos from one extreme position to the opposite side. Figure 1 Servo 1 shows a failure (all zeros) during part of the thermal/vacuum test. Figure 2 Servo 2 shows two major failures (servo “sticks” at 1000). Figure 3 Servo 3 shows a similar failure. Figures 4-7 show quite normal operation.

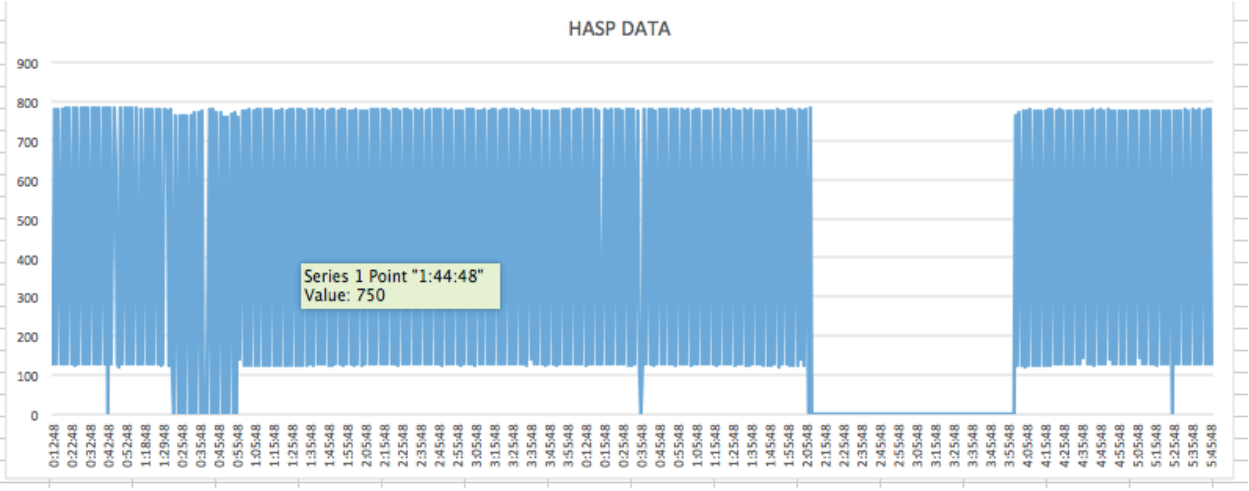

Figure 1 – Servo 1 Data

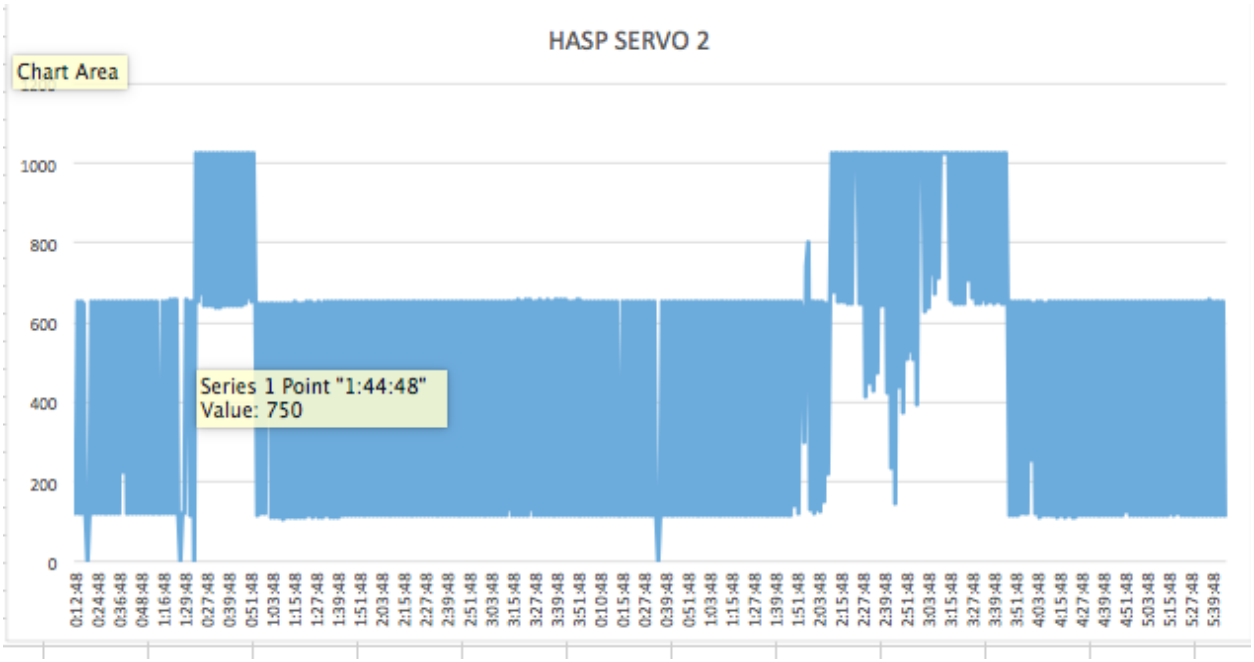

Figure 2 – Servo 2 Data

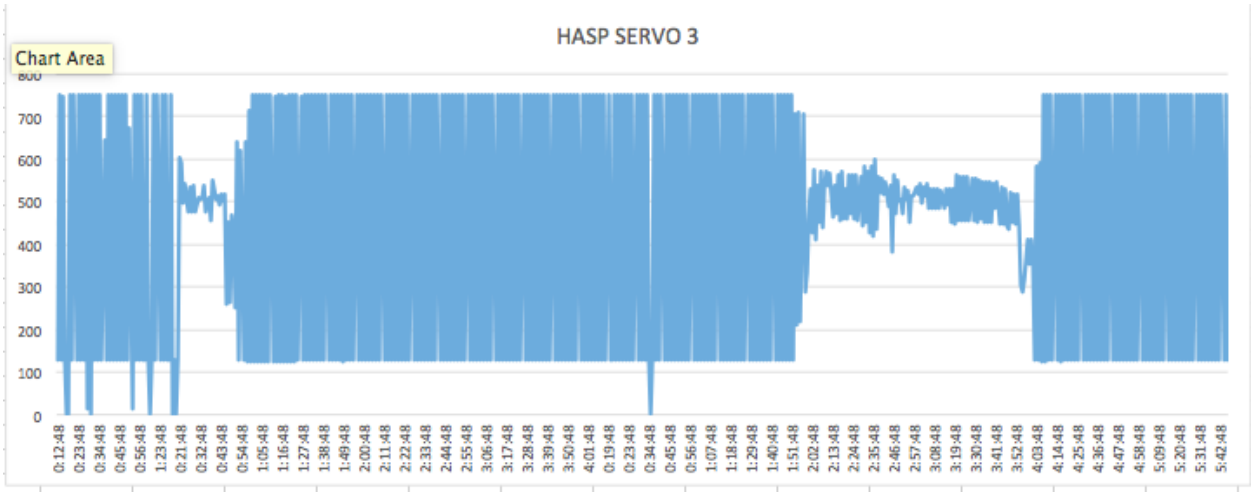

Figure 3 – Servo 3 Data

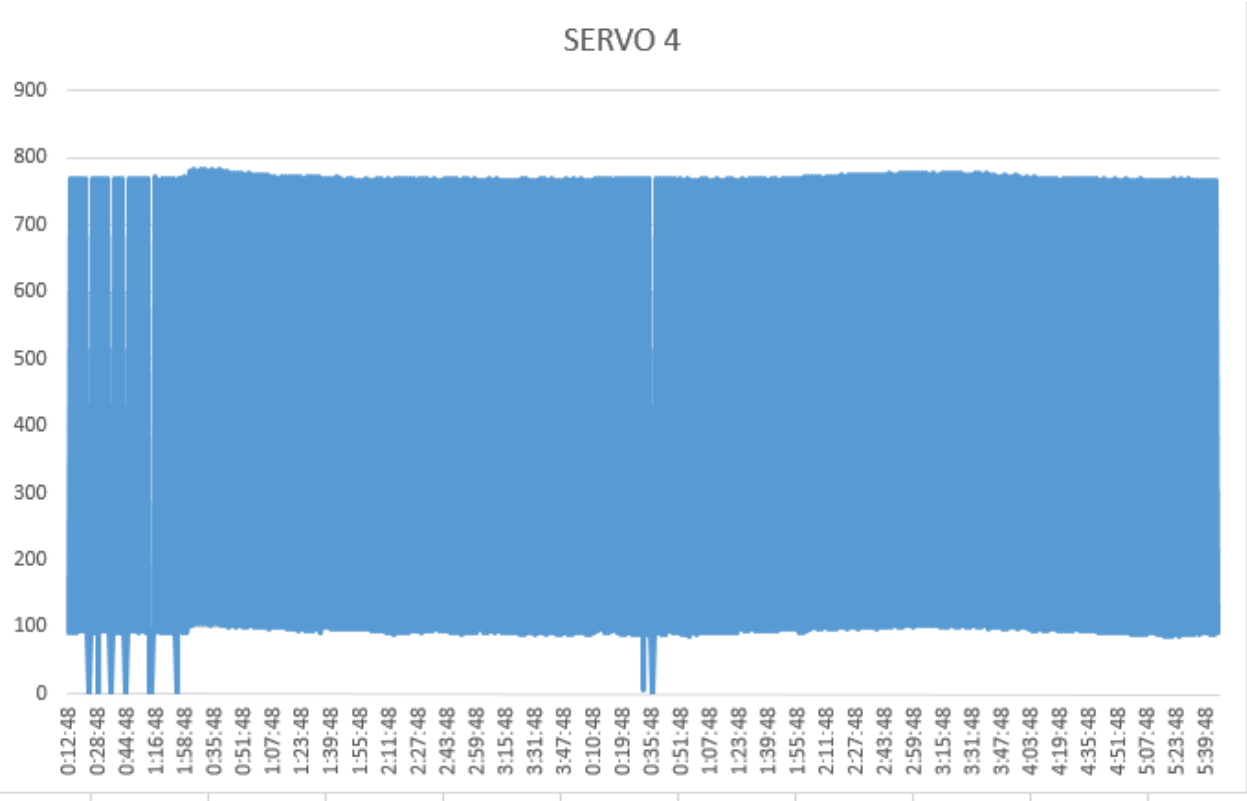

Figure 4 – Servo 4 Data

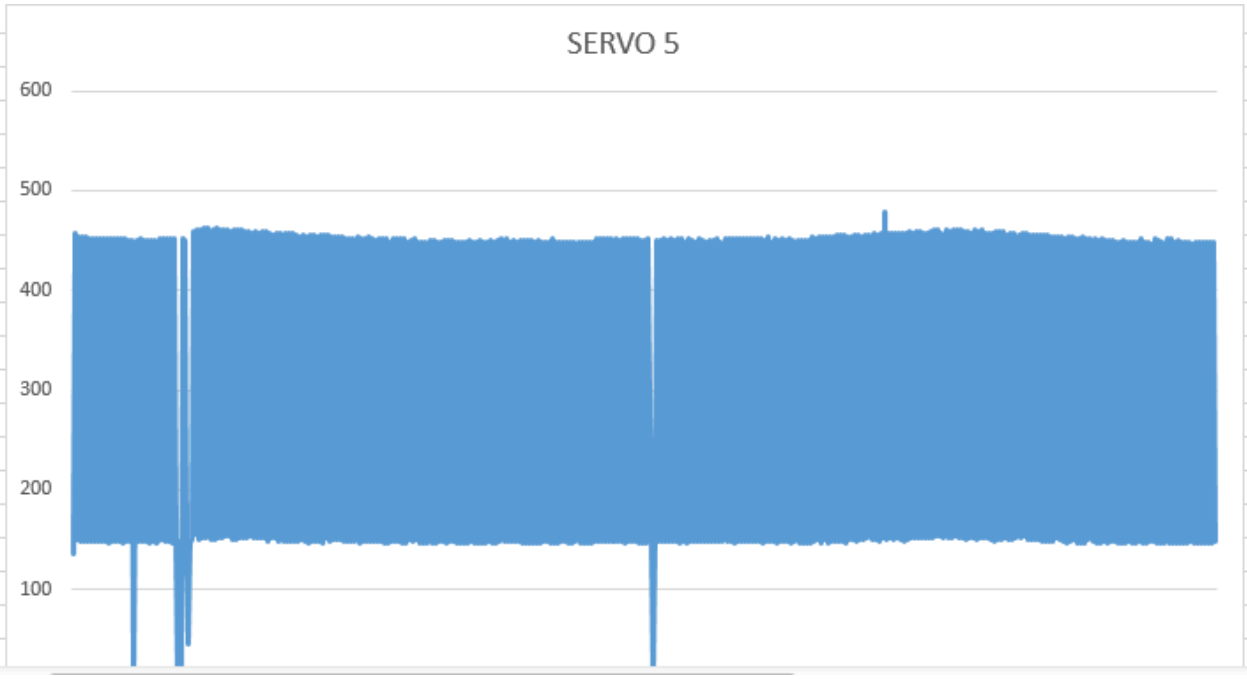

Figure 5 – Servo 5 Data

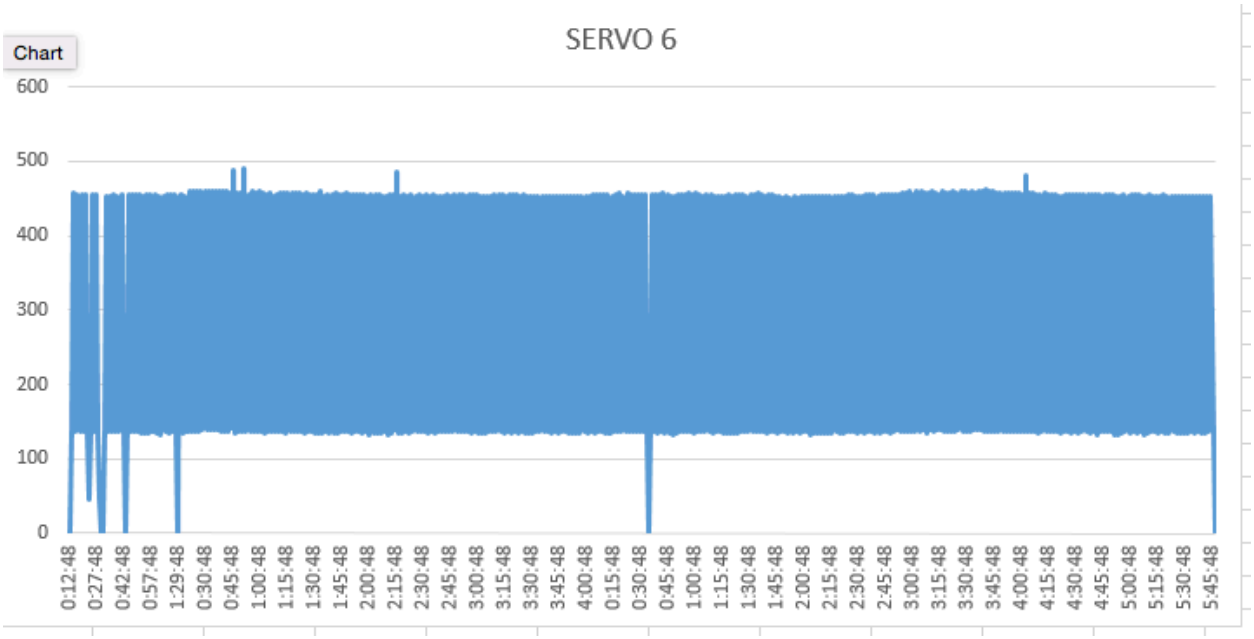

Figure 6 – Servo 6 Data

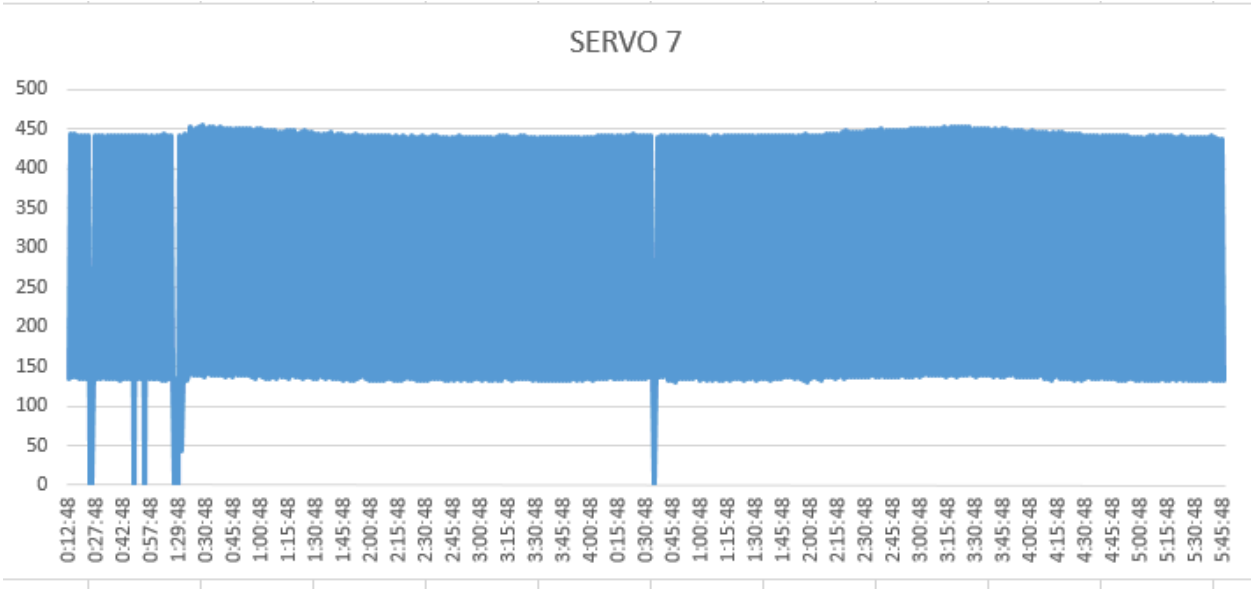

Figure 7 – Servo 7 Data

DEMOGRAPHICS

Students

• Bashar Alhafni: Undergraduate Student – Computer Science – Male – Caucasian – No Disability
• Phillip Carroll: Undergraduate Student – Industrial Design – Male – Caucasian – No Disability
• Joshua Hauge: Undergraduate Student – Industrial Design – Male – Caucasian – No Disability
• Abd Elfatah Karkory: Graduate Student - Mechanical Engineering – Male – Caucasian - No Disability
• Arjun Kumar: Graduate Student – Mechanical Engineering – Male – Asian - No Disability – Graduated May 2016 – employed as a mechanical engineer in non-aerospace company.
• Karan Kakanur Patel: Graduate Student – Mechanical Engineering – Male – Asian - No Disability
• Maheshwari Kumar Rakkappan: Graduate Student – Mechanical Engineering – Female – Asian - No Disability
• Rochen Krishna Thashanath Sajeevan: Graduate Student – Mechanical Engineering – Male – Asian - No Disability
Rishi Warokar (Graduate Student – Computer Science – Male – Asian – No Disability - Graduated May 2016 – employed as a mechanical engineer in non-aerospace company.
• Xuan Sam Zhang: Graduate Student – Computer Science/Electrical Engineering – Male – Asian – No Disability

Faculty and Mentors

• Dr. Jani Macari Pallis: Faculty - Mechanical and Aerospace Engineering – Female – Caucasian - No Disability
• Dr. Neal Lewis: Faculty - Technology Management - Male – Caucasian - No Disability
• David Mestre Education Partner - Discovery Museum and Planetarium:– Male – Hispanic - No Disability
• Lawrence Reed: Education Partner - Discovery Museum and Planetarium: Electrical Engineering – Male – Caucasian - No Disability
• James J. Pallis: Adjunct Faculty – Mechanical Engineering Design – Male – Caucasian - No Disability

POSTERS/PAPERS/PRESENTATIONS

Posters:

• High Altitude Student Platform, Dr. Jani Macari Pallis, Dr. Neal Lewis, Mr. Larry Reed, Mr. James Pallis, Mr. David Mestre, Bashar Alhafni, Sam Zhang, Phillip Carroll, Josh Hauge, Maheshwari Kumar Rakkappan, Karan Kakkanur Patel, and Rochen Thashanath Sajeevan. CT Space Grant Expo Date: October 14, 2016, Pratt and Whitney Museum Hanger.

• HASP (DATA), Dr. Jani Macari Pallis, Dr. Neal Lewis, Mr. Larry Reed, Mr. James Pallis, Mr. David Mestre, Bashar Alhafni, Sam Zhang, Phillip Carroll, Josh Hauge, Maheshwari Kumar Rakkappan, Karan Kakkanur Patel, and Rochen Thashanath Sajeevan. CT Space Grant Expo Date: October 14, 2016, Pratt and Whitney Museum Hanger.
• HASP (Testing and Experience), Dr. Jani Macari Pallis, Dr. Neal Lewis, Mr. Larry Reed, Mr. James Pallis, Mr. David Mestre, Bashar Alhafni, Sam Zhang, Phillip Carroll, Josh Hauge, Maheshwari Kumar Rakkappan, Karan Kakkanur Patel, and Rochen Thashanath Sajeevan. CT Space Grant Expo Date: October 14, 2016, Pratt and Whitney Museum Hanger.
• HASP (Robotic Arm), Dr. Jani Macari Pallis, Dr. Neal Lewis, Mr. Larry Reed, Mr. James Pallis, Mr. David Mestre, Bashar Alhafni, Sam Zhang, Phillip Carroll, Josh Hauge, Maheshwari Kumar Rakkappan, Karan Kakkanur Patel, and Rochen Thashanath Sajeevan. CT Space Grant Expo Date: October 14, 2016, Pratt and Whitney Museum Hanger.

Papers:
• Near Earth Heat Transfer Analysis: Experimental and Computational Results, Abd Elfatah Karkory, Master's Project, December 2016, University of Bridgeport.

Presentations:
• Phillip Carroll, Maheshwari Kumar Rakkappan, Joshua Hauge, Jani Macari Pallis, Ph.D., UB HASP Project, Presentation to the Board of Trustees of the University of Bridgeport, September 16, 2016.

• Maheshwari Kumar Rakkappan, Xuan "Sam" Zhang, Discovery Museum and Planetarium, Aeronautics Day, October 15, 2016.

• Maheshwari Kumar Rakkappan, Xuan "Sam" Zhang, UB ENGR 100X – Introduction to the Field of Engineering, Fall 2016.

• Maheshwari Kumar Rakkappan, Xuan "Sam" Zhang, UB MEEG 470 - Satellite Design and Technology. Fall 2016.

FUTURE WORK

The successful tests on HASP have aided the team in its final selection of servo-motors for the full-scale robot and its design.

We are pleased to share that the continuation and next steps of the robotic puppet project will be funded and supported under an Undergraduate Student Instrument Project (USIP) award of approximately $200,000 from NASA to Connecticut Space Grant. When the team applied for the USIP grant, they did not recognize that under USIP the same Palestine, Texas and Fort Sumner, New Mexico facilities could/would be used.

The HASP program has provided an important experience that has prepared us to successfully utilize these facilities on USIP. Additionally, this project has integrated "capacity building" for our state. The UB team will be working with faculty and students from the University of Hartford and Wesleyan University, who will be joining us at these Columbia Scientific Ballooning Facilities. We're glad to share with them.

LAST THOUGHTS/COMMENTS/FEEDBACK

Several of the HASP team members have participated in other aerospace projects and competitions, such as CanSat. We'd like to share that over all the other PDR/CDR templates, we prefer the PSIP and FLOP LSU HASP documents and templates. Adapted templates have now become the standard for all projects in our aerospace club and in Dr. Pallis's Satellite Design class. We're using them for our "Eclipse Pointing" concepts for the Solar Eclipse Project.

We feel that the HASP experience, successful test and now the award of the USIP has also given great credibility to our student's work at our university. Students want to be a part of our Aerospace Club projects. Dr. Pallis has also reported that one of the university's recruiters in India has shared that these projects are one of the main draws of aero students to the graduate mechanical engineering program at the University of Bridgeport.

This was our first time on HASP. At times we did not understand documents or what was requested of us. We wish that there had been a "mentor" for first time HASP participants. Sometimes when criticism was given in the monthly meetings the students (and mentors) did not feel comfortable asking questions.