HASP Student Payload Application for 2019

Payload Title: Robotic Arm Materials Matching and Manipulation: RAM3.1		
Institution: Durham Tech, UNC Charlotte, Colorado University of Boulder, and North Carolina State University		
Payload Class (LARGE):		Submit Date: 12/14/2018

Project Abstract: The need for satellite maintenance is growing as established satellites run out of fuel and degrade in the harsh environments of space. NASA's Satellite Servicing Projects Division (SSPD) is developing unmanned craft to provide a lower-cost, lower-risk method of extending legacy satellites' lifetimes. While only two active satellites are designed for maintenance, the next generation, including the James Webb Space Telescope, plan to leverage robotic refueling and maintenance. Our 2018 experiment for HASP tested relatively low-powered, semi-autonomous robotic dexterity, running repeated iterations of tests that require precision actuation, computer vision, and force-torque sensors. A robotic arm performed simple tasks such as toggling switches, twisting objects, and opening/closing velcro flaps as one might while refueling a satellite on-orbit. RAM 3.1 will test a series of small cameras for potential use on RAM. The purpose of this experiment is to find the best camera to use to read the APRIL tags and observe the effects of glare. The reading of these tags is integral to the arm being able to complete its tasks. Throughout the flight, we will measure any degradation in performance, response time, and accuracy. We will also test the efficacy of computer-vision in different lighting conditions.

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RAM3.1 An Investigation of Visual Fiducial Systems in Low Orbit

LaSPACE & NASA's Balloon Project Office

HIGH ALTITUDE STUDENT PLATFORM

CONTENTS

1. Abstract

The need for satellite maintenance is growing as established satellites run out of fuel and degrade in the harsh environments of space. NASA's Satellite Servicing Projects Division (SSPD) is developing unmanned craft to provide a lower-cost, lower-risk method of extending legacy satellites' lifetimes. While only two active satellites are designed for maintenance, the next generation, including the James Webb Space Telescope, plan to leverage robotic refueling and maintenance. Our 2018 experiment for HASP tested relatively low-powered, semi-autonomous robotic dexterity, running repeated iterations of tests that require precision actuation, computer vision, and force-torque sensors. A robotic arm performed simple tasks such as toggling switches, twisting objects, and opening/closing velcro flaps as one might while refueling a satellite on-orbit. RAM 3.1 will test a series of small cameras for potential use on RAM. The purpose of this experiment is to find the best camera to use to read the APRIL tags and observe the effects of glare. The reading of these tags is integral to the arm being able to complete its tasks. Throughout the flight, we will measure any degradation in performance, response time, and accuracy. We will also test the efficacy of computer-vision in different lighting conditions.

2. Project Overview

2.2 Overview

In 2015 Durham Tech formed a team for a sounding balloon competition called "The Unacceptable Risks." The Unacceptable Risks (tUR) worked together on their balloon payload for an academic year, and many of the students from this team graduated from Durham Tech and transferred to local universities, including UNC Charlotte, CU Boulder, and North Carolina State University.

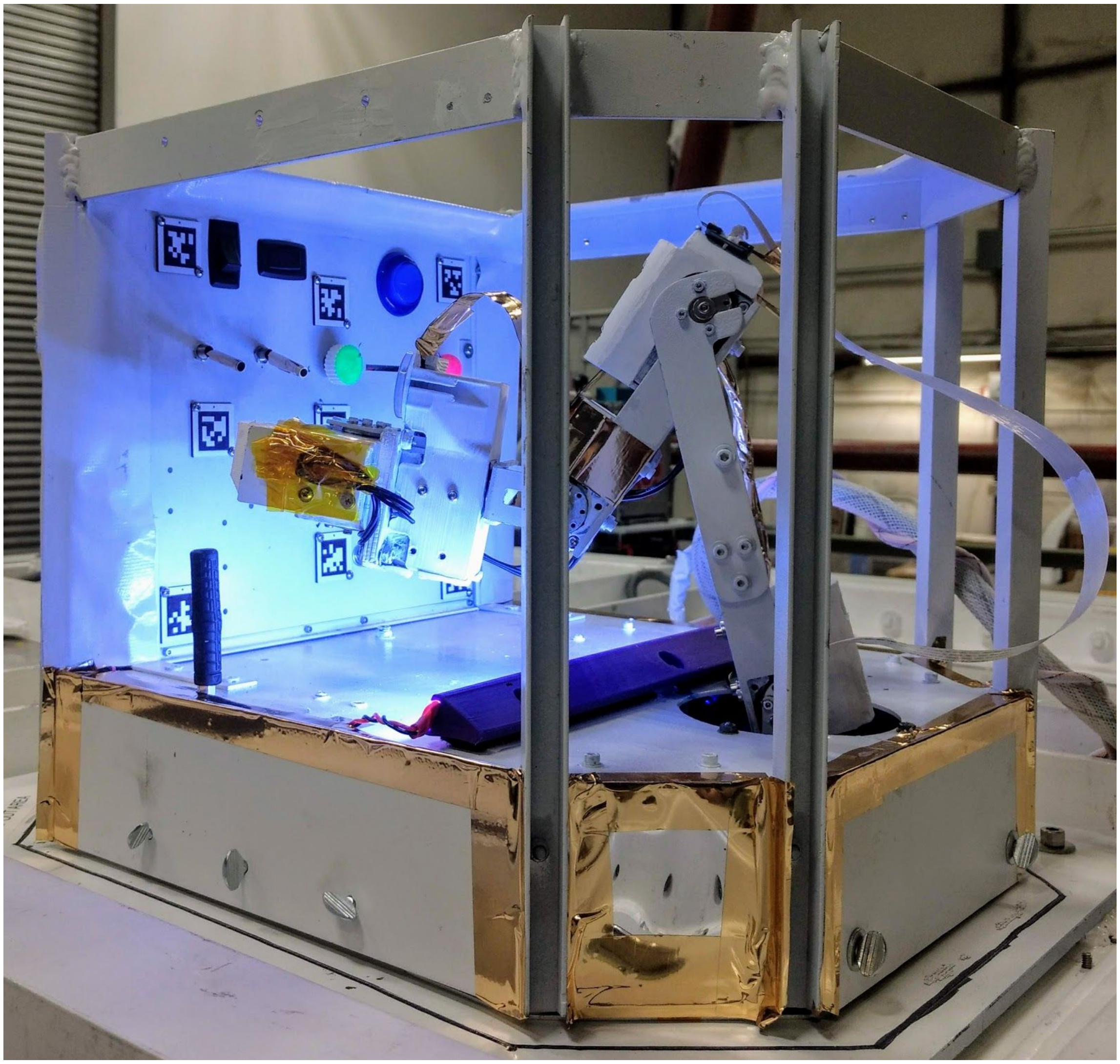
Satellite servicing is a growing need as established satellites begin to show signs of wear and tear in the harsh environment of space. Robotic arms are being engineered by NASA's Satellite Servicing Projects Division (SSPD) to provide a lower-cost, lower-risk method of repairing delicate equipment. Sophisticated unmanned robots will play a significant role in all future space exploration, especially as we complete the journey to Mars.

Our 2018 experiment for HASP tested the limits of low-powered, semi-autonomous robotic dexterity, running repeated iterations of tests that require precision actuation, computer vision, and Autonomy, Perception, Robotics, Interfaces, and Learning (APRIL) tags, over the course of a 12- to 18-hour flight in the stratosphere. Robotic Arm Manipulation and Materials

Matching (RA(M3)) was a mission that engineered a robotic arm that was mounted to our payload. This arm performed simple tasks such as toggling switches, twisting objects, and opening/closing velcro flaps as one might while refueling a satellite on-orbit.

This year we are applying with RAM3.1. RAM3.1 will focus exclusively on correcting the errors we discovered in our RAM launch and will test a series of small cameras for potential use on RAM. The purpose of this experiment is to find the best camera to use to read the APRIL tags, which are located on the busy box. The reading of these tags is integral to the arm being able to complete its tasks. A potential concern is that due to shadows and poor lighting, a low res camera might not be able to read the tags, therefore not sending the right command to the arm. We will fly three camera brands, and three of each camera. We will test the cameras in natural light and with artificial light. If the float extends into the nighttime hours, we will also observe the camera performance in darkness. Our experiment evaluates the impact of extended use in extreme conditions; the experiment will be in direct and uninterrupted sunlight, and heating/cooling must be carefully controlled in the absence of a convecting atmosphere.

RA(M3) supports all of the NASA mission directorates. Aeronautics Research will be necessary in order to provide a payload that will function in near space; students will run regular mechanical, electronic, and thermal tests as learned while working at NASA facilities. Robotic arms are helpful for Human Exploration and Operations; they lower the risks to human personnel by providing a way to service equipment, collect materials, grasp tools, and manage resources remotely. NASA is pairing robotic arms alongside human exploration as a sensible multiplier for human assets, used with many scientific applications, such as collecting soil on Mars, placing seismic instruments, and measuring atmospheric gases. Finally, robotic arms and computer vision are increasingly essential tools in Space Technology for fully-autonomous operations where latency or the environment make it impractical or dangerous to involve human controllers.



*Testing RAM before the 2018 integration

During the first two years of HASP, we have learned about NASA workflow, documentation, SolidWorks, travel logistics, budgeting, fundraising, personnel management, networking, and working with vendors. We have compiled a Post Launch Assessment Review to guide us in making improvements to our project this year. We have chosen a payload that, while still of use to NASA and the scientific community, is also more in line with the interests, hobbies, skill sets, and career goals of the team. This design will also allow us to do more conclusive testing on the ground so we will have a clear picture of how our hardware will perform during launch. We are starting with a much smaller scope and building in stretch goals. In case we meet or exceed our initial goals, we will then move on to the stretch goals; this stands in contrast to last year, where we started big and then dialed it back. This project also allows us to be self-sufficient and construct our experiment from scratch so that we will not have to rely on costly outside suppliers, arcane and unreachable tech support, or finicky and specialized hardware.

From the very beginning of the RAM3 project, our goal has been to have a robotic arm capable of performing tasks without any direct input from a user or from being hardwired into the programming operating the arm. We planned to accomplish this through a camera system mounted on the arm and gripper. Using this camera system and a series of AprilTags positioned near each of the items we want the arm to interact with, we hope to make this a reality.

AprilTag is a visual fiducial system that is useful for robotic but especially useful within our project because of the complete autonomy it allows us to have over our robotic arm once launched when we no longer have direct control.

A fiducial marker or AprilTag (Fig.1) is a small object with a black and white pattern that is placed in the field of view of a camera, that once an image is produced and processed, can be used to trigger a sequence of instructions that have been programmed into the base code of the overall system.

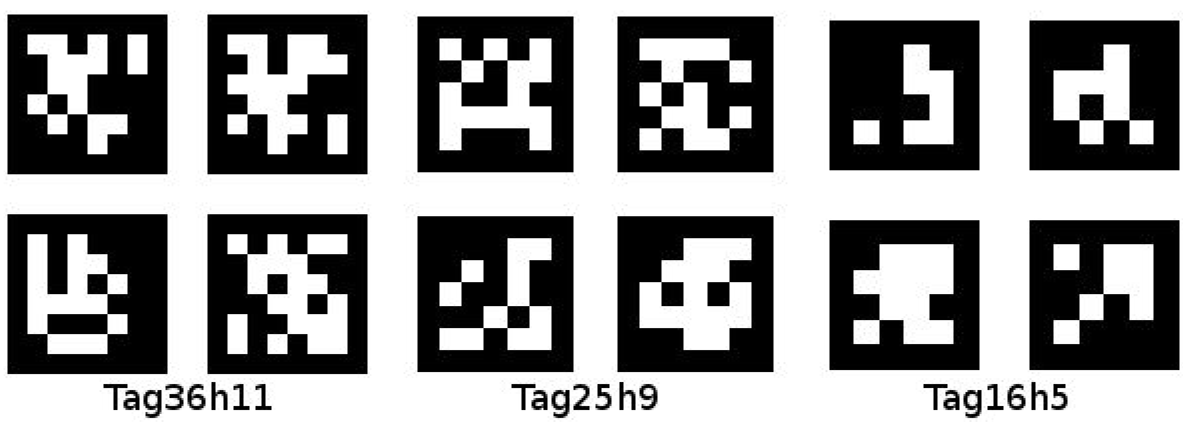


Fig.1

During ascent, as well as when the payload reaches float altitude, the payload will experience long periods of dark shadow followed by incredibly bright solar glare, we are concerned about what effects this will have, how severe these effects might be on the camera system and the overall impact on the ability to read AprilTags. Due to the intense black and white coloring of the tags, this seems to be a reasonable concern. Ultimately, we are unsure just how drastically unfiltered sunlight might alter the camera's ability to read the AprilTags.

We plan to address these concerns by flying an array of cameras from multiple manufacturers with various specs. The array will be double-sided, one side will face an AprilTagged board with just ambient light as the light source, whereas the other side will also face an AprilTagged board but will receive help from a small, powerful LED light source.

2.3 Methods

Because RAM3.1 is centered around whether various cameras can read AprilTags in extreme conditions, we have developed methods of testing for the cameras we are using along with what AprilTags they are reading so that we can adequately evaluate the performance of the camera. The information below provides additional information on the ins and outs of our testing and methods of testing.

- **Cameras We're Using:** All of the cameras that will be included on our payload are configured and sold by ELP; various manufacturers like Sony and Omnivision produce the sensors themselves. We chose to buy cameras from ELP because their configurations for the cameras are small, lightweight, powered by USB connections, have unique features that we can utilize for reading APRIL tags, and have a decent resolution on their images. The ELP camera models we will be using are USB3MP01H-L37, USB8MP02G-L75, and USBFHD01M-L21. For ease of naming, I will be referring to the models by their last three characters. For model L37, it has a size of 38 mm x 38 mm, mass of roughly 30 grams, max resolution it can run at 30 FPS is 1920 x 1080, lens has an 80 degree FOV, has plenty of adjustable parameters for images, has a lens correction feature, has black sun cancellation feature, temperature range of -20°C - 85°C, and needs a power supply of DC 160mA and 5V. For model L75, it has a size of 38 mm x 38mm, max resolution it can run at 30 FPS is 1024 x 768, but max resolution it can run at 15 FPS is 3264 x 2448, lens has a 75 degree FOV, has plenty of adjustable parameters for images, temperature range of -10°C - 70°C, and needs a power supply of DC 180 mA and 5V. For model L21, it has a size of 38 mm x 38 mm, mass of roughly 30 grams, max resolution it can run at 30 FPS is 1920 x 1080, but max resolution it can run at 60 FPS is 1280 x 720, lens has a 170 degree FOV, has plenty of adjustable parameters for images, has lens correction feature, has black sun cancellation feature, temperature range of -20°C - 75°C, and needs a power supply of DC 160 mA and 5V. For additional information about our cameras, please see our camera datasheets.
- **AprilTags We're Using:** AprilTags come in different shapes, complexity, and families. The AprilTag family we'll be using is 16h5. We're using this family because the shape of the tags aren't cryptic and easier for the camera to read. When our cameras reads AprilTags from the 16h5 family, it will initiate a command to our robotic arm.
- **Testing Criteria:** We primarily want the cameras to be able to function and read AprilTags in extreme environments. If we're able to accomplish that goal, then we will

test the abilities of the camera in other fields such as being able to read AprilTags despite not having sunlight or having an abundant amount of solar glare, if the cameras can read AprilTags from an angle, and a way to figure out the cause for a camera's failure to read an AprilTag.

- **Arrangement of Cameras: t**he cameras will be affixed in an array-like pattern with equal distance between each camera. The cameras will be attached to a flat surface and will face another surface with different AprilTags on them. On the AprilTag surface, we will have the tags in position so that they are directly in front of the cameras, to the side of the cameras, at an angle, tilted, etc. Keeping the cameras in a flat position while manipulating the position of the AprilTags is an efficient way to test the cameras ability to read AprilTags in unique cases
- **Expectations:** We are expecting our cameras to work sufficiently during the float. The cameras should be able to read the AprilTags during the night portion of the float without an issue. The cameras may have some difficulty reading the AprilTags from an angle and reading the AprilTags during excessive solar glare periods. In the event that a camera is not able to read an AprilTag, we want to know what is the source of the issue so that we can correct it in the future.

2.4 Science Goals

In order to know whether or not portions of our mission will result in failure or success, we have set aside a list of goals we are looking forward to accomplishing. If our cameras can read AprilTags despite being affected by UV rays, extreme temperatures, and with no data transferring difficulties, then we will consider this a success. If our cameras are malfunctioning and we are able to figure what is going wrong, we will consider that an important lesson learned. If our payload is able to descend back down to Earth intact, we will consider that a mechanical success. If our mission does conclude perfectly and some issues occur, then we will move forward professionally and efficiently to solve the issue as soon as possible without compromising the mission.

2.5 Concept of Operations

Our RAM^3 payload will be launched on an early September morning from CSBF in Fort Sumner, New Mexico. From there, the payload will be powered on. The estimated temperatures for this location at this time of the year will be 16°C. Once our payload crosses the tropopause, the temperature will drop down to a refreshing -55°C and the pressure will be around 10,000 Pascals. From here, the payload will coast in the stratosphere for roughly 8-16 hours while it performs functions on the cameras onboard. The chart below covers some of the expected temperatures, pressures, and the duration of the mission.

	Ambient Temp [˚C]	Pressure [Pa]	Expected duration
Early Sept. AM launch - Ft. Sumner, NM	15 to 25˚C	101,600	indefinite
Crossing tropopause	-55˚C	10,000	20 minutes
Float @ 120kft (30-35 km)	-30˚C	500 to 2,000	10 to 16 hours
Crossing tropopause	-55˚C	10,000	20 minutes
Impact	20 to 30˚C	100,000	instantaneous, we hope
Awaiting recovery	0˚ to 40˚C	100,000	4 hours to 3 days

2.6 Testing Plan

To ensure that all of our equipment works correctly during every aspect of this mission, we will put it through rigorous testing prior to the float. The chart below describes some of the types of testing we will conduct on portions of the payload that caught our attention and our methods of testing. All of the materials/equipment mentioned will be subjected to temperature and pressure testing before being installed onto the final payload. The devices that we will use for temperature testing is a Forma CO_2 Incubator, which can get up to temperatures of 55°C, and the Revco Lab Freezer, which can drop temperatures down to -80°C. The devices that we will use for pressure testing is a 3-gallon stainless steel vacuum chamber with a 3 CFM two-stage vacuum pump that is capable of reducing the pressure inside the chamber to 22.5 µmHg.

Type of Testing	**Method of Testing**	**Materials Used**
Whether or not the installed cameras will be able to read APRIL tags during the nighttime portion of the float.	On the ground, we'll subject our cameras to a fairly dark room with some APRIL tags to see how the cameras perform in darkness. If cameras don't do too well, we can	• LED light bar (Possibly) • 9 high resolution cameras • APRIL tags

	introduce a light bar to assist cameras. If the light bar is needed for the cameras to see the APRIL tags, then we'll have to install a light bar onto the final payload before the float.	
Will we be able to receive transmissions/information from the cameras when they are in operation?	We'll develop code and a method of receiving transmissions from the cameras through the use of downlinks from the Udoo X86 Ultra single board computer.	• Assorted materials that are used to make the data receiving device • Udoo X86 Ultra Single Board
Whether or not our cameras will be able to read the APRIL tags from an angle.	Before the float, we'll take the cameras, put them in a room with a suitable amount of light, and arrange them in front of APRIL tags that are placed at an angle. If the cameras are able to read the APRIL tags at an angle, we want to know what is the maximum angle at which the camera can read the tags. Once we figure out this information about the maximum angle, we'll see how well the cameras can read APRIL tags from an angle during the float.	• APRIL tags • 9 high resolution cameras
How will solar glare affect camera images and videos?	We can add certain filter or lens to the camera to	• Lens or filters • 9 high resolution

	reduce the amount of solar glare experienced by the camera. To see how badly the camera is affected by solar glare, we will attach the lens or filter to the camera is see how well it can read APRIL tags when the sun/intense light is in the background.	cameras
If or when an error occurs with the camera attempting to read an APRIL tag, how will we know what error occurred?	We can develop a method of having the camera take a picture of the APRIL tag when the camera attempts to read it or we can simply watch the camera's video feed when it attempts to read the tag. From here, we can evaluate the video or picture to see if there was too much glare, too low of a resolution on the camera, or too low of a temperature for the camera to function and read the tag.	● 9 High resolution camera ● APRIL tags
Will intense UV rays from the sun alter APRIL tags during the timespan of the float?	We can place some spare APRIL tags under a UV light during a duration of time to see how the tag is affected (i.e. discoloration). If we notice that the tags don't hold up too well under UV rays, then we can apply a gloss of UV-resistant epoxy	● UV light source ● APRIL tags ● UV-resistant epoxy (Possibly)

	to the tags.	

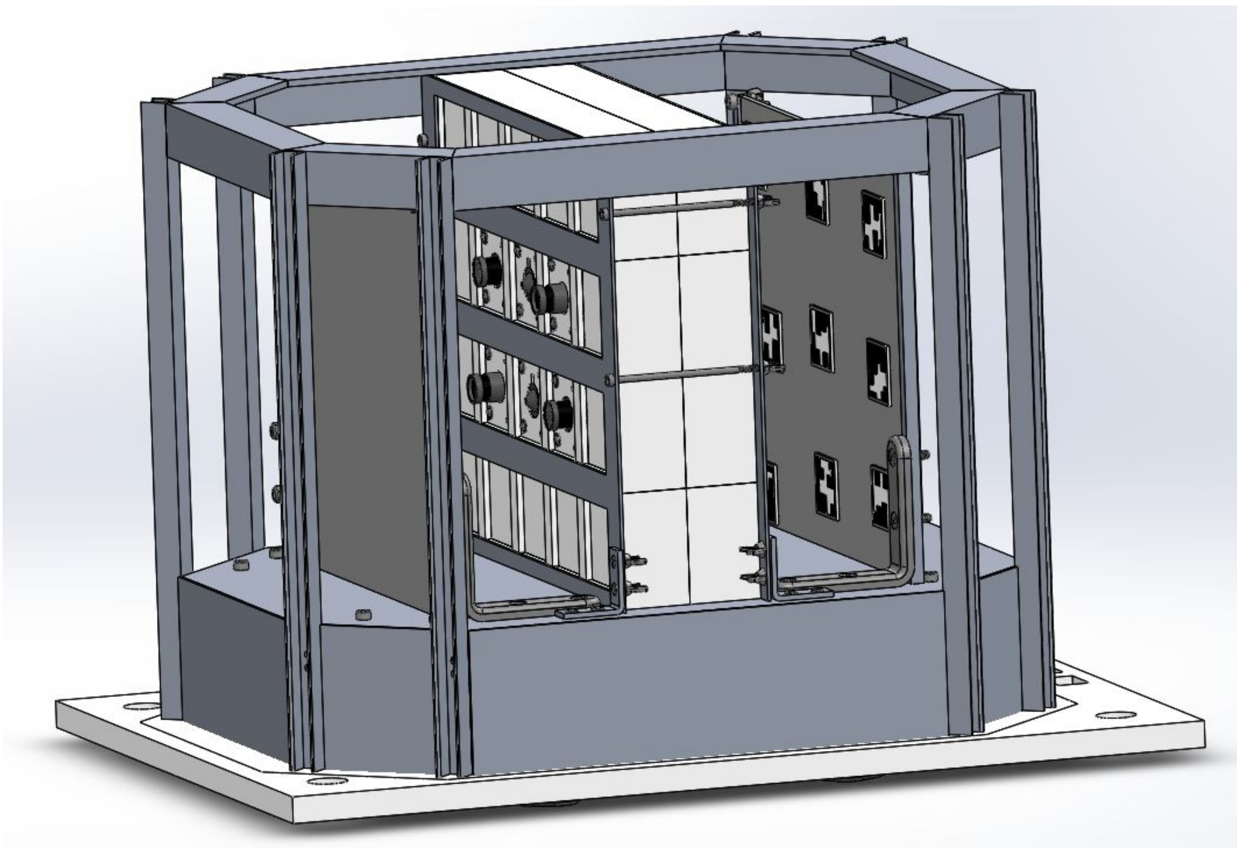


Fig 1. Overall View of payload

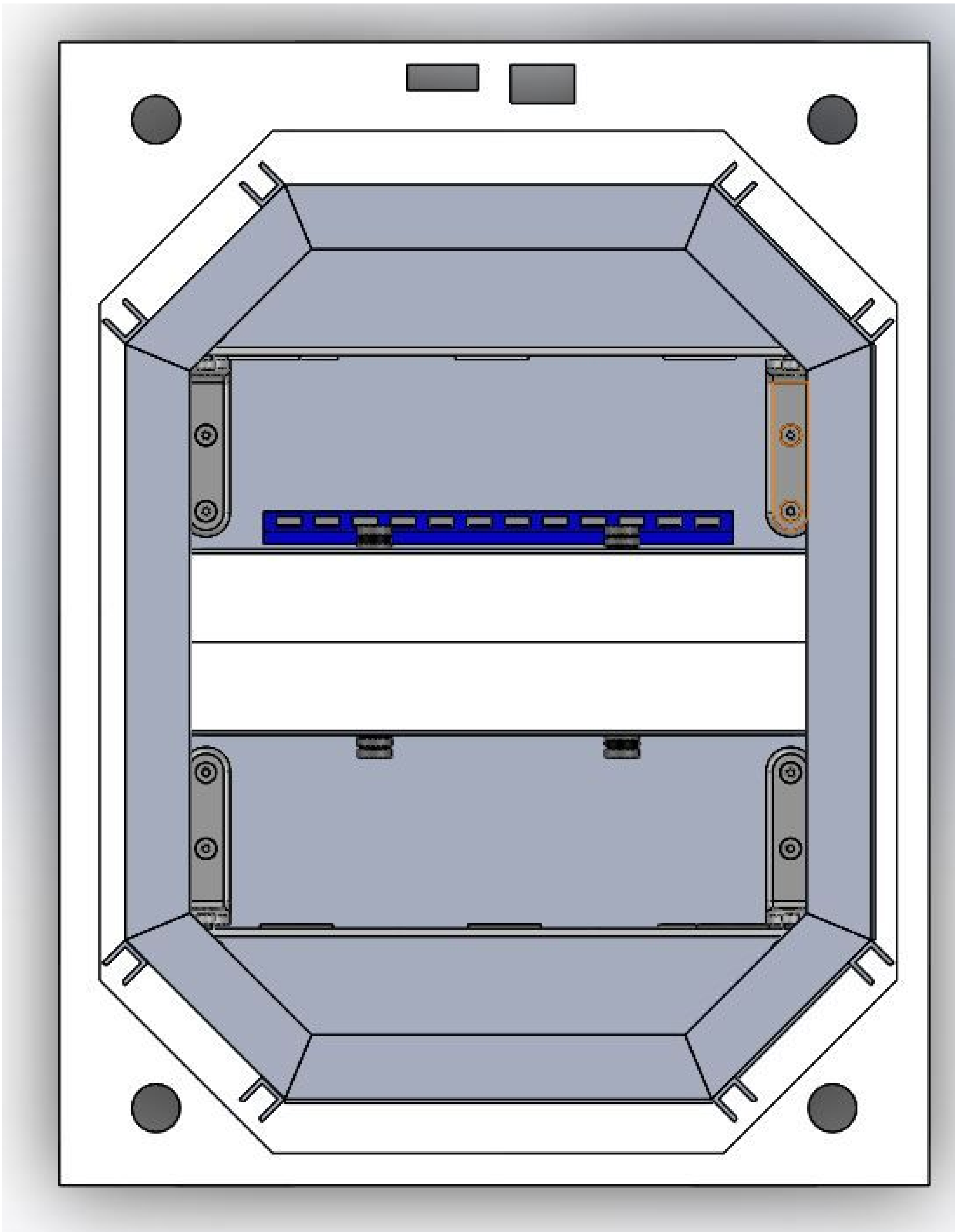


Fig 2 Top down view of payload

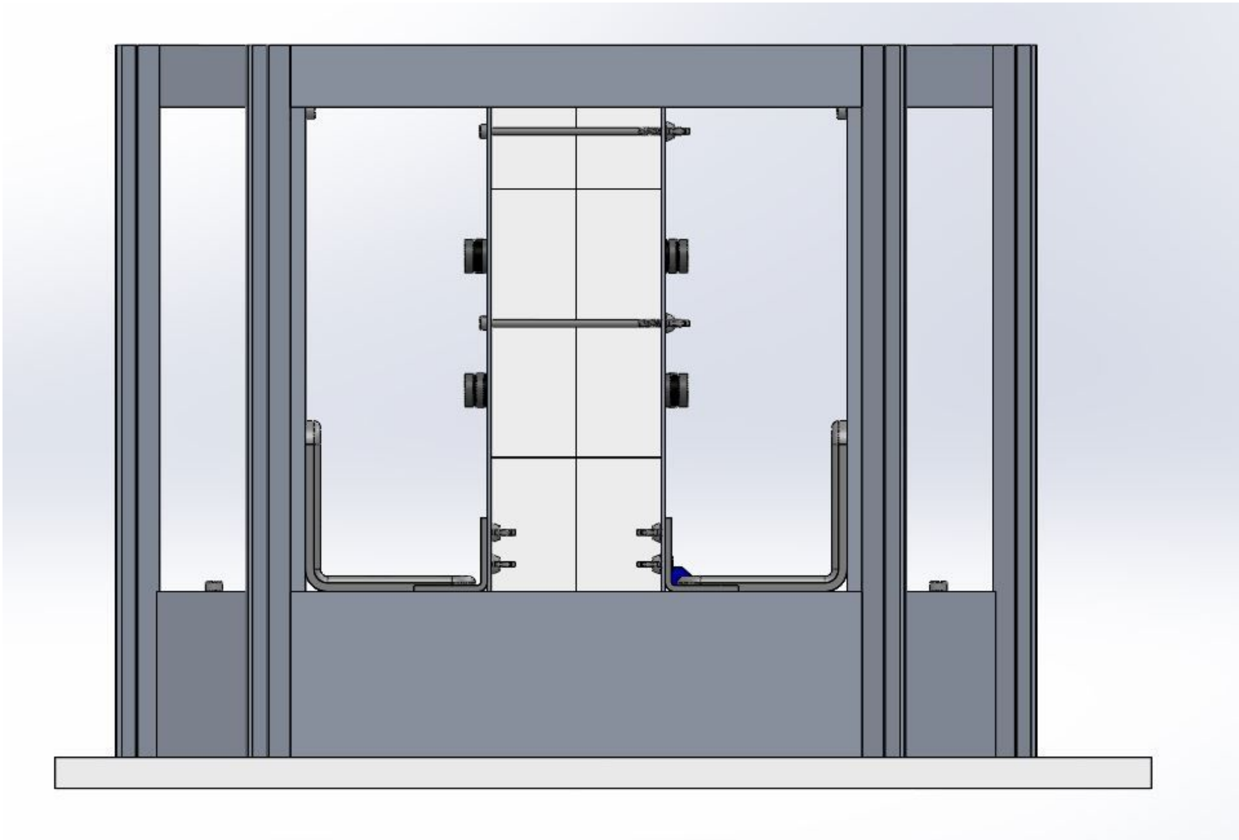


Fig 3 Side view of payload

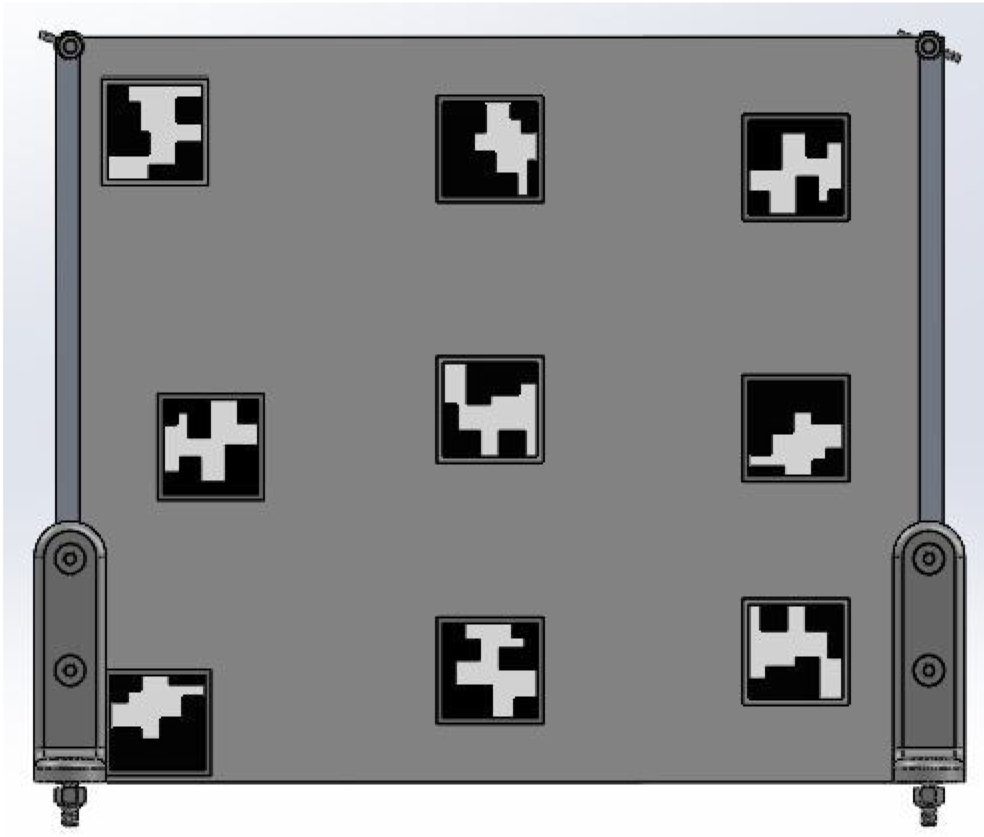


Fig 4 "Busy Box" with AprilTags

*Unlike our "Busy Box" last year, this years Busy Box will consist only of AprilTags. Positioned in predetermined spots the AprilTags will service as the visual fiducial system for this experiment.

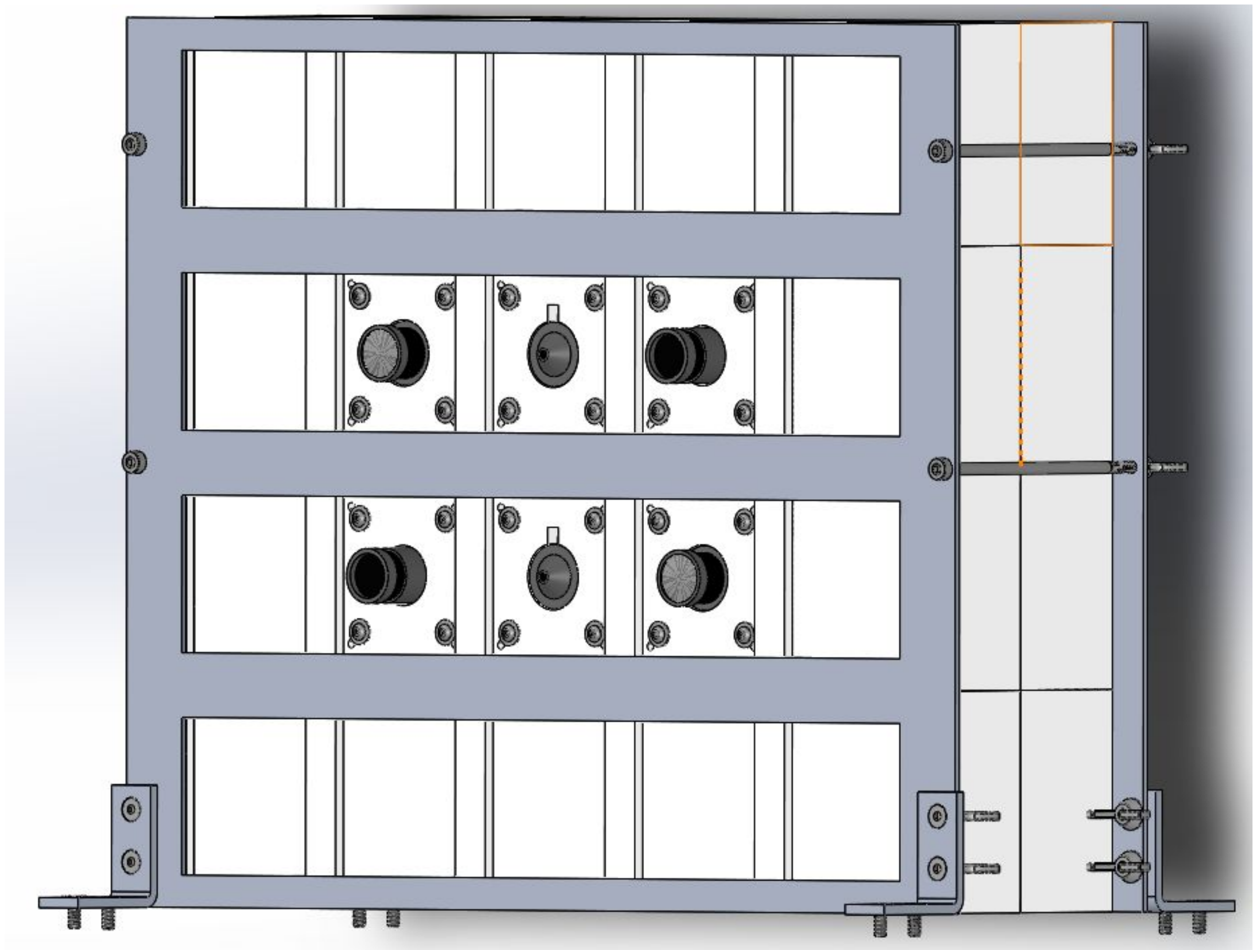


Fig 5 Camera Array with mounting hardware

*The camera array will be a locking 3D printed module mounting system supported by an aluminum frame to provide structure.. Configured to match that of a “Connect Four” game board, the array will have multiple slots in the 4 x 5 grid for cameras to mount to. During testing, we will assess each camera in various configurations to find the optimal layout of the cameras. Due to the different sizes of the cameras, we will have a mounting for each one that will allow it to fit into a universal location. The remaining locations will be filled with a placeholder which is designed with ample room for cables. This allows modularity for the ability to quickly and easily modify the mounts whenever we need, to help find the ideal position for each camera. 3D printing gives us the ability to quickly create and test different arrangements of cameras as well as change any other modifications needed like a slight angle or for one to extend closer to the busy box.

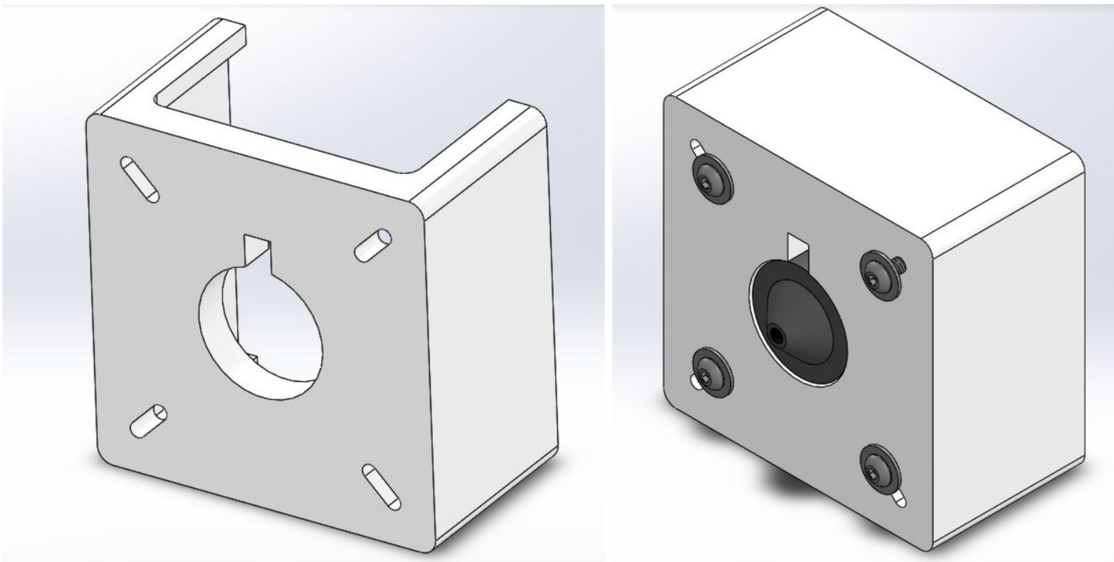


Fig 6 Camera cube

*Custom cube for camera (L) and camera mounted in cube (R)

3. Project Timeline

The team has weekly Google Hangout video conference calls.

November 16, 2018	Q & A Teleconference
December 14, 2018	Application due date
~January 14, 2019	Announce student payload selection
January –April 2019	Monthly status reports and teleconferences
January 2019	Application Revisions
January 2019	NCSU builds the mechanical payload, UNCC builds the electronics
February 9, 2019	Durham Tech Build Day
February - March 2019	Durham Tech Testing
April 15, 2019	NASA On-site Security Clearance Document due
April 26, 2019	Preliminary PSIP document due

June 2019	Mini-integration Testing
June 28, 2019	Final PSIP document due
May – August 2019	Monthly status reports and teleconferences
July 19, 2019	Final FLOP document due
July 15 – July 19, 2019	Student payload integration at CSBF *
August 25 – August 29,	2019 HASP flight preparation *
August 30, 2019	Target flight ready *
September 2, 2019	Target launch date and flight operations *
September 5 – Sept 8, 2019	Recovery, packing and return shipping *
December 6, 2019	Final Flight / Science Report due
September – November 2019	Monthly status reports and teleconferences

4. Design Specifications

4.1 Software

There is very little low-level software and almost no high-level software that will be needed to be developed by the team. As it is the team's third year flying on HASP, they have experience with microcontrollers like Arduino and Single Board Computers (SBC) like Raspberry Pi. This means that most of our software requirements for this flight are already either done or well outlined for this year's HASP flight--it is only a matter of fitting them to our present requirements.

With the team planning to run the UDOO Ultra x86, another SBC, software team will have the task of adapting our existing Raspberry Pi downlinking software to the UDOO, and adjust the data handling to accommodate our new types of data. As a large payload, our payload will take full advantage of the 4800 Baud Rate Serial Downlink (8 data bits, no parity, 1 stop bit and no flow control). Software team will focus on reading and downlinking one camera at a time. However, this does not take full advantage of the given bandwidth as it is unlikely that data will fill the baud rate provided. To fill the extra space, the software will attempt to downlink as many images as possible, and perhaps even video.

- **Overall Software:** The SBC, much like last year, will use the Robot Operating System (ROS) as the overall framework that connects all of our pieces of software together. This allows us to use a large quantity software that has been pre-produced and pre-tested (by us, from our flight last year, and other professional developers).
- **Cameras:** Since all of our cameras are USB operated, the team can use the same USB Cam ROS node that was used last year to read all the cameras. Also, the payload can

store images using the ROS Topic image snooping software that the team developed last year. A stretch goal for this node would be to develop it to handle taking highly compressed video.

- **April Tags:** To process the images in flight, the next generation of April Tag reading software for ROS will be used. Conveniently titled, “AprilTags2_ROS,” this version offers a more robust and optimized interface than its predecessor. It interfaces easily with the USB Cam ROS node.
- **Downlink and Uplink to HASP:** Software that was used for the Raspberry Pi last year will be modified to work with the UDOO’s GPIO capabilities and modified for our new packets. It will run on ROS, just like the version for the Raspberry Pi.
- **Downlink Packet:** The team will use its standard packet design that was used for last years payload, and modify it to meet our new priorities. The team, upon the recommendation of Dr. Guzik (“It’s always a mistake not to have human readable data.”) will add a 30-byte string that is human readable. This portion of the downlink will help us certify quickly and easily at Integration, and it will provide a method for the payload to password-based status messages in the data such as, “Connect Good,” “Payload Functioning,” or “Camera Error.” To handle the April tag data, a new sub-packet will be created for downlinking which April tags are being seen and by which camera.
- **Uplink Packet:** We expect the flight to be a mostly passive experience. We will implement commands to reset various camera buffers, but in general, we do not expect to send any commands. Most any issues that are encountered will likely be handled by a payload power on/off. The payload will also not require any GPS signal to be pushed to it. Our SBC this year has its own RTC and battery to power it.

"Data Packet"; assume a standard packet size of 520 bytes	Byte	Title
Simple '\x1\x21' header indicating the start of a new packet of data.	1-2	Header
8 byte time_t value: time data was sent from network manager to HASP gondola.	3-10	Time Sent Gondola
Single byte: number of different data chunks in the Data Packet section.	11	# of Data Chunks
Two bytes: total size of actual data represented in the Data Packet section.	12-13	Total Size of Data Chunks
Checksum / allows room for growth as the project develops.	14-20	Checksum / Filler
30 Bytes: Human readable string that can confirm general payload status, and allow for easy verification of serial downlink during Integration.	21-50	Human Readable Data

Actual meat of a packet. It could be any of the following: *- image data* *- april tag data*	51–518	Data Packet
Simple '\x3\xD' terminator indicating the end of a packet of data.	519–520	Terminator

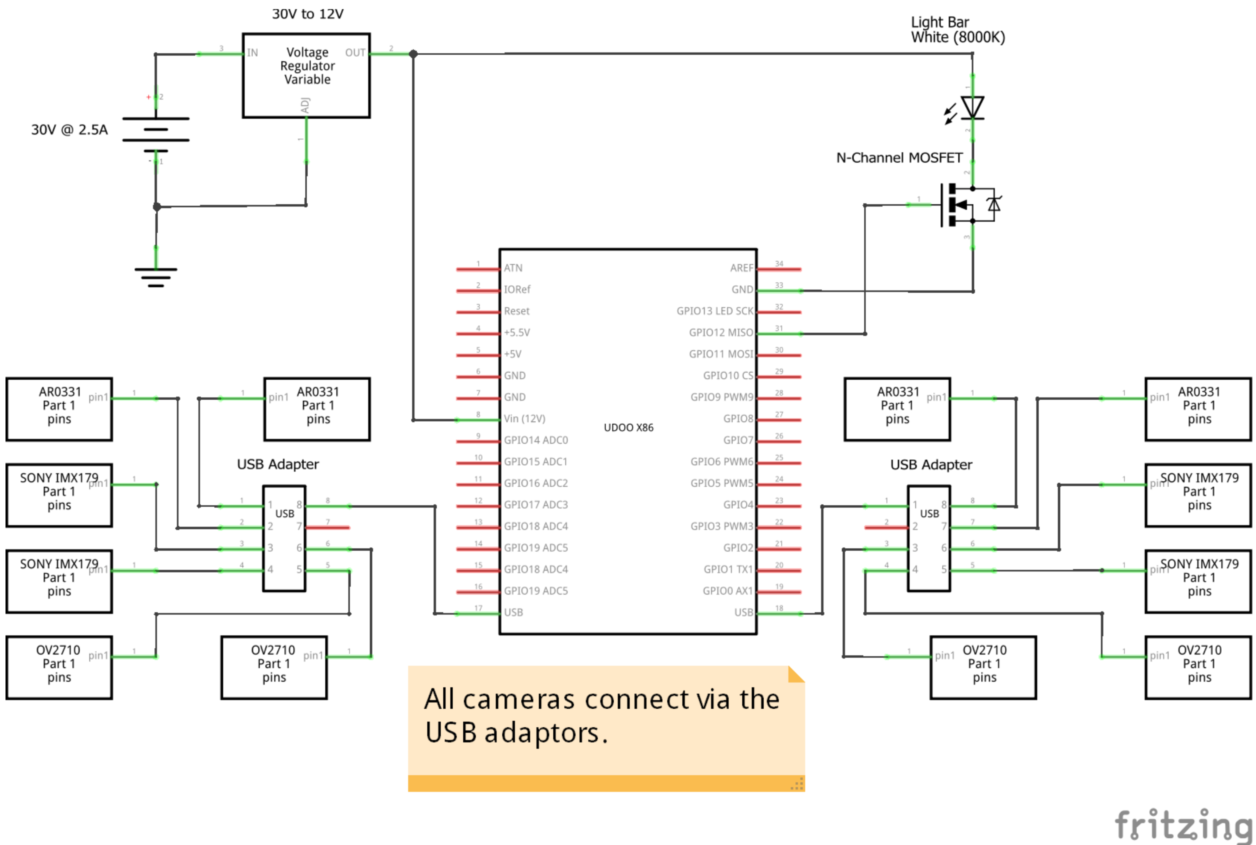
Image Data; assume a maximum packet size of 467 bytes	Byte	Title
Constant for image parts indicating type: '\x30'	1	Type
Indicates position in an image for reconstruction.	2	Part
Which photo this part belongs to.	3–4	Photo ID
Actual amount of valid data sent in the image part portion.	5–6	Size
Data of an actual part of an image.	7–467	Image Part

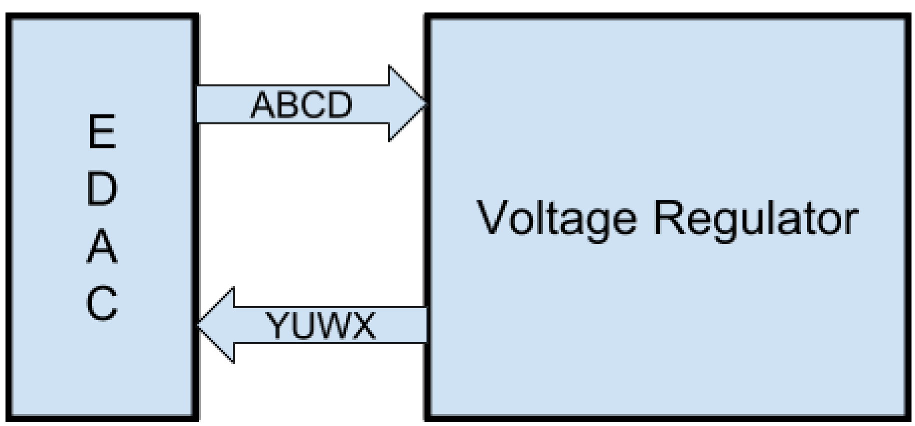
April Tag Data; assume a static packet size of 19 bytes	Byte	Title
Constant for AprilTag data: '\x35'	1	Type
8 byte time_t value: time this data was recorded.	2–9	
Camera Being Used	10	Camera In-Use
Bool value: Can tag one be seen?	11	TagOne
Bool value: Can tag two be seen?	12	TagTwo
Bool value: Can tag three be seen?	13	TagThree
Bool value: Can tag four be seen?	14	TagFour
Bool value: Can tag five be seen?	15	TagFive
Bool value: Can tag six be seen?	16	TagSix
Bool value: Can tag seven be seen?	17	TagSeven
Bool value: Can tag eight be seen?	18	TagEight
Bool value: Can tag nine be seen?	19	TagNine

4.2 Power Budget:

Total Power Draw for Entire Payload		
System	**Voltage (V)**	**Peak Power (W)**
Cameras (x12)	5	12
LCD Lighting	12	0.8
UDOO X86	12	36
Total Expected Peak Draw:		**48.8**

4.3 Wiring diagram:





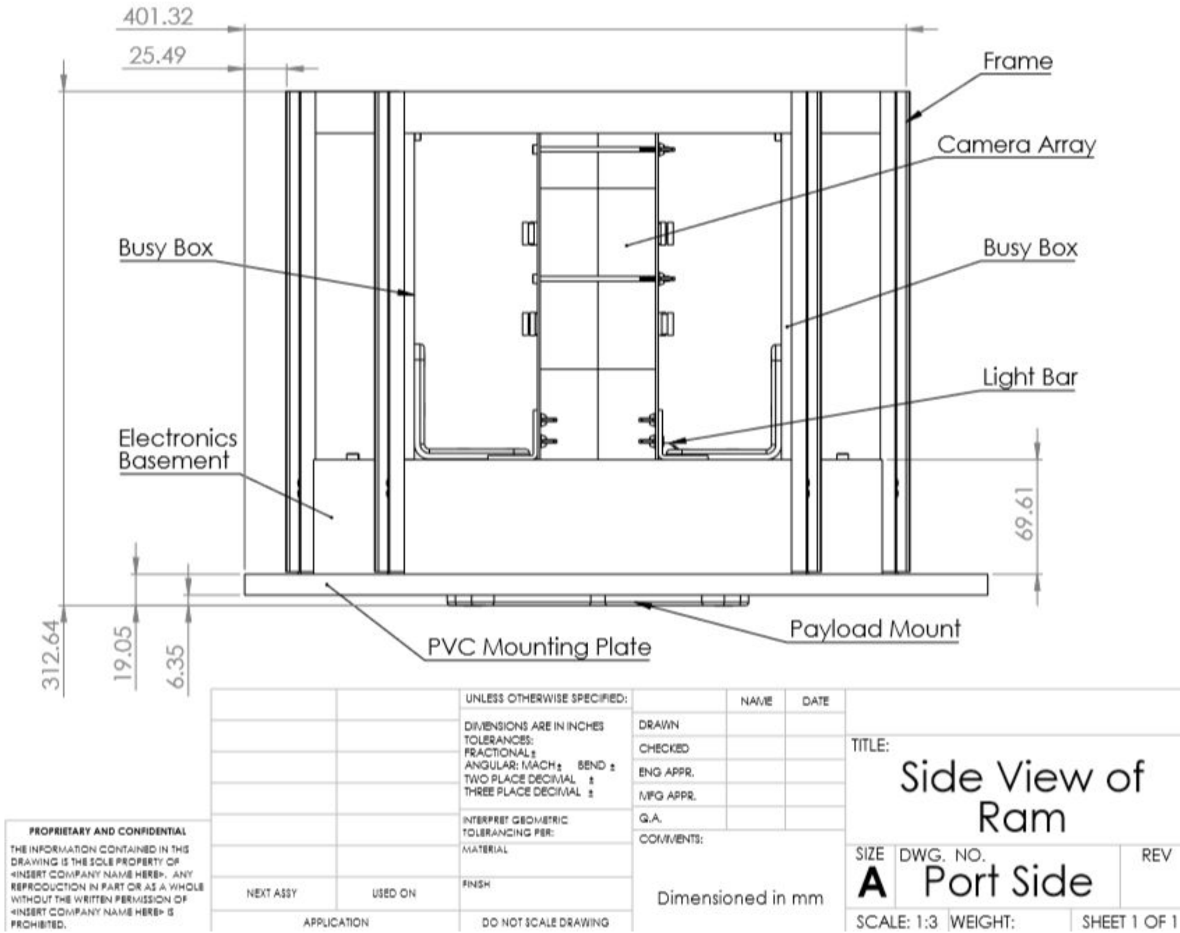
5. Preliminary Drawings

5.1 Construction narrative

- **Frame:** Our frame will be horizontal octagons of ⅛" 6061 aluminum angle, welded together, supported in the vertical by 8 pieces of ⅛" 6061 aluminum u-channel, also welded together. The frame's primary purpose is to be an over engineered roll-cage to protect the arm and electronics in the event that the HASP rigging falls onto the payload during landing; its secondary purpose is to support our thermal insulation and our electronics.
    - The frame is bolted to the PVC plate and aluminum baseplate (from a sheet of 1/16" 6061) by 8 ¼" steel bolts.
    - The aluminum shelf in the middle of the payload which holds the robot arm will be made from 3/32" aluminum.
    - The electronics basement and Busy Box will be contained in 1/16" aluminum sheet, painted white, lined with multi-layer insulation (MLI.)
- **Busy Box:** The Busy Box will consist of a single bulkhead of 1/16" aluminum into which are mounted all AprilTags. The entire Busy Box bulkhead will slide into two channels in the vertical mounting posts, which we will bolt to the frame. Two set-screws will hold it securely in place. This gives us a sturdy payload that requires relatively little bolting together, yet which is modular enough to replace or repair malfunctioning components.
- **Electronics Basement:** The basement is defined by the bottom plate, the 'middle shelf' on which the camera array is mounted, and the sides of the payload. We plan on routing and tagging most of our wiring while this shelf is removed, then adding the shelf and plugging the microcontrollers etc. in with mini-Molex connectors.
- **Camera Array:** The camera array will be constructed using a 3D printer, with ABS plastic. Its structure will mimic that of a "Connect Four" game board with five rows running across and four columns dropping down. Due to the various sizes of the cameras, a small enclosure will be made for them. This will also be 3D printed. After mounting the cameras in the enclosures, all cameras will be a uniform size, thus giving us more control over positioning.

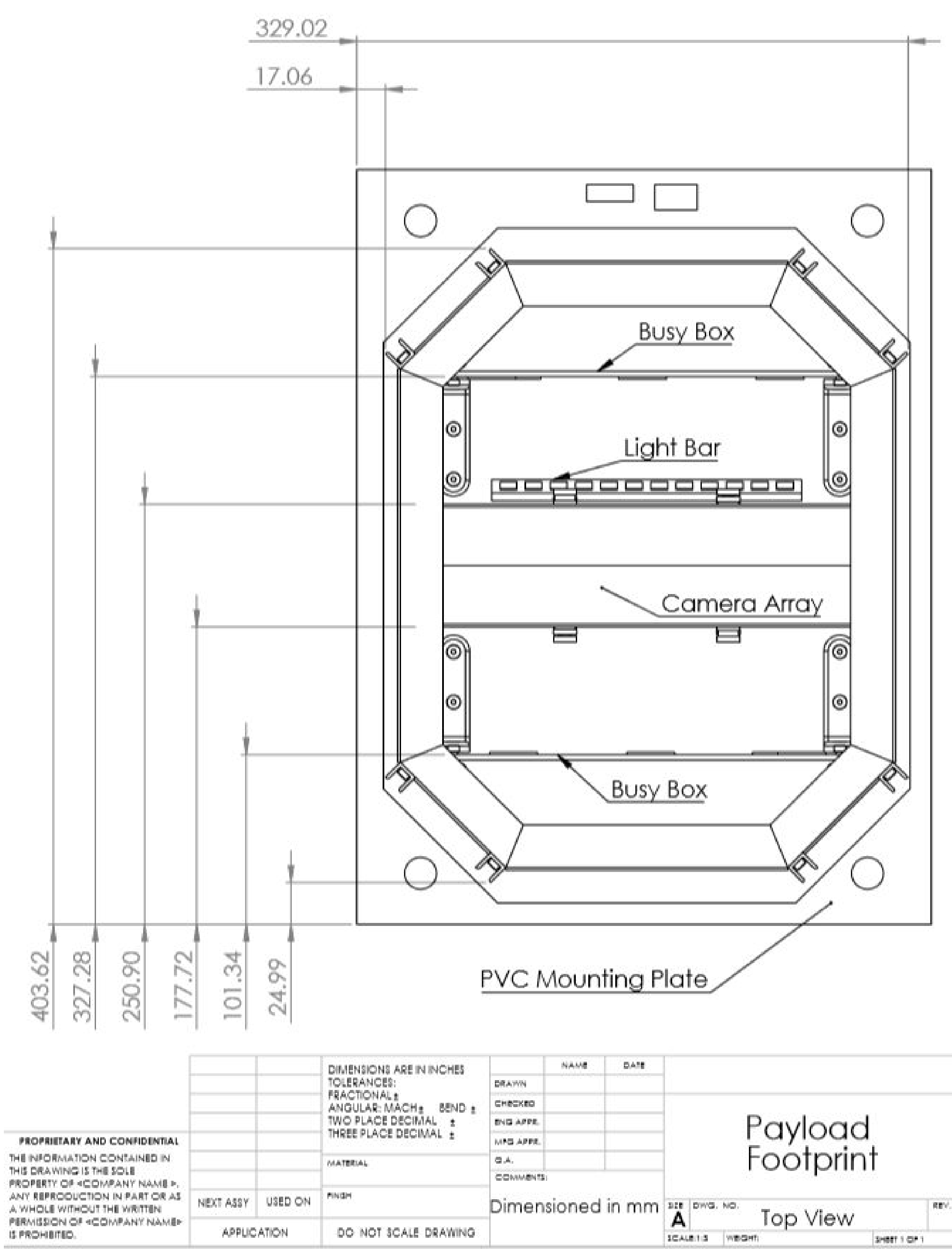
5.2 Dimensioned Drawings

5.2.1 Port Side View of RAM

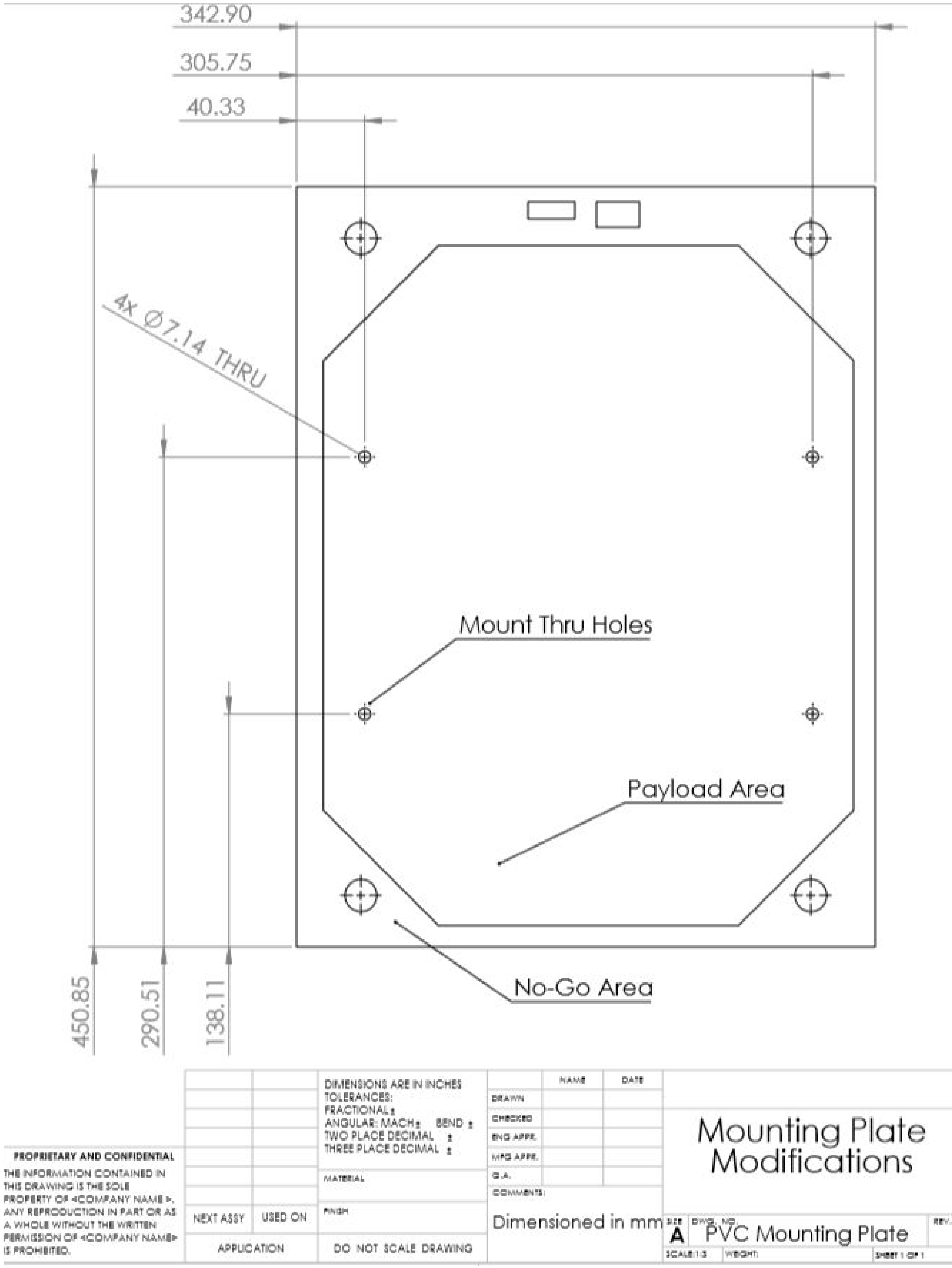


Note: The RAM payload is symmetrical on the aft-fwd and port-starboard axis.

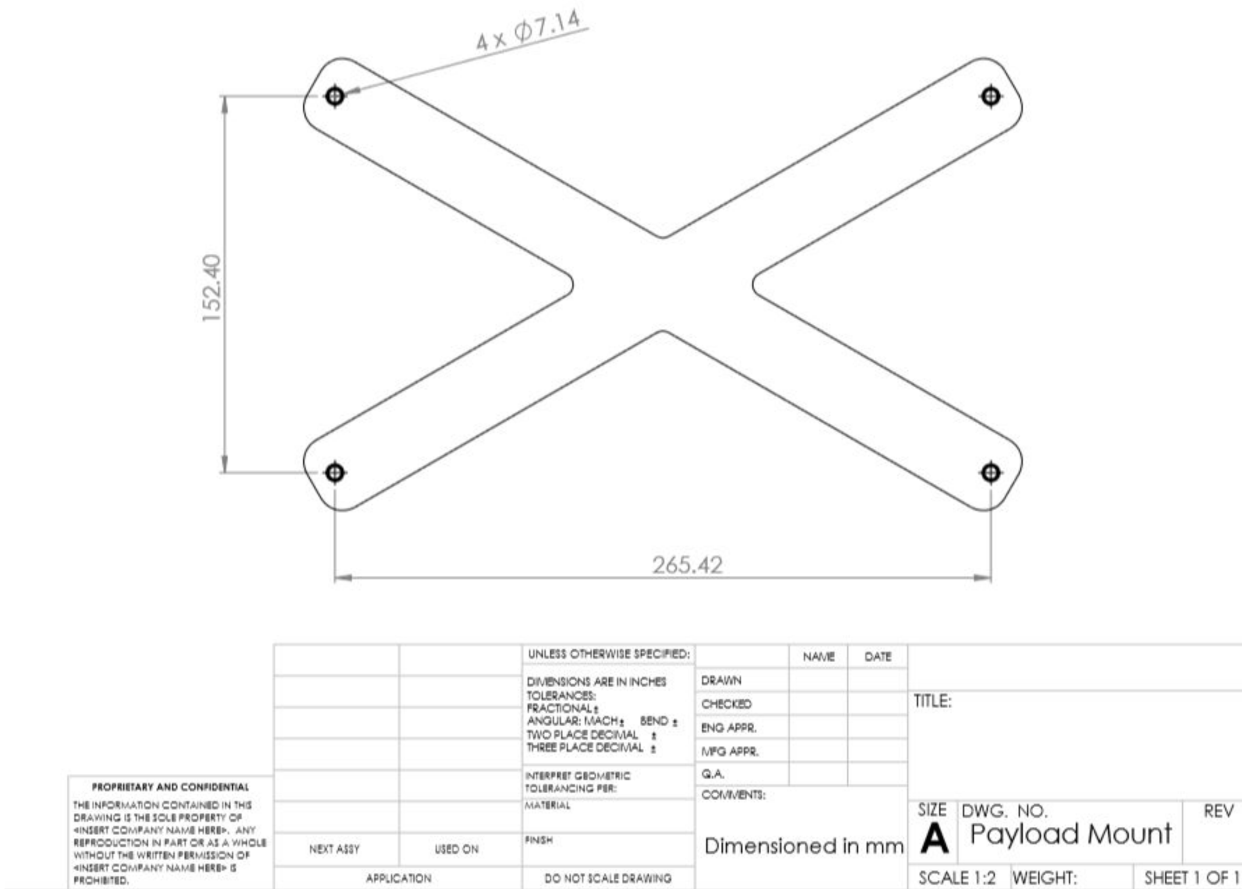
5.2.2 Top View Showing Main Payload Components and Footprint on the PVC Mounting Plate



5.2.3 Payload Mounting Holes on PVC Mounting Plate

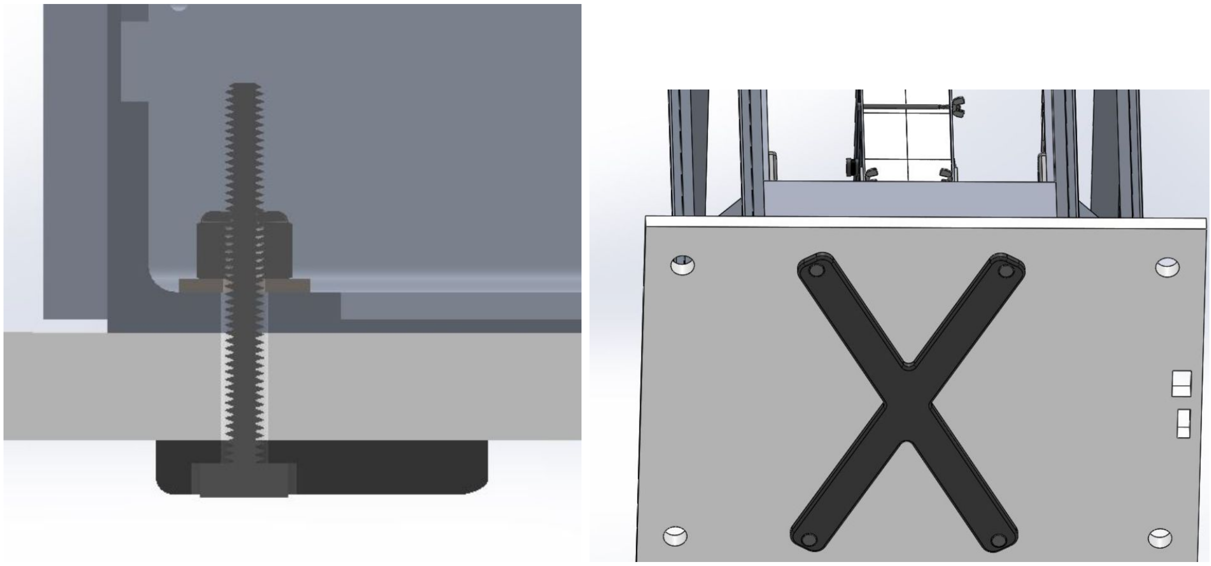


5.2.4 Mounting Crossmember



*RAM will be mounted to the payload in the same manner as it was for 2018. The mount crossmember will sandwich the PVC mounting place between the payload bottom plate and itself. Four ¼” bolts that are welded into the crossmember protrude through the mounting holes on the PVC mounting plate and through the bottom frame rails of the payload. They are fastened with nylon locking hex nuts.

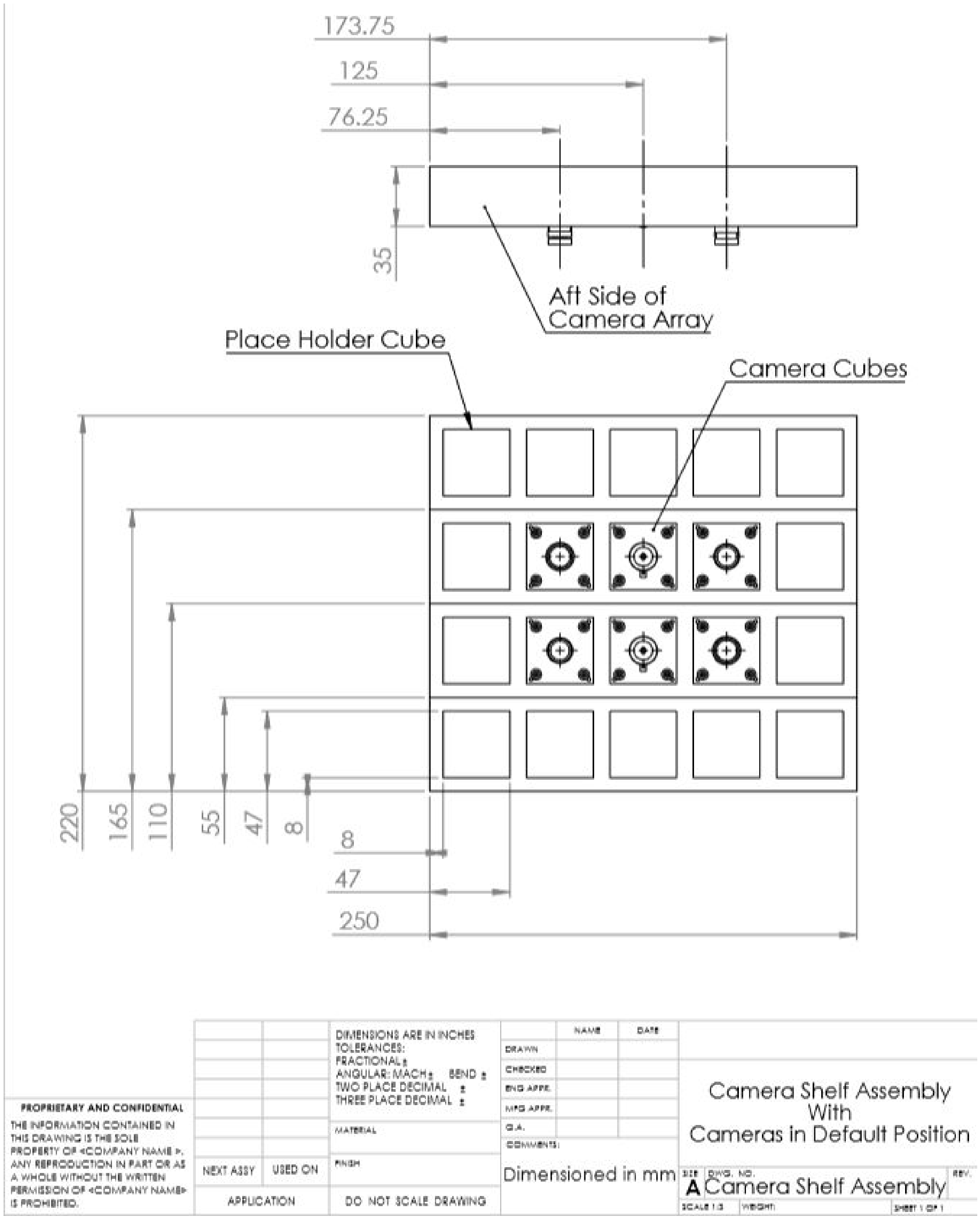
5.2.5 PVC Mounting plate and Frame rail



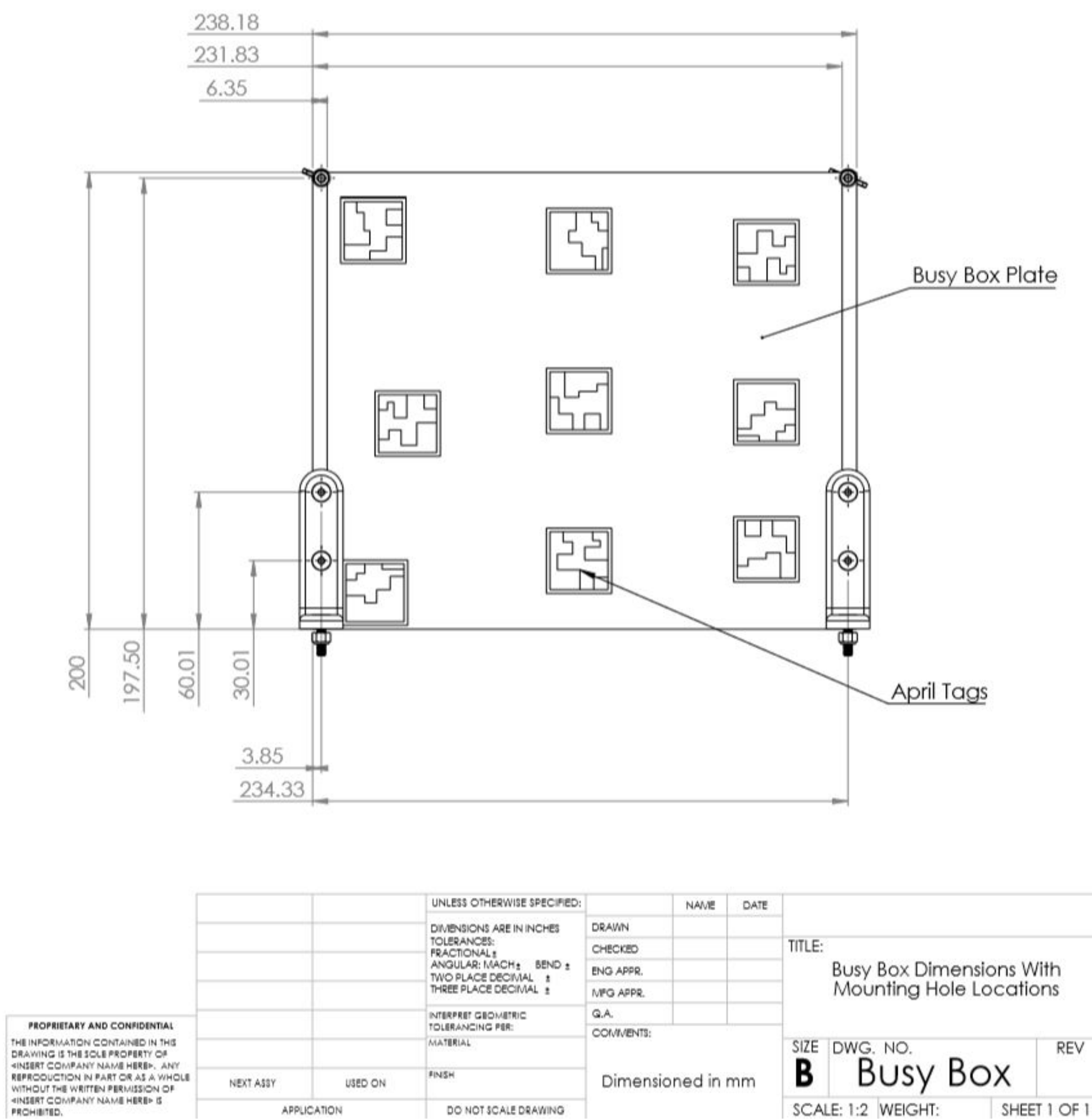
Fig

*Section view of the crossmember, PVC mounting plate, and bottom frame rail (L) and bottom view of mounted payload (R)

5.2.6 Aft Camera Shelf



5.2.7 Busy Box


238.18
231.83
6.35
Busy Box Plate
200
197.50
60.01
30.01
April Tags
3.85
234.33
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
Dimensioned in mm
TITLE:
Busy Box Dimensions With Mounting Hole Locations
SIZE
B
DWG. NO.
Busy Box
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

5.3 Thermal Control Plan

We know from previous experience that the payload will have to withstand a wide range of temperatures. The challenge is to keep the payload warm during ascent while preventing our electronics from overheating in the lack of air and constant solar exposure at float. Our approach to passive thermal control is based on previous projects:

- Mechanically, we have chosen materials proven to be resilient by past balloon projects.
- Electronically, the Raspberry Pi has a distinguished record of service in sub-orbital operation, having flown on multiple short- and long-duration flights by NC Near Space, University of Bridgeport, and CSBF. Last year we procured aluminum housings for each Raspberry Pi which are designed to mitigate overheating. They will be mounted to the mid-plate which will act as an additional heat sink.
- We will use four layers of mylar and tulle to insulate the electronics bay which has been successful in past projects.
- We will heat sink our heat-emitting electronics (i.e., voltage regulators / DC-to-DC buck converters) to the mid plate, and side hatches with brackets and blocks of aluminum, Kapton tape, and thermal paste.
- We paint our electronics hull and payload frame in white appliance enamel to protect our payload from solar IR load, reducing our absorptance.

6. Payload Summary

6.2 Mass Budget

	Part File Name	Material	Quantity	Mass (g)	Error (±g)
Frame and Body					
	Right Aluminum (Panel)	6061 Al Sheet	1	58.8	0.1
	Mid Plate	6061 Al Sheet	1	427.3	0.1

	Right Aluminum Panel (EDAC and DB9) Ports	6061 Al Sheet	1	75.3	0.1
	Left Aluminum Panel	6061 Al Sheet	1	297.8	0.1
	Front Aluminum Panel	6061 Al Sheet	1	78.5	0.1
	Aluminum Hatches	6061 Al Sheet	1	317.38	0.1
	Bottom Aluminum Panel	6061 Al Sheet	1	120.95	0.1
	Bottom Electrical Panel	Delrin Sheet	1	156.18	0.1
	Payload Mount	Steel	1	1001.53	0.1
	Frame Assembly	1” x 1” x 0.125” AL Angle	1	1834.4	0.1
	Panel Fasteners	18-8 Stainless	15	1.5	0.5
	Misc Washers/Fasteners	18-8 Stainless		1.0	0.1
		Subtotal		4370.64	1.6
Busy Box					
	Busy Box Panels	Delrin	2	558.72	0.1
	Busy Box Upright Posts	0.25” x 0.25” Al C-Channel	4	53.36	0.1
	Bracket Mounts	3” x 3” L-Bracket	4	55.48	0.1
	Fasteners	18-8 Stainless		4	0.1
		Subtotal		671.56	0.4
Camera Array					
	Placehold Cubes	Kynar	28	575.96	0.1
	Camera Mount Cubes	Kynar	12	246.84	0.1
	Camera Array Shelves	Kynar	8	711.44	0.1
	Face Plate	6061 Al Sheet	2	196.14	0.1
	Mounting Brackets	1.25” x 1.25” Al L-Bracket	4	18.6	0.1
	Fasteners	18-8 Stainless		3	0.5
		Subtotal		1751.98	1.0
Electrical					
	ELP-USBFHD01M-L21		4	40	0.5
	ELP-USB8MP02G-L75		4	40	0.5
	ELP-USB3MP01H-L37		4	40	0.5
	Light Bar	Kynar	1	20.13	0.1
	Raspberry Pi		2	62	0.1
	Raspberry Pi Housing	Al Stock	2	300	0.1
	BME 280		4	4	0.1
	Electrical Busses		2	250	1.0
	LM2596 DC to DC		3	59.5	0.1
	USB AV Cords		12	200	0.5

	Wiring Allowance			750	225
	Sparkfun R232 Shifter		1	30	1
	Thermocouple Amp MAX31855		10	12.6	1
	Fasteners			15	0.1
	Mounting Brackets		12	100	5
		Subtotal		1923.23	235.6
		TOTAL		8717.41	238.6

6.3 Integration Procedures

Briefly describe of your anticipated procedures during integration with HASP:

○ When we arrive at CSBF, we will first power on RAM to ensure there was no damage sustained during travel.

○ While RAM is powering on, we will test each camera independently to insure none of them have incurred any damage during travel.

○ After the camera inspection, we will assemble the camera array with the full suite of cameras given no damage.

○ We will have written a ~5-minute "integration trial" that runs through a brief stress test that draws the most electrical current. This will be helpful for us, internally, as a system check, and for us, externally, to prove we operate within the power constraints of HASP.

○ Once we are integrated to HASP, we will run the integration trial. If we do not blow a fuse or otherwise exhibit any possible electronic or mechanical failures during this trial, we will regard it as successful.

○ The integration trial will output a special message that will confirm successful integration at-a-glance in the data.

○ This should take 10-20 minutes.

6.4 Special Requests/ Hazards

You may also request resources that somewhat exceed those specified for your payload class or those that are not mentioned in this document. However, each such request must be accompanied by a description of the impact if the requested resource is not granted.

- We do not require any additional resources or accommodations.

- Our payload design contains no pressure vessels, radioactive materials, biological materials, lasers, cryogenic materials, high voltage, strong magnets, pyrotechnics, intentionally-dropped components, or hazardous chemicals.

6.5 Preliminary FLOP

- Team will ship payload to site. Upon arriving on location, team will inspect the payload for any damage. It will power-on and run through a series of tests to ensure that everything is still working.
- Payload will then get in line to be re-integrated onto HASP.
- The flight expects to be a mostly passive experience, requiring no intervention unless something goes wrong.

7. Team Management and Structure

7.1 Narrative

The team is sponsored by Julie Hoover, an instructor of geology. She is also the mentor of the UNM NASA Swarmathon, and the NC Space Grant High Altitude Ballooning Competition. Ms. Hoover organizes travel, oversees the budget, orders supplies, drives the proverbial mini-van and keeps the team on task. She has been the PI on 14 NASA grants at Durham Tech.

The majority of the students on the team participated in HASP 2017 and had been working together on projects continuously since 2015. The team has a great rapport, knows each other's strengths and weaknesses, and genuinely loves doing these projects together.

James Acevedo has gone to live on a farm, so we have replaced him with James Cowell. James has over 20 years of construction experience, and he brings a unique perspective to the team, many of those years were spent in a position of leadership, so James is well versed in the expectations of him as the team leader. When he decided to leave the construction field, he managed to get a job as a junior engineer. Despite being vastly underqualified for the position, he worked in the field for two years — this is what lead him to pursue a degree in Computer Science. He is transferring to UNCC in the spring of 2019 with the objective of earning his BS in Computer Science. James is transferring from Durham Tech to UNC Charlotte where he will join DTCC alumni Seth Close.

Seth Close graduated from Durham tech with an Associates in engineering and is currently a student at UNCC, pursuing a degree in electrical engineering. He will be putting together the wiring diagrams, 3D printing, and power budgets for the project.

Meredith Murray is managing our fundraising, photography, and social media. Meredith maintains our Facebook page to keep donors and other interested parties apprised of the team's progress and any project-related press. She also works to find creative ways to raise funds and local businesses to sponsor the team.

Dan Koris is overseeing the software and assisting in picking out the hardware while attending CU Boulder full time. Joining Dan on the software team is Kyle, is going to be helping with the software for the project. He is currently going to school at UNC Charlotte and is majoring in computer science.

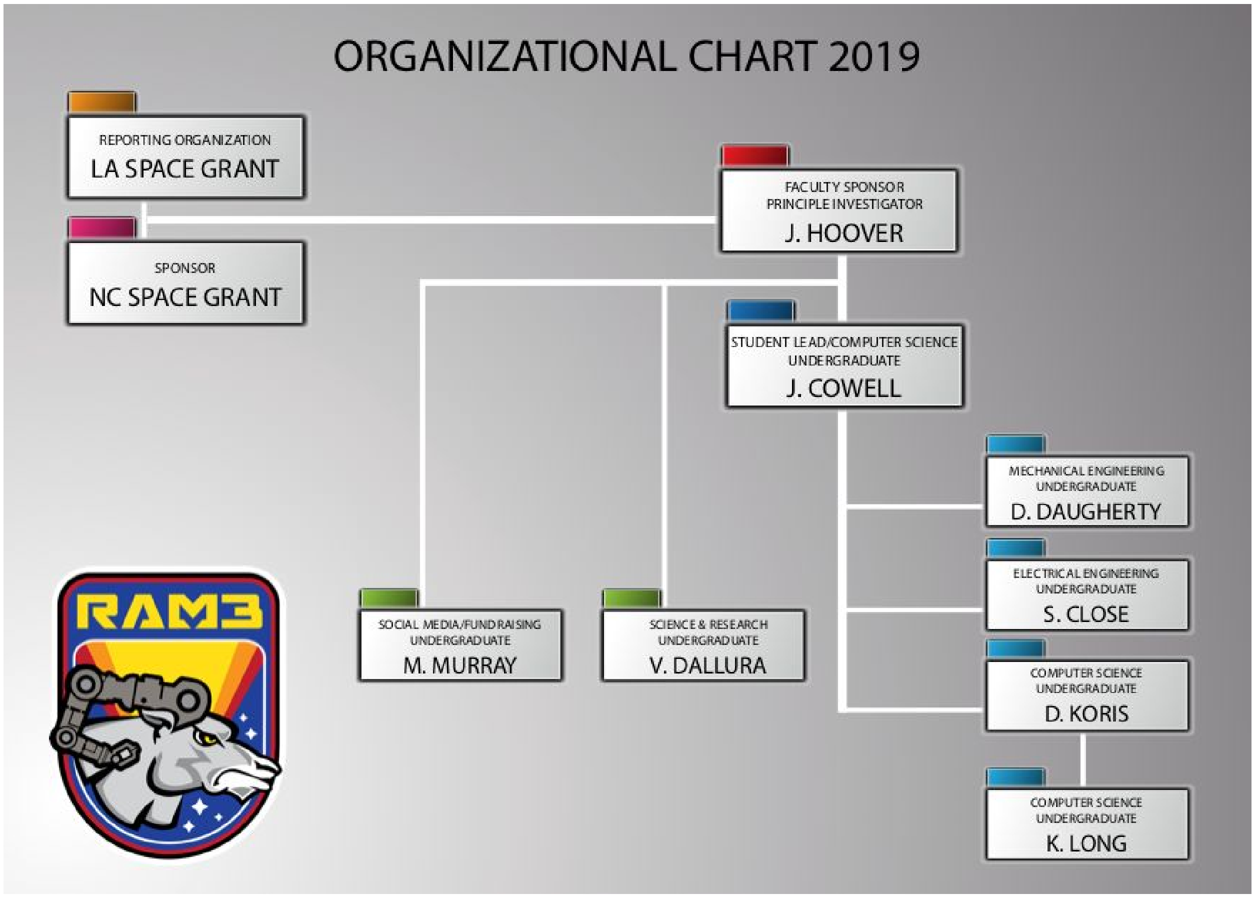
Dan Daugherty will oversee the mechanical design and manufacture of RAM. RAM3.1 will be his third HASP project with tUR (fifth project overall) as the mechanical and manufacture lead... He will work closely with Dan Koris, Seth Close, and James Cowell in hardware configuration, 3D printing, and machining of the payload components.   He is a senior in the mechanical engineering program at NCSU and is a DTCC alumnus.

The rest of the tUR team is from Durham Tech. Vinny is in charge of science and testing. He is participating in an engineering competition that pits local community colleges against one another. This competition has refined his researching and communication skills by a fair amount. Vinny also has a decent amount of math experience under his belt; evident by his current enrollment in calculus 3 at DTCC. He is an ambitious individual that can tackle any task that is given to him, which makes him a vital member to the project.

We meet at least once a week for full team meetings online on Google Hangouts. We have workspaces in Charlotte and Durham. One convenient feature of the UNCC team members is that they all have spouses who live in Durham; so it is easy to convince them to come back on the weekends and get the whole team together.

We anticipate sending the full team to Integration in Palestine, TX, and flight in Fort Sumner, NM

7.2 Project Personnel Management Table



7.3 Personnel Demographic Table

Name	Team Role/Title	Email	Address
Julie Hoover	*Faculty Sponsor* Principal Investigator	hooverj@durhamtech.edu 919-536-7223 x8021	Collins Building 1637 Lawson St Durham, NC 27703
Daniel Daugherty	Mechanical Engineering *Undergraduate*	dadaugh2@ncsu.edu	411 Coalinga Ln, 106 Raleigh NC 27610
Daniel R. Koris	Computer Science *Undergraduate*	korisd@gmail.com	830 Wilkerson Ave Durham, NC 27701
Meredith Murray	Social Media & Fundraising *Undergraduate*	murrraym5844@connect.durhamtech.edu	221 Ivy Meadow Ln Durham, NC 27707
James Cowell	Student Lead/Computer Science *Undergraduate*	mcowell@outlook.com	6015 Lewis St. Apt. #1004 Charlotte, NC 28262
Seth Close	Electrical Engineering *Undergraduate*	Sclose1@uncc.edu	540 Bramlet Rd. Apt B. Charlotte NC 28205
Vinny Dallura	Science and Research *Undergraduate*	dallurav3545@connect.durhamtech.edu	3006 Miller Road Hillsborough, NC, 27278
Kyle Long	Computer Science *Undergraduate*	klong57@uncc.edu	1436 Old Tara Lane Fort Mills, SC, 29708
Skip Smith	Ascent Green Energy *Industry Partner*	skipsmith@ascentgellc.com	26-2180 Highway 7, Concord, Ontario L4K 1W6, CA
Jobi Cook	*Industry Partner* NC Space Grant	jobi_cook@ncsu.edu	Campus Box #7515 North Carolina State University Raleigh, NC 27695-7515 919-515-5933
George Hoover	*Industry Partner* The InnovaNet Group Senior Advisor, Mechanical Engineering	hoover4740@gmail.com	510 Nina Dr Graham, NC 27253 336-512-9831
Jimmy Acevedo	*Industry Partner* NASA's Goddard Space Flight Center Advisor & HASP alumnus: 2017-06	james.acevedo@nasa.gov	5006 Indian Lane College Park MD 20740 240.350.1084

	(GOAT) and 2018-11 (RAM^3)		
Ryan Theurer	*Industry Partner* Ernst and Young Advisor & HASP alumnus:	theurerr5244@gmail.com	520 West 5th st. Apt 1010, 28202 Charlotte

Name ***School / Year***	**Team Role/** ***Major***	**Email**	**DoB**	**Gen der**	**Ethnicity/ Disabled?**
James Cowell *UNCC Jr.*	Student Lead *Elec. & Comp. Eng.*	mcowell@outlook.com	01/13/85	M	White/ No
Seth Close *UNCC Jr.*	Engineering Electrical Engineering	seth.d.close@gmail.com	02/24/96	M	White/ No
Daniel Daugherty *NCSU Sr.*	Engineering *Mech. Eng.*	dadaugh2@ncsu.edu	09/22/81	M	White/ No
Dan Koris *CU Boulder Jr.*	Programming *Comp. Science*	korisd@gmail.com	03/02/87	M	White/ No
Meredith Murray *DTCC/ Elon Jr.*	Social media and Documenting *Strategic Communications*	meredithslmurray@gmail.com	10/07/88	F	White/ No
Vinny Dallura *DTCC So*	Science and Research *Nuclear Engineering*	dallurav3545@connect.durhamtech.edu	11/03/99	M	White/ No
Kyle Long *UNCC So.*	Programming *Comp. Science*	klong57@uncc.edu	09/16/98	M	White/ No

7.4 Financial Support

NC Space Grant has awarded tUR $5000 as part of the Team Initiative Grant. This grant is designed to help student teams succeed at opportunities like HASP that are unfunded. The team maintains a GoFundMe page and plans yearly fundraisers. This year we have also entered a holiday photo contest in the hopes that we can use the prize money to buy t-shirts. We have planned a huge yard sale for the Spring semester.

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