HASP Student Payload Application for 2008

Payload Title: **MRE II-Microwave Reception Experiment: Characterization of the 45- 60Ghz Band**

Payload Class:	Institution:	Submit Date:
Large	**MCNEESE STATE UNIVERSITY**	**12/17/2007**

Project Abstract:

The project focuses on characterizing the microwave background at stratospheric altitude in the frequency band between 45 and 75GHz. With emerging technologies pushing the useable bands higher, it becomes important to understand possible interferences in higher frequency bands. The secondary goal of this experiment is the testing for a possible future cryogenic HASP mission designed specifically to detect the Cosmological Microwave Background (CMB). MRE II will use the latest passive microwave reception technology on the smallest scale ever attempted to capture and analyze these waves.

The McNeese MRE II team consists of five senior engineering students, and all have past engineering experience in various fields; two have prior experience in the LaACES program (MRE, 2006). The team is structured into a group dynamic much like that seen in industry. Every member is accountable for their own budget and technical area, but they are encouraged to interact in a team environment to exchange ideas and get the job done.

The MRE II module will utilize HASP's 30 VDC power supply to power thermal control and processing equipment. A DB9 connector will be used to transmit real-time telemetry via HASP's telemetry system using the provided RS-232 link. Data will be stored on board, via high capacity data storage. To address possible problems in the sampling rate, given the high frequency of the original data band, we are going to use a heterodyne system.

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McNeese State University

HASP 2008 Proposal
MRE II
Microwave Reception Experiment

Payload Description:

Introduction:

The proposed experiment is named MRE II: Microwave Reception Experiment.

The main goal of the experiment is to measure and characterize the microwave spectra in the range between 45 to 75 GHz at stratospheric altitudes.

New telecommunication technologies are pushing used bands higher and higher in frequency, therefore characterizing the background noise is useful design tool. The motivation to characterize the noise at stratospheric altitude is very important because it is the edge of space, and the acquired data would be relevant in terms of satellite communication, sub-orbital flight mission and atmospheric planetary exploration. The experiment is also intended to measure possible astronomical signals that are hindered or completely blocked by the lower layer of the atmosphere. This experiment, therefore, has useful applications both in the practical field of telecommunications and in the more purely scientific field of astrophysics. The stratospheric altitude reached by the balloon payload allows us to get above undesirable possible signals from terrestrial sources.

Our focus will be to measure microwave in the range between 45 and 75 GHz. We have chosen this range because it is above the dedicated military communication band of 42.5 GHz. Most of the signal present in this region should be of natural origin, both from the earth atmosphere and the galactic and cosmological environment. See Science section below for more accurate discussion.

Science:
The main goal of this project is obtain data in the frequency range of microwave radiation between 45 to 75 GHz.

At the expected balloon altitude of 120,000 feet, the microwave spectrum will be dominated by a relatively few sources. These include:

- The cosmic microwave background
- Atmospheric emission lines (primarily oxygen, ozone, and water vapor)
- Atmospheric continuum emission
- Diffuse Galactic continuum (free-free and synchrotron emission)
- Galactic line emission (primarily CO lines, but there are others)

Figure 1 shows a plot of the expected representative spectra. The cosmic Microwave background has a blackbody spectrum at 2.725 K. Except for the bright atmospheric lines, it will be the dominant source at 120,000 feet. It's obviously a continuum spectrum with no lines. The atmosphere radiation is generally fainter than the CMB except for the complex of oxygen and ozone lines near 60 GHz. Galactic continuum emission is negligible above a few GHz, while the Galactic line emission is fainter still. The atmospheric lines are pretty narrow. In order to separate them we will need at least 1 GHz spectral resolution. Anything broader will lump the complex of lines near 60 GHz into one big bump.

We believe there is not much else in terms of sources at such a high altitude and frequency range. For example, according to our calculations the sun black body radiation it is pretty negligible in this band. Measuring the CMB with any precision would require cryogenics. Initially we have considered the use of cryogenics in our project but we have opted for a simpler and more robust design as our first attempt to measure microwaves from the sky. We are going to use the latest technology to reduce the antenna temperature as much as possible. If we failed to measure, atmospheric lines are pretty bright so to measure and resolve them should be relatively easy. Getting 1 GHz or better spectral resolution would be quite difficult if we would decide to use direct detection, but a heterodyne system should have no trouble to achieve such resolution.

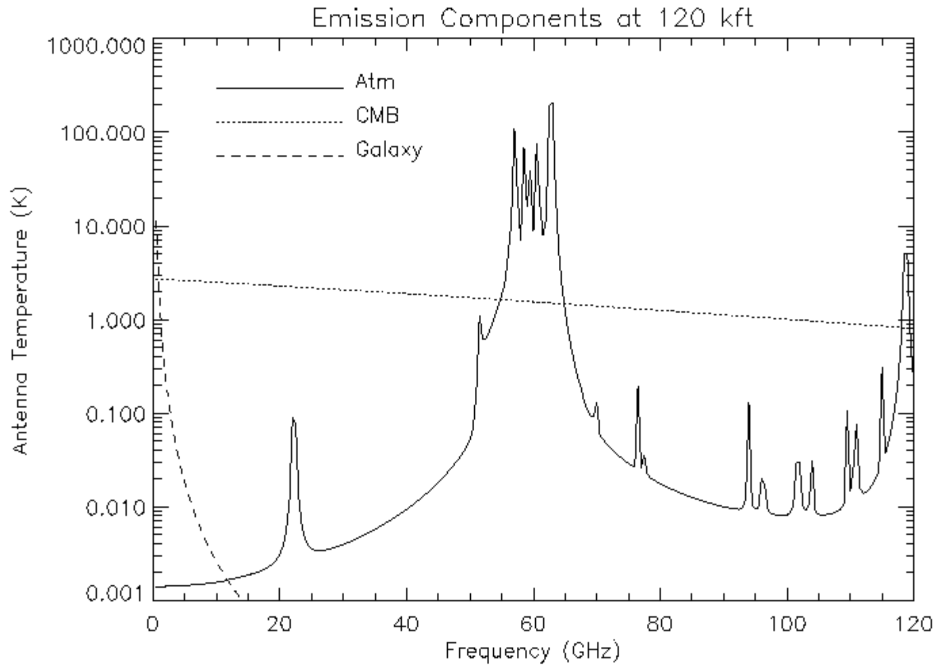


Figure 1: The expected radiation spectrum of the microwave radiation at 120,000 feet. Reproducing such a spectrum will be the main goal of our project.

We expect the instrumental shot noise to be our main noise source. The best available electronics that we can afford with our budget will be used to reduce this source of noise.

It will be also interesting to see the effect on our measured spectrum of the different ambient temperature as it changes during the different time of the flight, in particular during sunset.

Payload description and Principle of operation:

Structure:
All the equipment beside the horn antenna will be hosted inside a box made of insulating foam material. We have provided drawings of the size and shape of the box in Figure 3 attached in the appendix. A feed horn antenna will sit on top of the box, firmly secured to the overall box structure, pointed at a given optimal angle (to be found by eventual testing) towards the sky.

Receiving Equipment:
We have attached a concept sketch (Figure 5) for 2 different WR-15 waveguide based configurations, both using Scalar Feedhorn Antennas with 25 degree half-power beam widths and could be based on an operating frequency centered at 50 GHz (with total bandwidth of 20 Hz).

The top version is a basic amplified detector system with an X10 video amplifier. This is a simpler instrument and less expensive. Our estimated cost for this setup is about $10,000. If the budget will allow, we will favor the second design that allows for a greater sensitivity, frequency resolution and versatility. This design is about $5,000 dollars more expensive than the first one.

Main Components:

- Scalar Feedhorn Antenna
- Low Noise Amplifier (possibly a High Electron Mobility Transistor) 19db Gain, 4.5db NF
- Band Pass Filter
- Balanced Mixer
- IF Amplifier
- Gunn Oscillator
- Bandpass filter
- Coaxial detector

Data Acquisition, Storage and Analysis:
The data acquired by the receiver will be stored on board on a data storage system with a large memory capacity. We are also going to configure our system to use the HASP telemetry system to rely data to the ground. We are going to heterodyne our data to decrease the sampling rate requirements given by the high frequency range we intend to observe. We are exploring different possibilities for our data storage and ADC system. See Dowlinking Capabilities for further details on our telemetry requirements. The data analysis will be done using MatLab code that will we have prepared and tested in advance.

Thermal Design:
The microwave sensors used in this experiment are sensitive equipment and must operate at their designed temperatures for optimal performance. To ensure that the desired operating temperature is maintained, a heating system and insulation will be used. The heating system will use thermistors to determine the temperature in the box. This information will be sent to a digital logic system that will start and stop the heater at a specified temperature. Insulation will be used to reduce the load put on the heater system. There is a possibility that the horn may need to be kept colder than the rest of the equipment which is another reason why insulation will be used.

Principle of Operation
The receiving equipment will be started at the ground, to collect reference data. We will test our instruments to see if we get saturations from man-made sources on ground. The main antenna will collect the microwave photons and the signal will be amplified and shot noise reduced by the LNA amplifier kept at close distance from the antenna. A band filter will select the desired band (45-75 GHz) that we intend to study. An input-output matching circuit composed of a balanced mixer and a Gunn oscillator will reduce the noise even further. Finally a coaxial detector will measure the amplified signal and produce an IF output. The final output will be sent to a Digital Converter and stored on a data storage device with high memory storage capability.

Team Structure and Management:
The team members are senior engineer students in different specialization fields. The proposed project constitutes also the students capstone senior project.

The team members are the following:

- Raymond Fontenot -Mechanical Engineer (team leader)
- Glen Monceaux -Mechanical Engineer (Structure, Integration/Construction)
- Don WEST -Mechanical Engineer (Thermal, Integration/Construction)
- Leah Tatum -Electrical Engineer (Instrumentation/Testing, Receiving Equipment)
- Thomas Gobert -Electrical Engineer (Data Acquisition and Analysis and Storage, Downlink, Signal Processing)

The team has access to two advisors:

- Dr. Giovanni Santostasi, - Experimental and Theoretical Astrophysics, Advisor
- Dr. Valentine –Electrical Engineer and Microwave Technology Expert, Advisor

The team is going to spend several hours per week to work on the more detailed design phase of the project and actual construction.

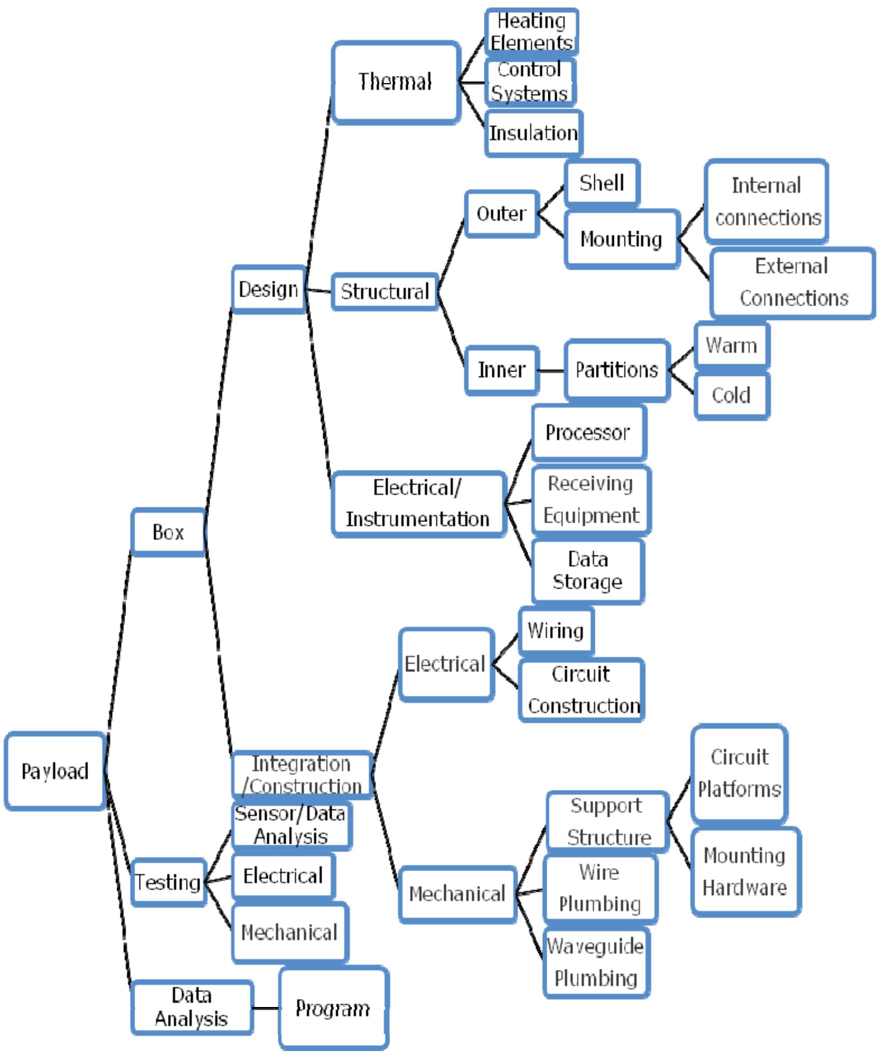
Regular meetings will be held with the advisor to discuss progress and possible problems and obstacles to the progress of the project. Extensive testing of the equipment will be supervised (even if remotely) by engineers of the company from which we will acquire the equipment. We have already contacted a couple of possible candidate companies that have offered extensive advice and support. A Florida company has offered to have students be hosted at the company site to do in loco equipment testing and calibration.

Work Breakdown Structure for Payload:

1) Box
    a) Thermal
        i) Insulation
        ii) Heating
            (1) Heat Elements
            (2) Control Systems
        iii) Cooling
    b) Structural
        i) Outer
            (1) Shell
            (2) Mounting
                (a) Internal Connections
                (b) External Connections
        ii) Inner
            (1) Partitions
                (a) Warm
                (b) Cold
    c) Intergration With Instrumentation
        i) Electrical
            (1) Wiring
        ii) Mechanical

(1) Support Structure
(a) Circuit Platforms
(b) Mounting Hardware
(2) Wire Plumbing

2) Instrumentation
a) Receiving Equipment
b) Signal Storage
c) Signal Processing
d) Calibration
e) Data Analysis



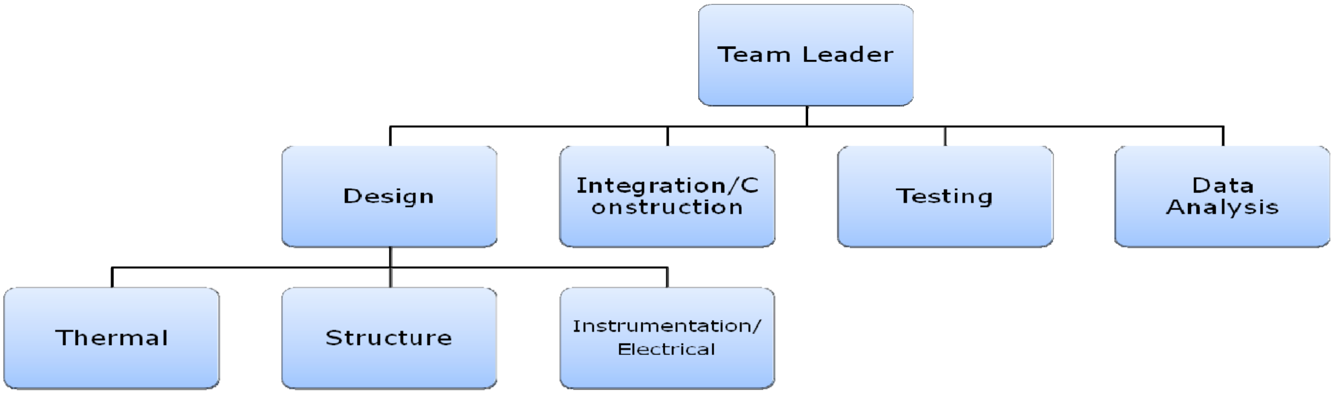


Fig 2: Organizational chart illustrating the Team Structure. The team members in charge of the different parts of the project are listed above.

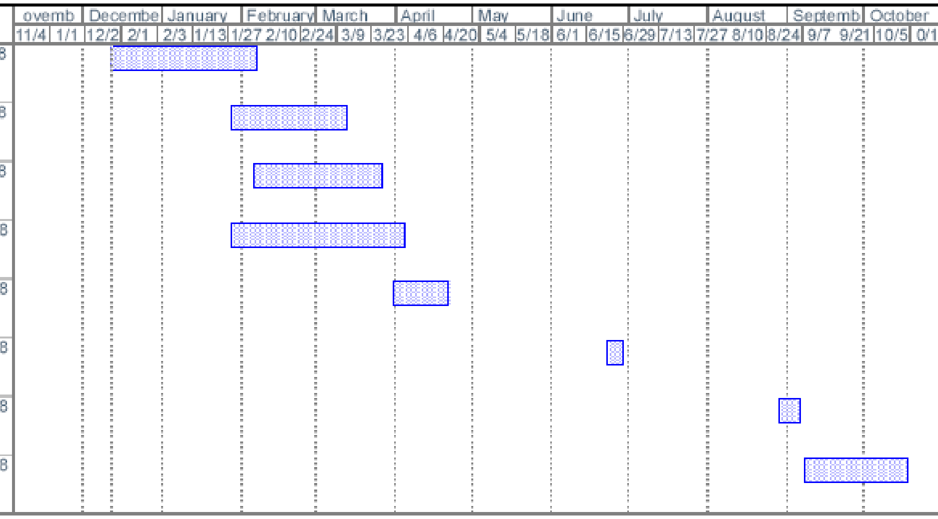
Time Schedule:

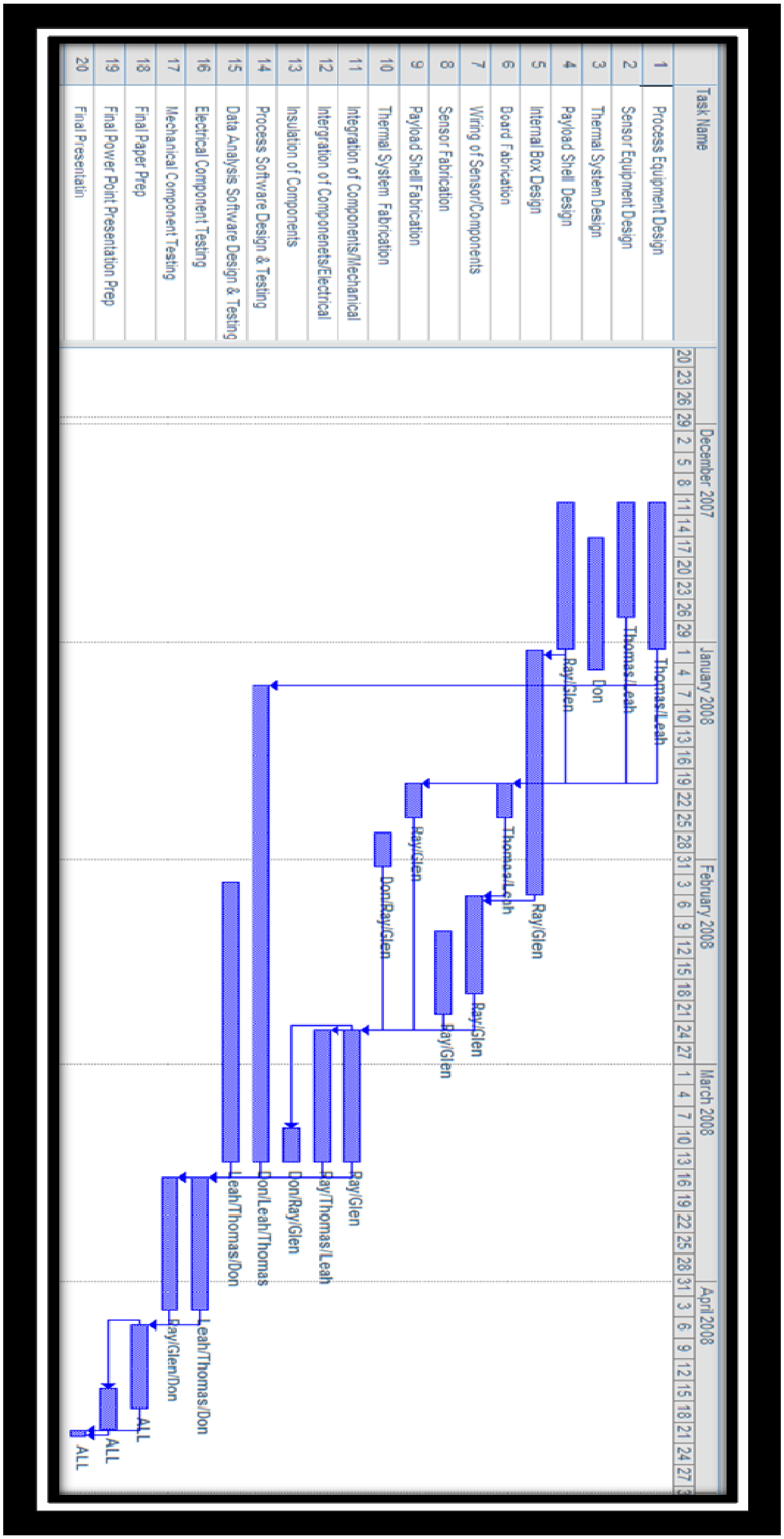
ID Task Name Duration Start Finish
1) Design 41 days? Wed 12/12/07 Wed 2/6/08
2) Integration/Construction 33 days? Mon 1/28/08 Wed 3/12/08
3) Testing 36 days? Wed 2/6/08 Wed 3/26/08
4) Data Analysis Design 50 days? Mon 1/28/08 Fri 4/4/08
5) Project Reporting 16 days? Mon 3/31/08 Mon 4/21/08
6) Integration with HASP 5 days? Mon 6/23/08 Sat 6/28/08
7) Flight 6 days? Fri 8/29/08 Fri 9/5/08
8) Data Analysis 30 days? Mon 9/8/08 Fri 10/17/08

Time Charts:

MRE II HASP SCHEDULE

ID	Task Name	Duration	Start	Finish
1	Design	41 days?	Wed 12/12/07	Wed 2/6/08
2	Integration/Construction	33 days?	Mon 1/28/08	Wed 3/12/08
3	Testing	36 days?	Wed 2/6/08	Wed 3/26/08
4	Data Analysis Design	50 days?	Mon 1/28/08	Fri 4/4/08
5	Project Reporting	16 days?	Mon 3/31/08	Mon 4/21/08
6	Integration with HASP	5 days?	Mon 6/23/08	Sat 6/28/08
7	Flight	6 days?	Fri 8/29/08	Fri 9/5/08
8	Data Analysis	30 days?	Mon 9/8/08	Fri 10/17/08





Task Name
1 Process Equipment Design
2 Sensor Equipment Design
3 Thermal System Design
4 Payload Shell Design
5 Internal Box Design
6 Board Fabrication
7 Wiring of Sensor/Components
8 Sensor Fabrication
9 Payload Shell Fabrication
10 Thermal System Fabrication
11 Integration of Components/Mechanical
12 Intergration of Componenets/Electrical
13 Insulation of Components
14 Process Software Design & Testing
15 Data Analysis Software Design & Testing
16 Electrical Component Testing
17 Mechanical Component Testing
18 Final Paper Prep
19 Final Power Point Presentation Prep
20 Final Presentatin
December 2007
January 2008
February 2008
March 2008
April 2008
Thomas/Leah
Thomas/Leah
Don
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Design Specifications of the Payload:

We have estimated that our project will readily meet the following requirements set for the large HASP payload class:

- Weight<20 kilograms (44lbs): Approximately 7 kilos for equipment and 1 kg storage devices, 0.5 kg structure.
- Measure no more than 12 x 15 x 12 inches. See Figure 4.
- Withstand 120,000 ft balloon flight environment of 5-15 hrs
- Withstand 10g vertical and 5g horizontal shocks
- Special Requests: Antenna will need to extend > 2.5" (currently anticipated extension will not exceed above payload).
- Energy requirements: Our preliminary calculations show we will stay well within the maximum requirements given by the on the board HASP power source.

Downlinking Capabilities:

In our design, we plan to include the downlink capability in order to conduct real-time data acquisition for the purpose of GPS tracking and sustainability issues. The downlink will include two analog channels, which we will occupy and transmit the data signals to a ground based unit via telemetry which we will intercept and decode. We will not be using the uplink, which involves the discrete commands and the four byte commands of the installed software which will take care of the executing of commands. In the electronic design, the group will design and program a counter which will act as a timed command executer. It will initiate sensing and detecting operations, via this counter, and downlink the status readings to the ground based unit by way of the two analog ports that are connected to the output of the payload.

Preliminary Drawings: Attached are the preliminary drawings for the project

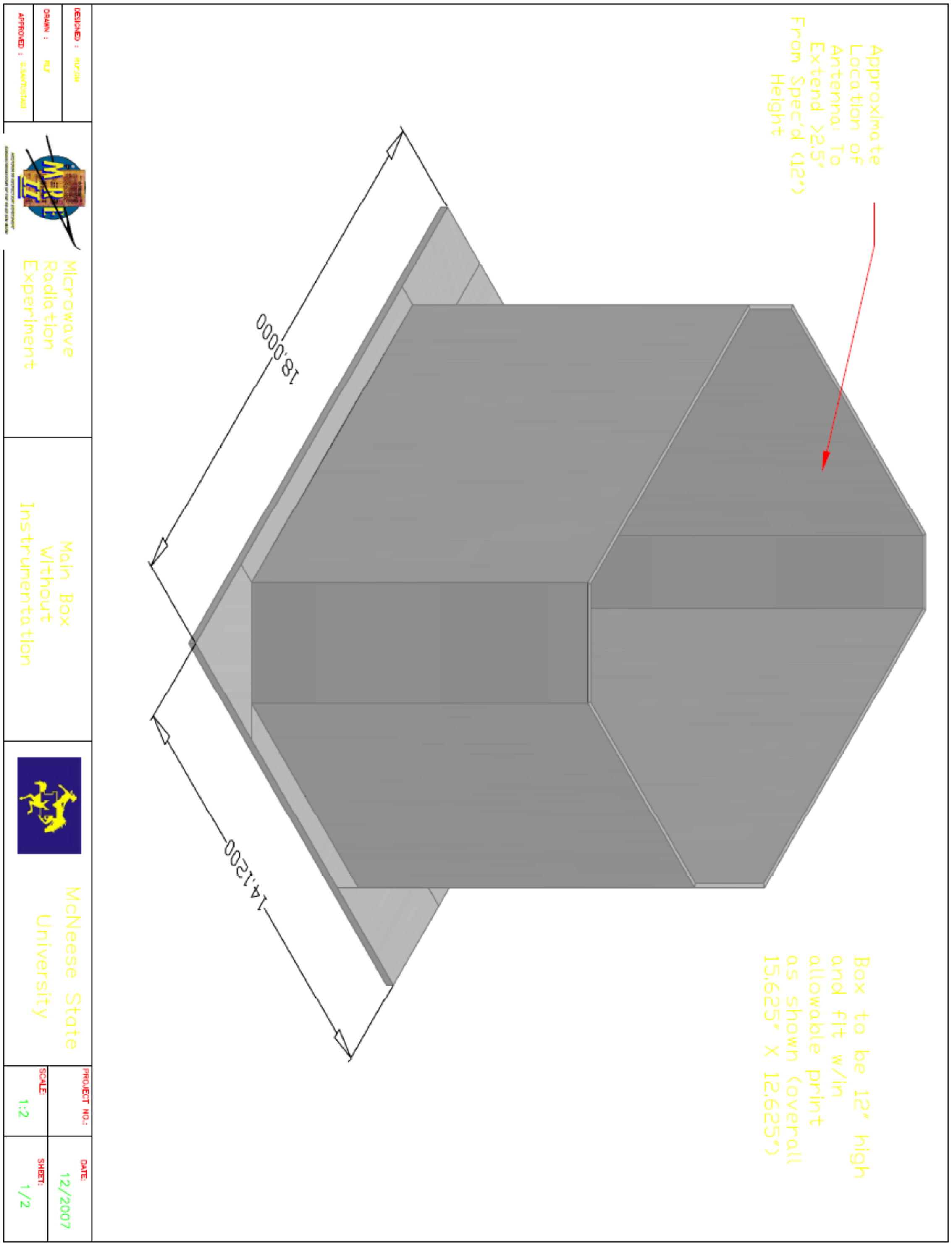

Fig. 3: Overall schematic of the payload. The drawing shows the size of our box that will contain the electronics of our receiving apparatus, the thermal control system and data storage device. A feed horn antenna (not shown in this preliminary drawing) will protrude from the top of the box and oriented at an optimal angle to be pointed towards the sky. The box is made of insulating foam material.

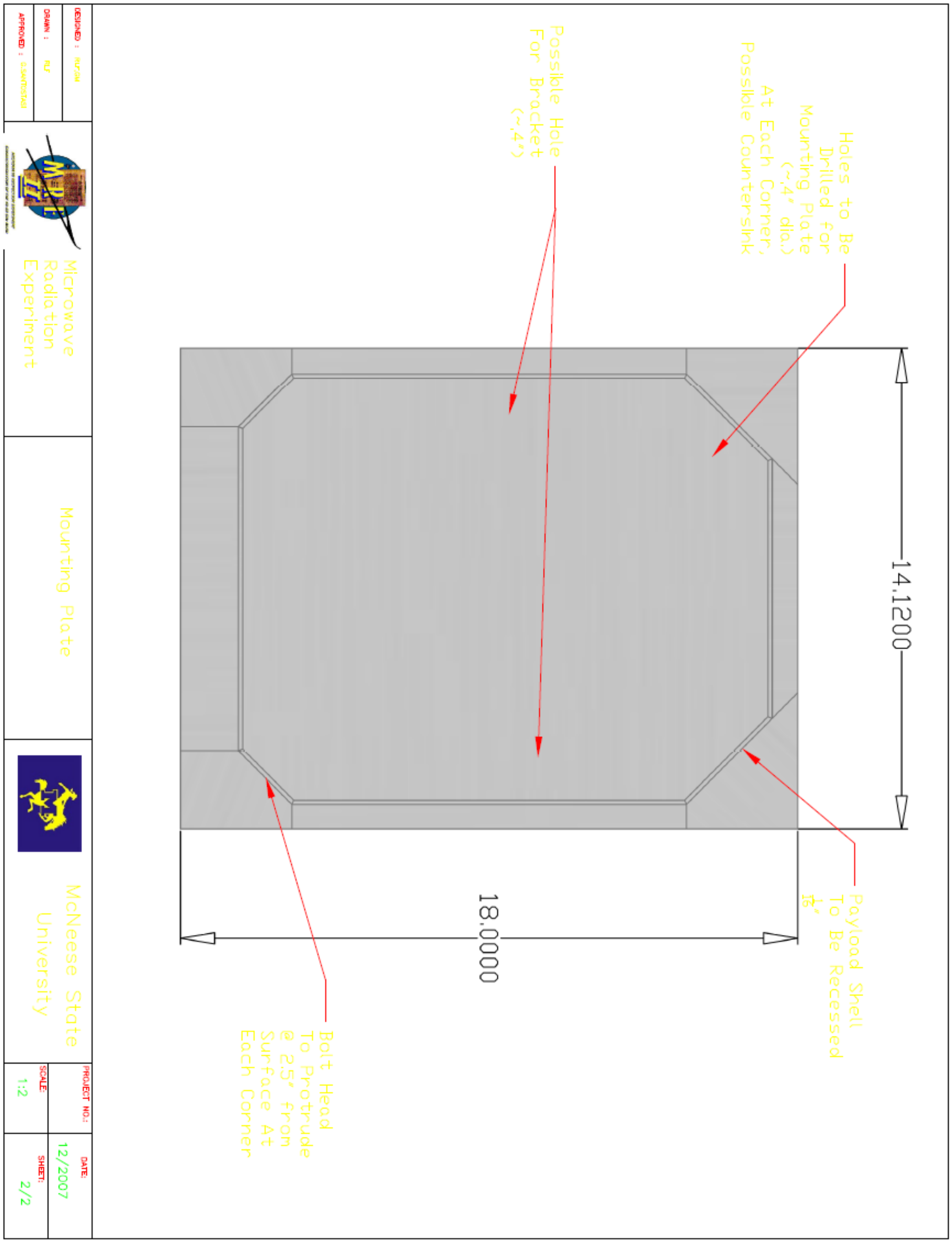

Fig. 4: The mounting plate modifications to which attach the box illustrated in Figure 1.

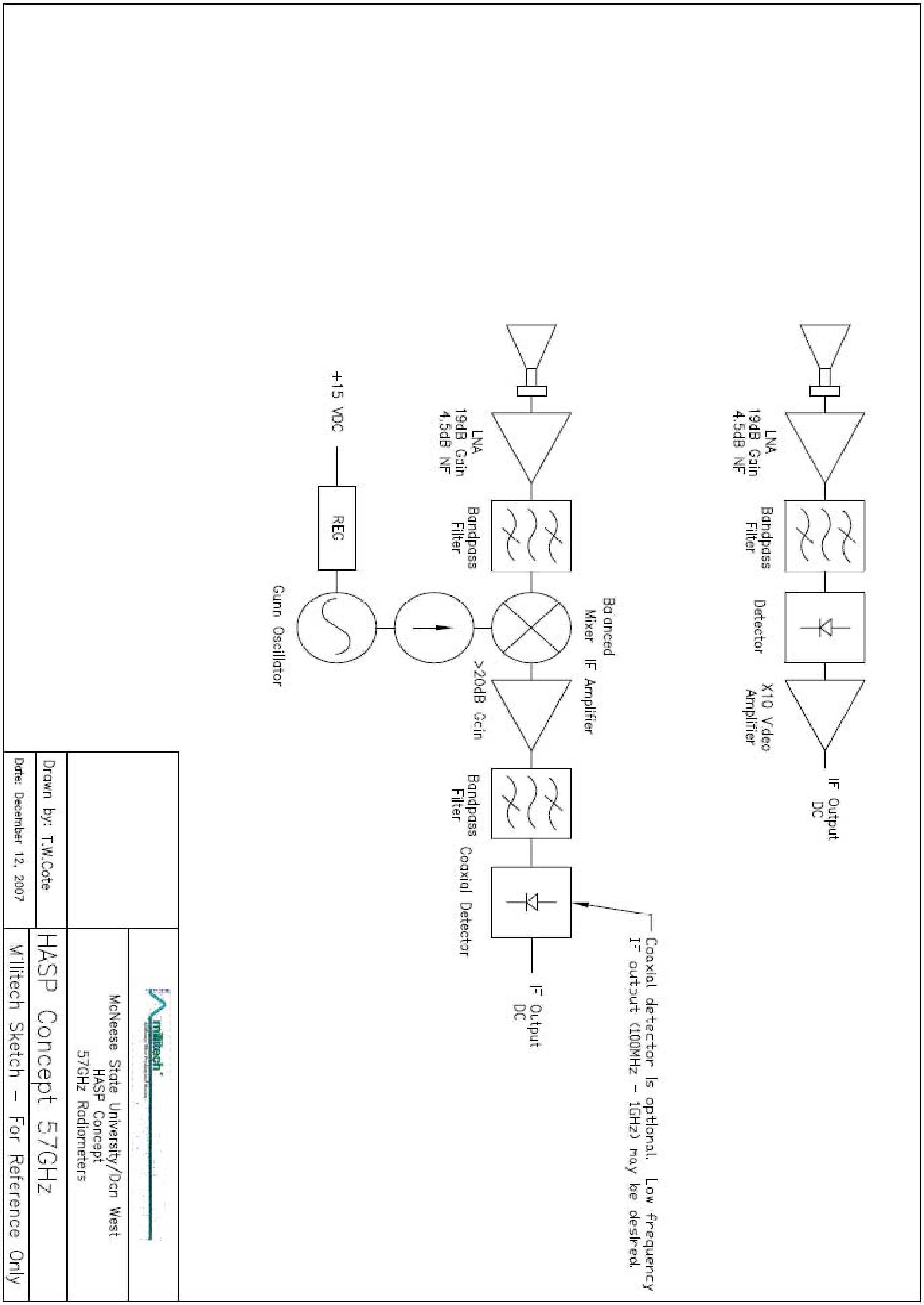

Fig 5: Schematic diagrams of two possible radiometers to measure the microwave radiation in the sky at around 57 GHz. The top design is for a simpler, less expensive but less precise radiometer. The lower diagram represents a more precise and flexible instrumentation. This is our favored setup if budget will allows us to build it.

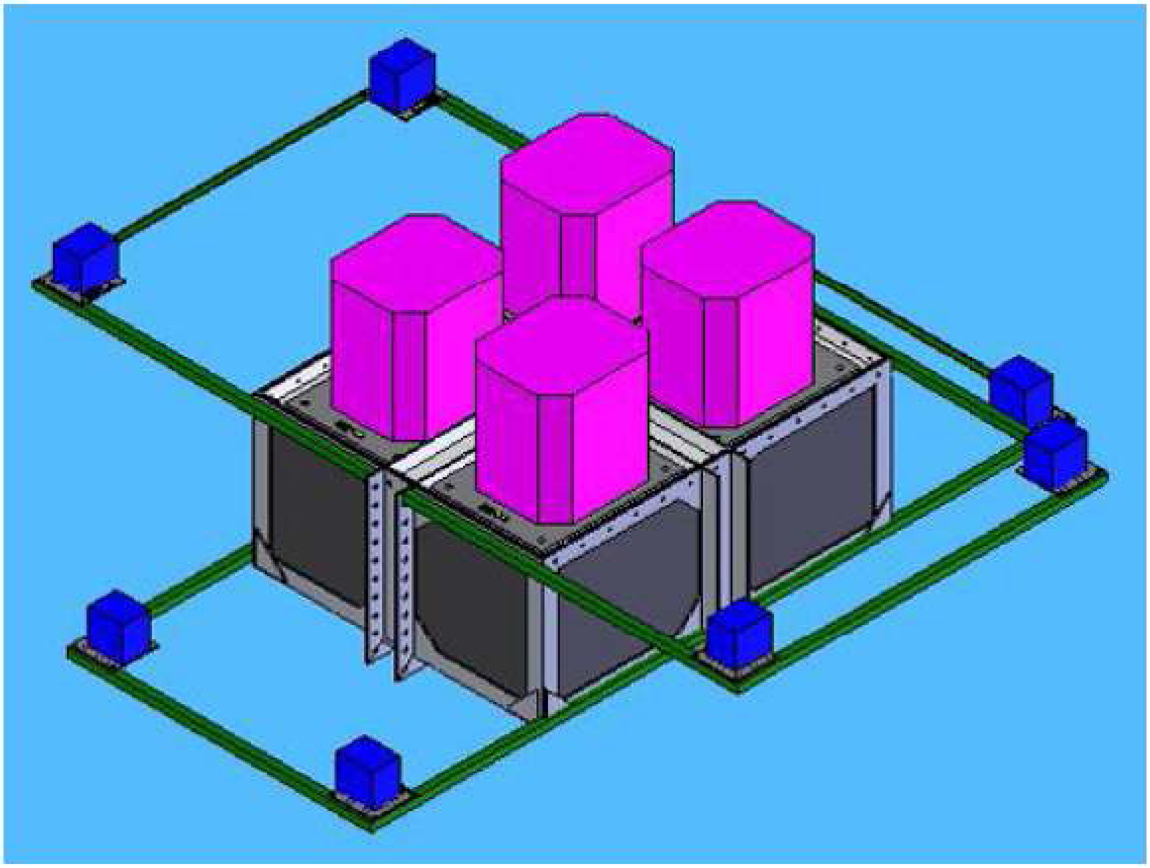

Fig 6: 3-D view of HASP platform with payload configurations from (Note: located opposite of cosmocam, because of possible interference.)