HASP Student Payload Application for 2009

Payload Title: MRE II-Microwave Reception Experiment: Characterization of the 45-75 GHz Band

Payload Class:	Institution:	Submit Date:
Large	McNEESE STATE UNIVERSITY	12/19/2009

Project Abstract:

The proposed 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 and higher, it becomes important to understand possible interferences in higher and higher frequency bands. This experiment has also, as secondary goal, the testing of equipment 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.

The McNeese MRE II team consists of 6 engineering students. All 6 of the students have past engineering experience in various fields; 5 have prior experience in the LaACES program (MESS). 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 .

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 also be stored on board via high capacity data storage. We are going to use a heterodyne system to address possible problems with too high sampling rate.

Team Name:	Team or Project Website:
MIST: McNeese International Space Team	Under construction: www.MIST.html

	Student Team Leader Contact Information:	Faculty Advisor Contact Information:
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McNeese State University

HASP 2008 Proposal
MRE II
Microwave Reception Experiment

History of the project:
McNeese State University submitted a proposal to fly a large payload on HASP in December 2008. McNeese was one institutions selected to fly on HASP in September 2009. The equipment for our project was pretty complicated and we had to require an external source to gather the necessary components for our design. Millimeter Wave Co, Florida was the company chosen for this job. The McNeese students designed, created and assembled the payload structural part of the project. They also worked on the data acquisition system and wrote code to simulate the detector in all its components.
The results were consistent with our expectations and the design seemed functional and robust. The thermal issues of the flight were also addressed through simulation and preliminary testing. The MRE project was not able to meet the August deadline for integration and we missed the September flight. There were many reasons for this failure to meet the projected deadlines in our 2008 proposal, but the final result was that we were not able to acquire all the detection equipment in time for integration. Millimeter Wave has confirmed the arrival of all the components and we have schedule a trip in early January to the company headquarters to test and retrieve the equipment. All the students from the previous MRE II have graduated in May. We have formed a new team of students, many of whom have experience with high altitude balloon projects (through the La-ACES program). We are requesting a second opportunity to fly with HASP. We are very confident, given all the work already done and the acquisition of all the components for our project that we will be very successful and we will meet all the set deadlines.

Progress Report
Work done:

- Designed Payload in all the details
    - Weight < 20 kilograms (44lbs)

    - Measure no more than 12 x 15 x 12 inches
    - Withstand 120,000 ft balloon flight environment of 5-15 hrs
    - Withstand 10g vertical and 5g horizontal shocks
- Built structural components of the payload
- Performed heavy simulations & analyses of thermal system and receiver
- Tested thermal system (without detection equipment).
- Created software for data acquisition, processing and analysis
- Millimeter Wave company procured the main components of the radiometer
- Data acquisition components are ordered

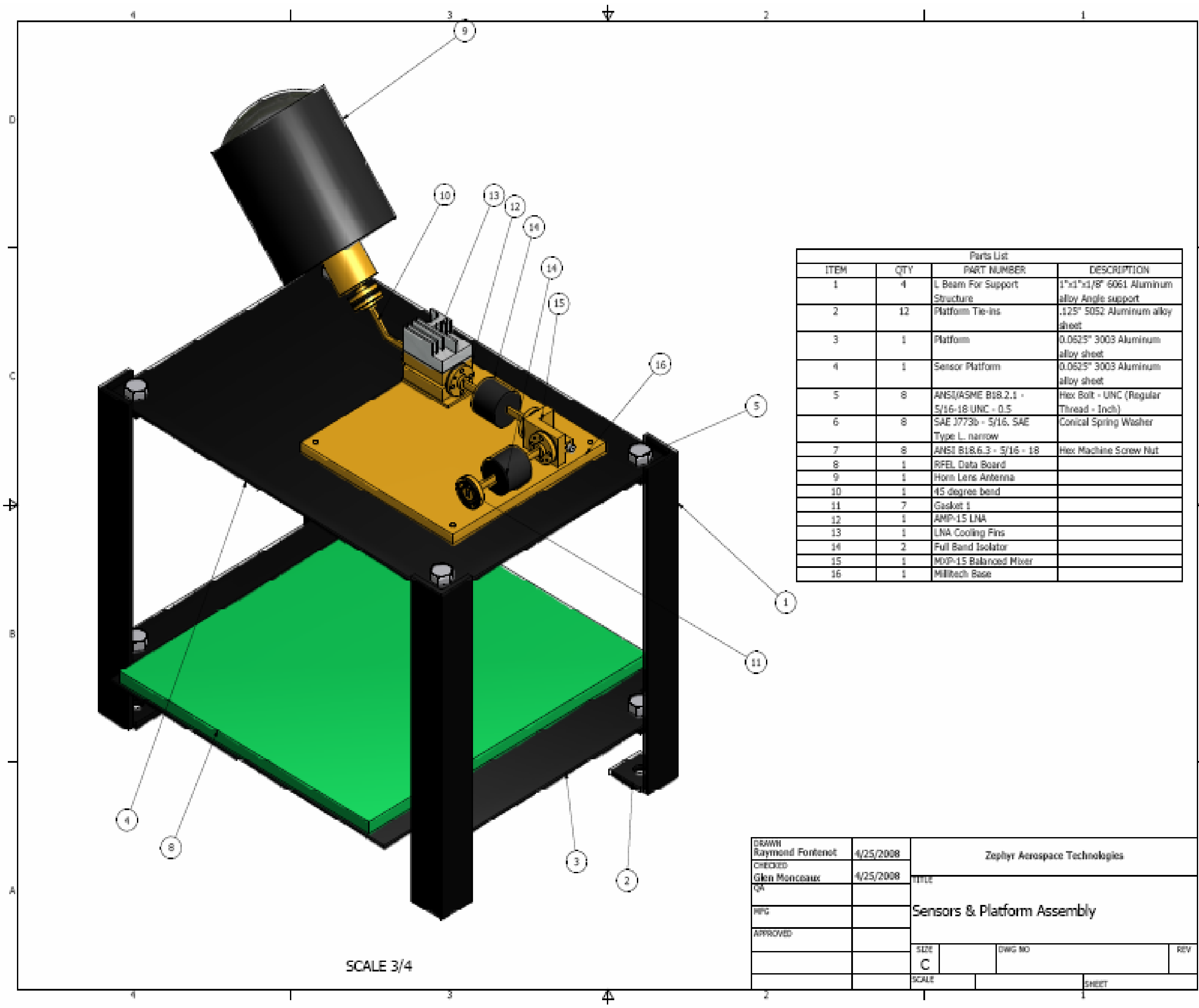
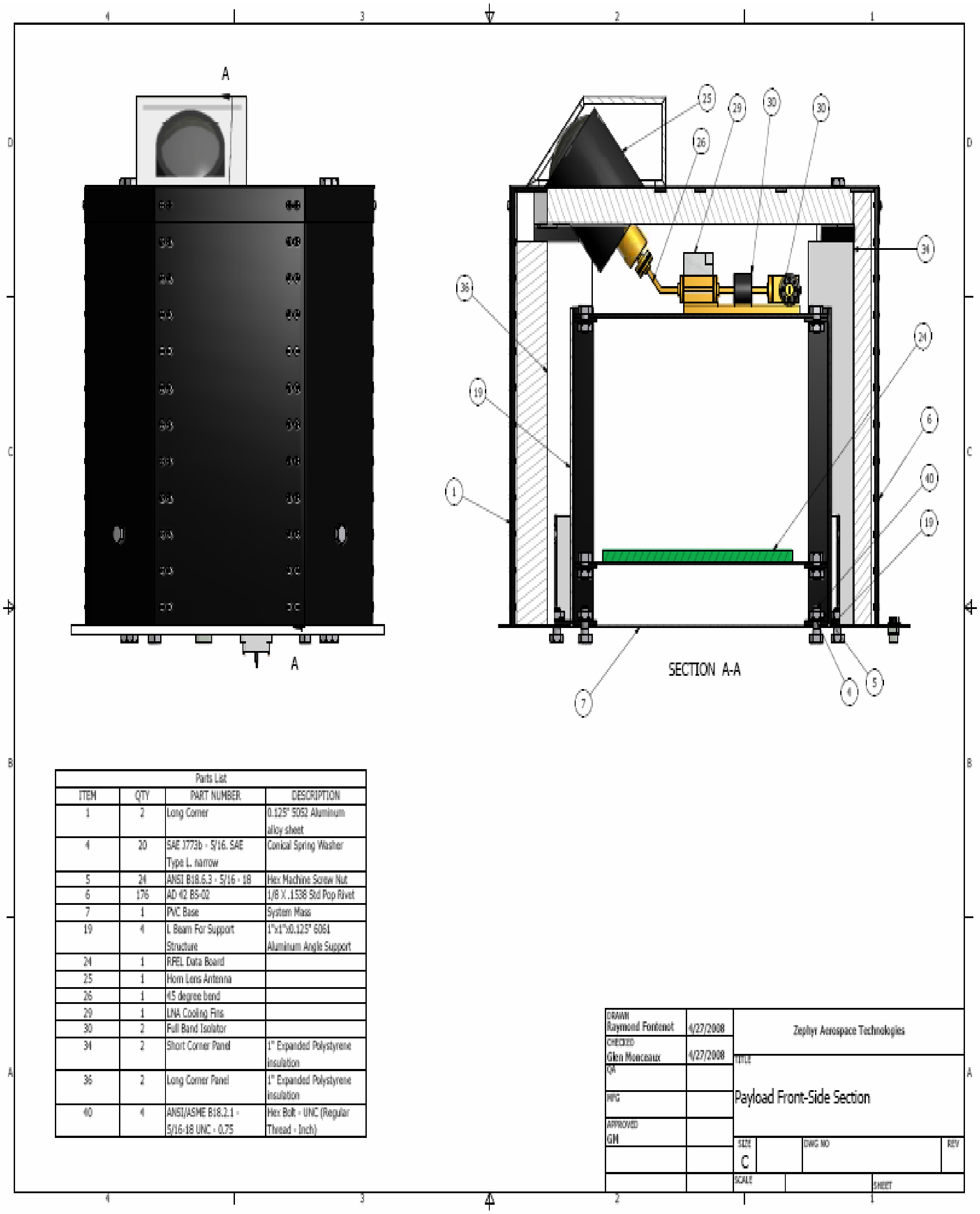


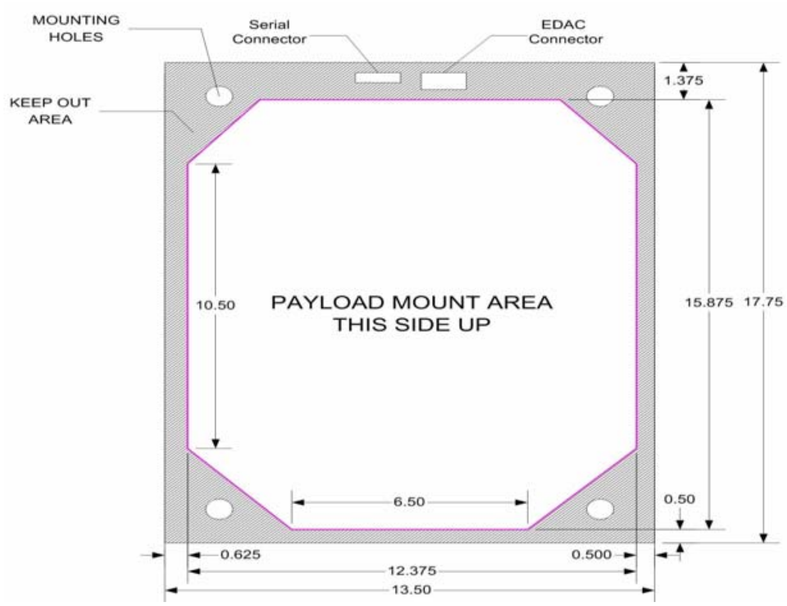
Figure 1: Drawings of the internal components of our payload. The green plate represent the electronics of the data acquisition system. See attached MRE design package for details on the data acquisition system.



Parts List			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	Long Corner	0.125" 5052 Aluminum alloy sheet
4	20	SAE J773b - 5/16. SAE Type L. narrow	Conical Spring Washer
5	24	ANSI B18.6.3 - 5/16 - 18	Hex Machine Screw Nut
6	176	AD 42 BS-02	1/8 X .1538 Std Pop Rivet
7	1	PVC Base	System Mass
19	4	L Beam For Support Structure	1"x1"x0.125" 6061 Aluminum Angle Support
24	1	RFEL Data Board	
25	1	Horn Lens Antenna	
26	1	45 degree bend	
29	1	LNA Cooling Fins	
30	2	Full Band Isolator	
34	2	Short Corner Panel	1" Expanded Polystyrene insulation
36	2	Long Corner Panel	1" Expanded Polystyrene insulation
40	4	ANSI/ASME B18.2.1 - 5/16-18 UNC - 0.75	Hex Bolt - UNC (Regular Thread - Inch)

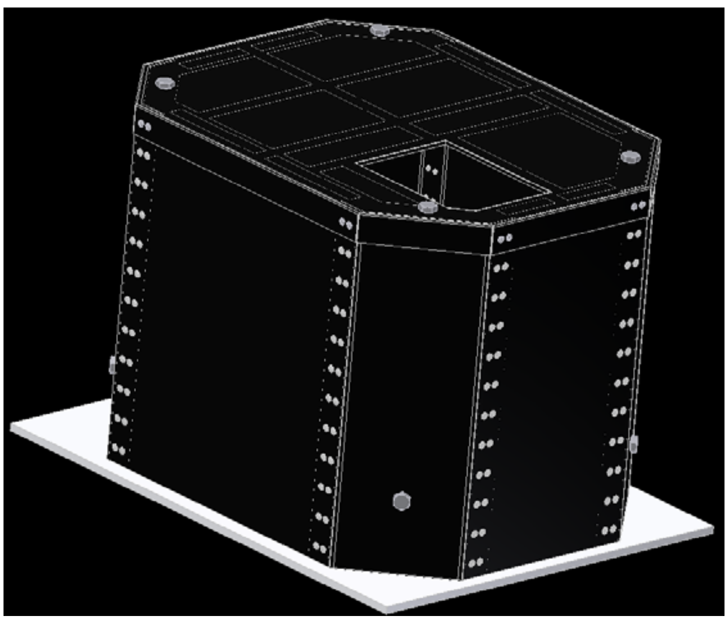
Figure 2: The external structure of the payload compared with the internal components of the payload.

Payload Interface



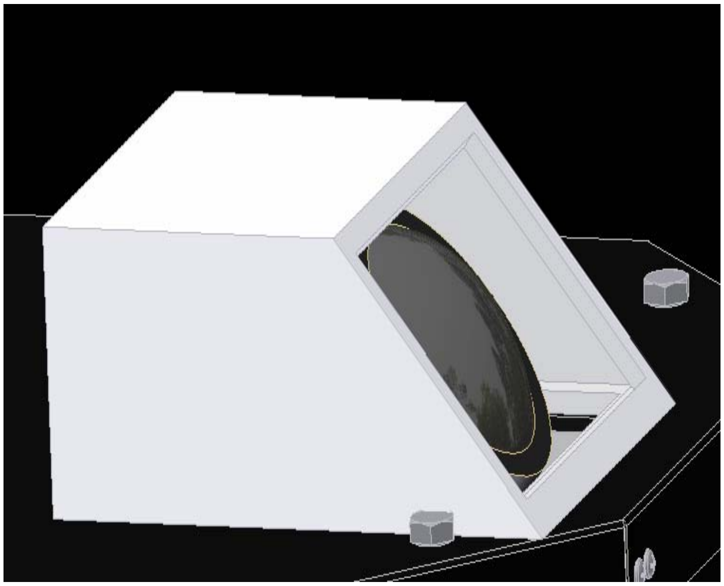
Payload Shell

- Corners are major structural pieces along with top frame and brackets
- Sides and top for environmental sealing and added strength



Antenna Enclosure

- Made of Foam Core for weight concerns
- Mylar window for undistorted signal



A. Non-hazardous
B. Relevant mechanical information

We have used Rivets and Bolts for fasteners.

Rivets

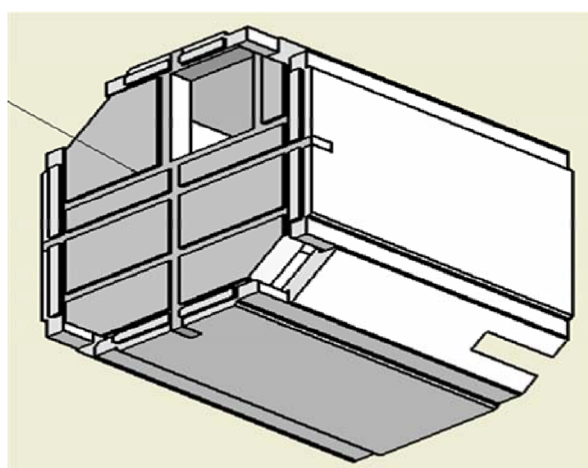
- Aluminum alloy, 1/8” dia., 0.125” grip length.

Bolts

- Carbon steel, 5/16” dia., 0.75” lengths.

For insulation Styrofoam has been used

- 1” Expanded Polystyrene
  - Solid plastic blown into foam using blowing agent.
  - 90% polystyrene
  - 10% gaseous blowing agent.
  - Insulates and dampens vibration.
  - AKA “STYROFOAM”



I. Power Specifications:

The EDAC 516 connector supplies the payload with 30 volts DC and 2.5 amps and has the grounding connections for all of the systems. By utilizing correctly sized resistors, the system can have its recommended supply of voltage to each component.

The leads of the SWG will give an output between 5 and 10 volts that will control the VCO.

Figure 8.9 shows the power supply diagram for the system.

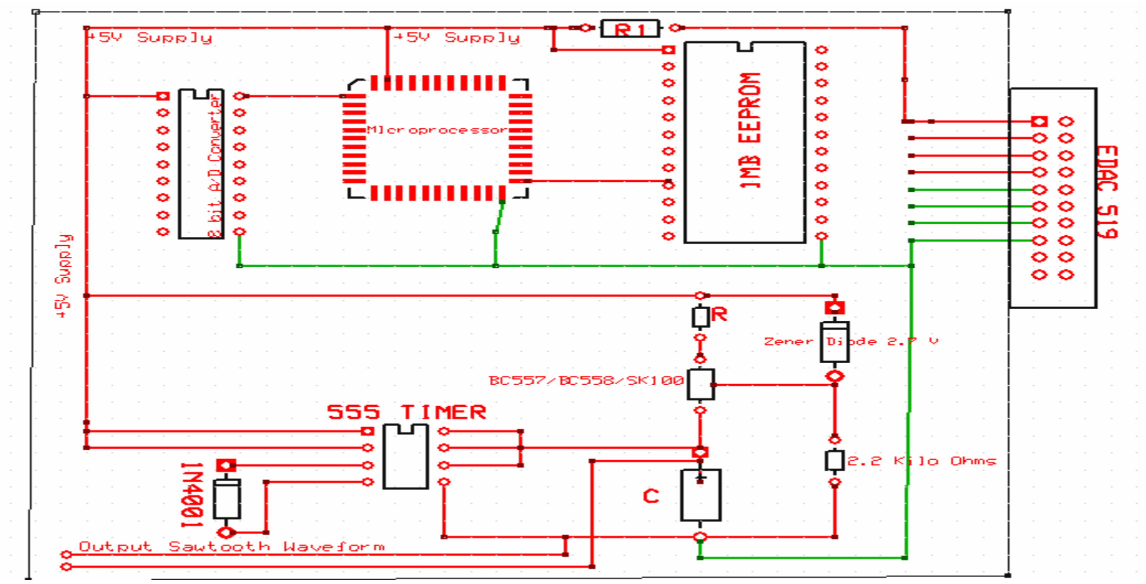


Figure 4: Power Supply Diagram

A. Other relevant power information-

The thermal system will be powered by D sized lithium ion batteries that are used for military projects going into the atmosphere. Figure 6.3 displays the military grade D batteries used for the project. There will be 6 of these as primary and 3 additional batteries in series as secondary power supply.

Figure 5: LS 33600C Saft D Batteries

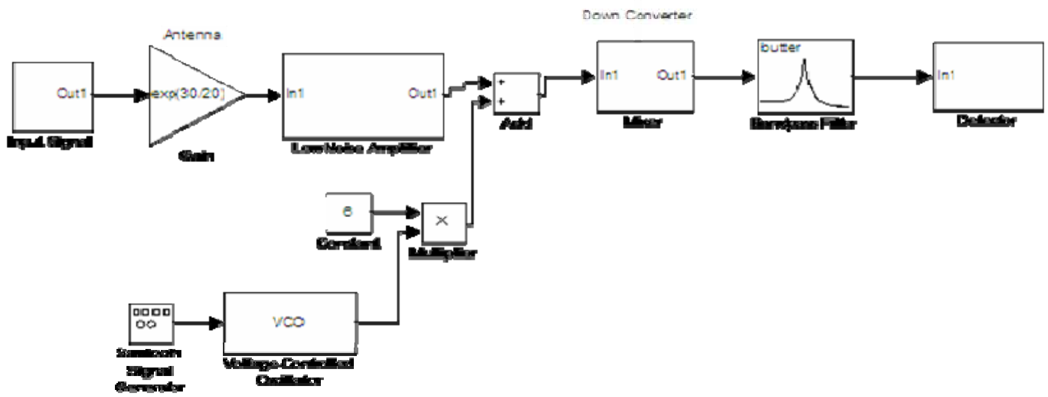
The Basic Stamp board for thermal system will be powered by two 9 volt batteries in parallel, which will be of the same military quality as the D sized batteries.

Figure 6: Military Grade 9 Volt Batteries from Saft

Simulation

Purpose – To determine the feasibility of our design as it accomplishes our objective

Receiver Design in Simulink



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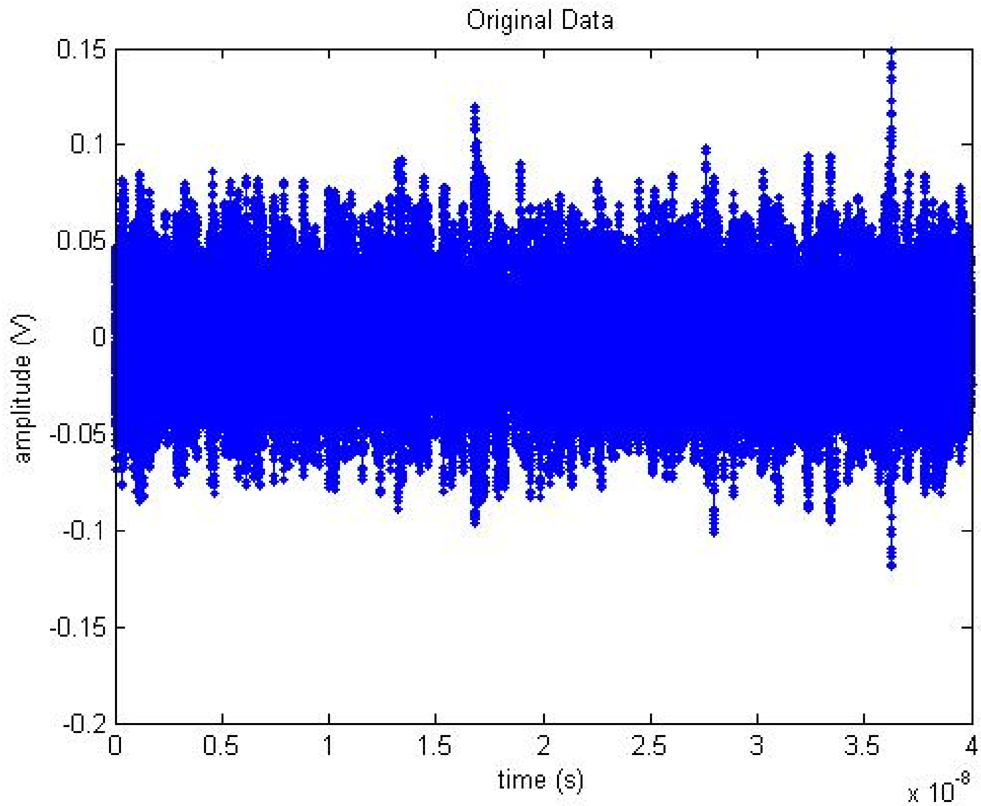


Figure 7: Simulated input data. The data is mostly white noise plus a Lorentzian colored noise component. The colored noise is a simple model for the 60 GHz O2 resonance line. See science objective section.

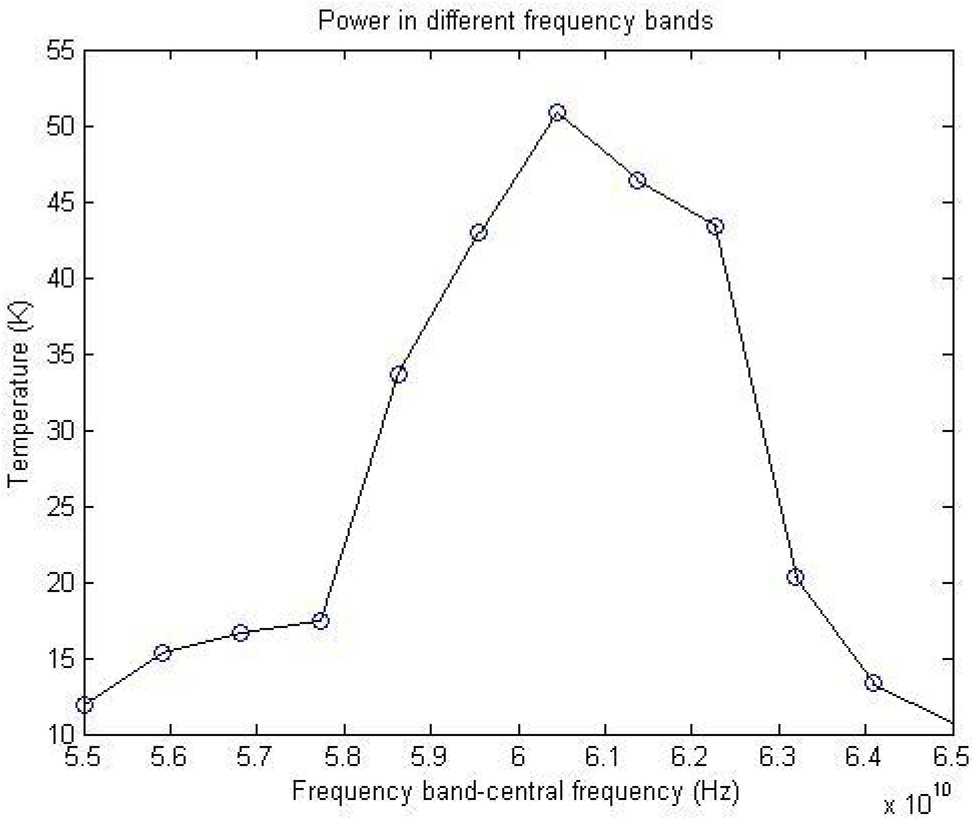


Fig 8: Simulated average power response of the radiometer at the final detection stage.

Work to be done:

- Travel to Millimeter Wave company in Florida to test and retrieve radiometer components
- Link data acquisition to radiometer
- Test radiometer and data acquisition system
- Test thermal system together with radiometer and data acquisition system in condition similar to the one encountered during the flight.
- Run an experiment for about 1.5 days
- Analyze data collected in tests.
- Get ready for integration
- Prepare logistic for flight

Modified 2008 Proposal

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 this region is considered the edge of space and the acquired data would be relevant in terms of satellite communication, sub-orbital flight missions 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 around 42.5 GHz. Most of the signal present in the selected 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 to 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 the cosmic background radiation, the atmospheric lines are pretty bright so to measure and resolve them should be relatively easy. We can then use such lines for calibration purposes. 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 a resolution.

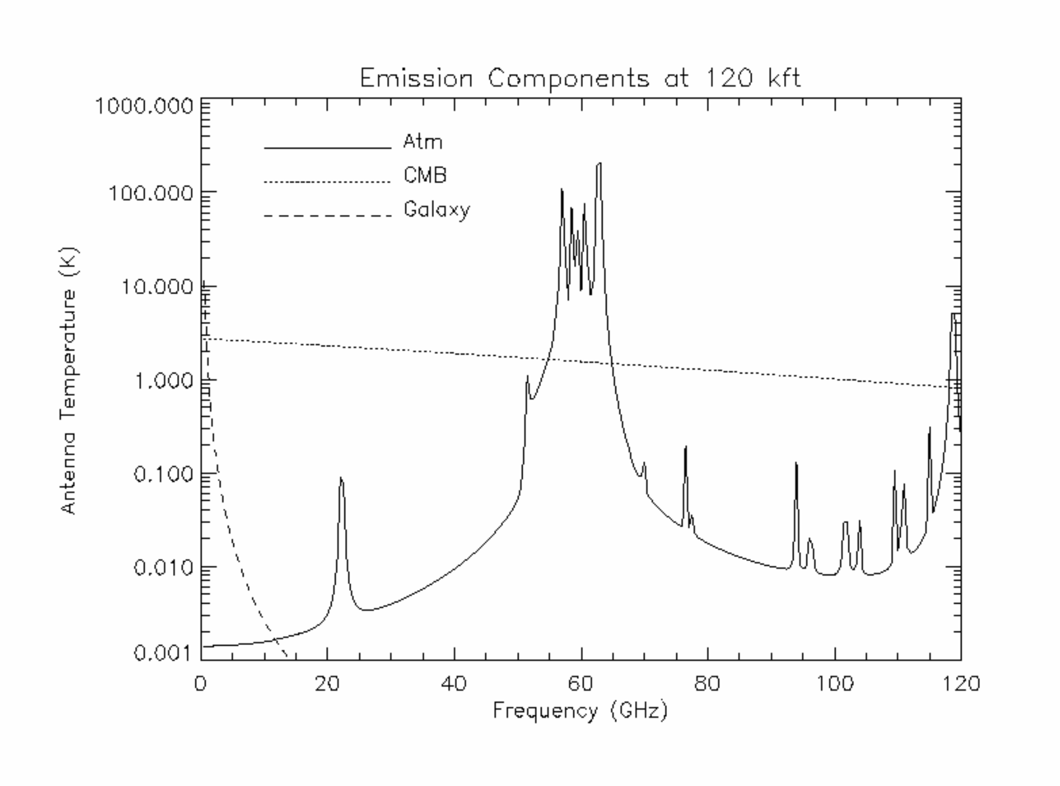


Figure 1: The expected radiation spectrum of the microwave radiation at 120,000 feet. Reproducing such a spectrum will be the main goal of our project.

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:

Our main receiving device is a microwave radiometer. 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 a X10 video amplifier. This is a simpler instrument and less expensive. Our estimated cost for this setup is about 10,000 $. If budget will permit we will favor the second design that allows for a greater sensitivity, frequency resolution and versatility. This design is about $ 5000 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 saturation 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. Further, for redundancy, we will send the data to the ground via the onboard HASP telemetry system.

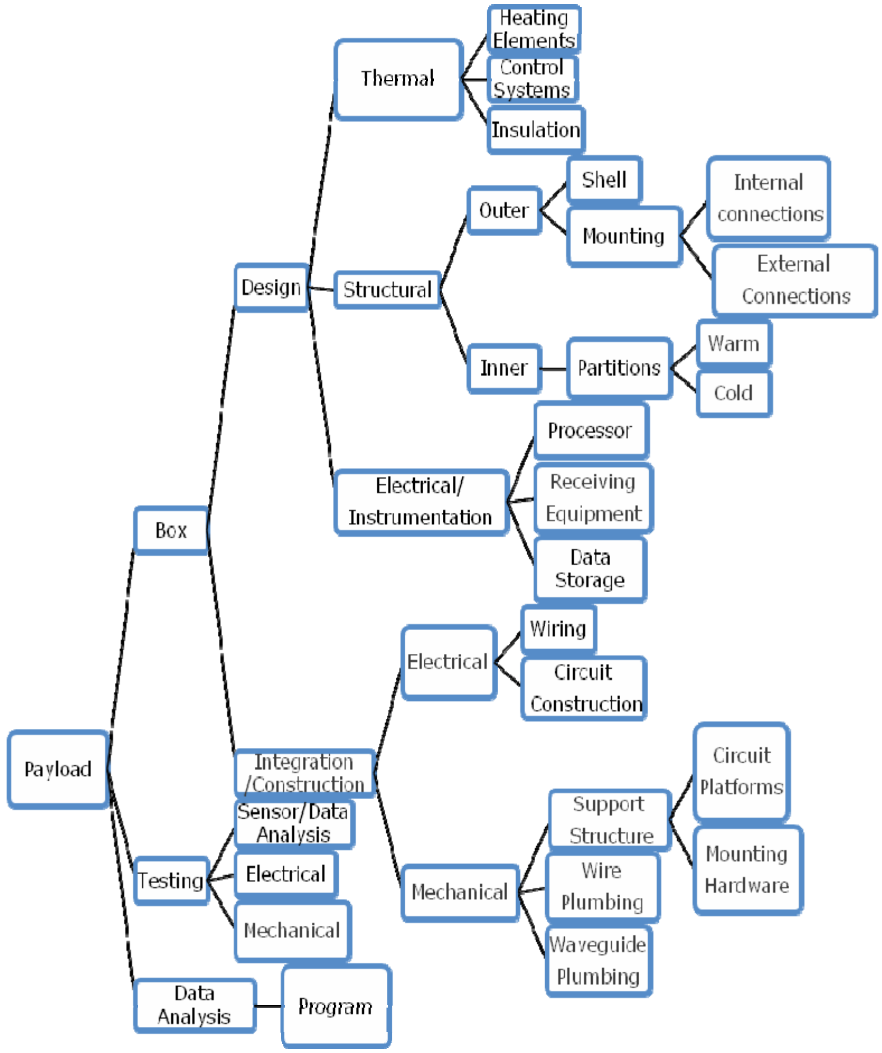
Team Structure and Management:

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:
Ramji Neupane -Electrical Engineer (team leader)
Dilip Roshan Das-Mechanical Engineer (Structure, Integration/Construction)
Sovit Poudel -Mechanical Engineer (Thermal, Integration/Construction)
Sunit Pradhan-Electrical Engineer (Instrumentation/Testing, Receiving Equipment)
Mukesh Wagle –Computer Scientist (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. Therill 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 meeting 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 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) Integration 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



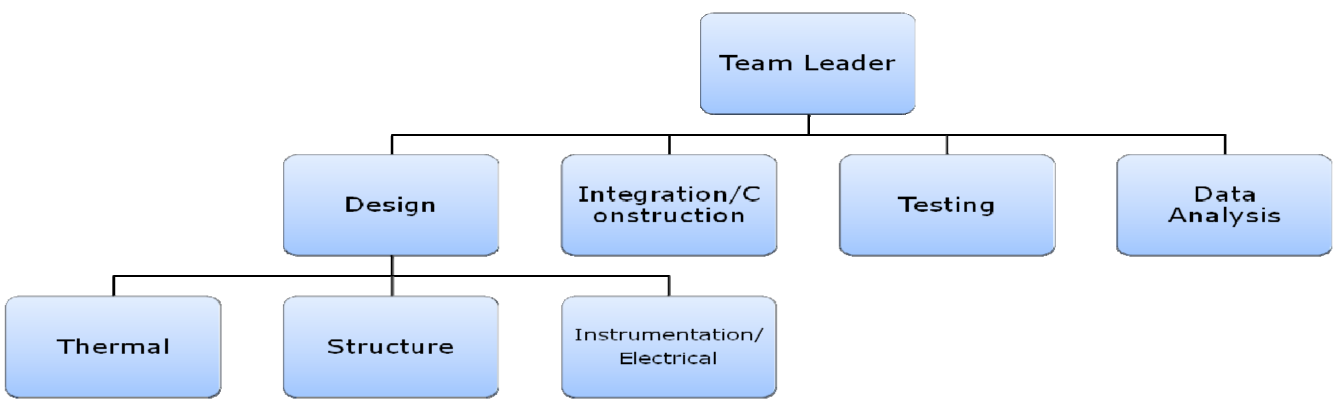


Fig 2: Organizational chart illustrating the Team Structure. The team members in charge of the different parts of the project are listed above.

Time Schedule:

Planning and organization
We don't have the whole team of last year for the project. So our HASP advisors recruited a group of new students at McNeese. We have divided the team into specific groups. For each group there will be assigned responsibilities and jobs.
Research, Brainstorming and Training
Basic principles of microwaves electronics and their implementations are being discussed within the team members. All members of HASP McNeese will be trained on basic components of electronics. How electronics work in a circuit and how to implement them for our project is started in the middle of September 2008 and will be ending on 2nd week of April 2009.
Data Acquisition
One of the vital part of project is to store the data which will be received from the microwave detector. The data will be stored in a memory chip of a Rabbit microcontroller in digital form for the successive analysis. We are working to finalize a data acquisition system with enough memory support, necessary processing performance and light weight.
Documentation and Project Proposal Submission
Meet the deadline proposal of December 19th 2008.
Company Visit
-Our microwave receiver is being manufactured by an electronic company.
-Microwave receiver with power sensor is included.
- We will visit the company on 1st week of January 2009 to collect and test the equipment.
Final design
The Final design of HASP McNeese 2008/2009 will be completed within 9th of April 2009. This design will include reception of microwave, processing and storage. After this, we will be testing the design using McNeese's facilities.
-Testing for about 2 weeks after the final design phase
-Bugs in the design will be studied and will be eliminated.
-Work on HASP's deliverables
-From 9th of May to 20th of May, the final design will be tested in compound of Columbia scientific Balloon center.

Integration and testing at the CSBF
-Data received in CSBF will be studied.
-Bug and any problem encountered will be solved
-Design will be more robust.
Flight to New Mexico
-Take care of the travel logistics to Fort Summer, New Mexico
-Organize the data acquisition and control team
-Analyze the payload flight data
-Write Scientific Report

Time Charts:
See attached Gantt Chart.

Contact Information:

Name: Ramji Neupane
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Name: Dr. Giovanni Santostasi (Assist. Professor and project advisor)
Phone: 1-(337)-244-3763
Email: gsantostasi@mcneese.edu

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 kg for receiving equipment and 1 kg storage devices, 5 kg structure, 2 kg thermal.
- 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 30 VDC power source. The thermal system will use the 30 VDC directly, while the radiometer will need to scale down the voltage to 15 V.

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.
Also see the attached MRE II Design Package.

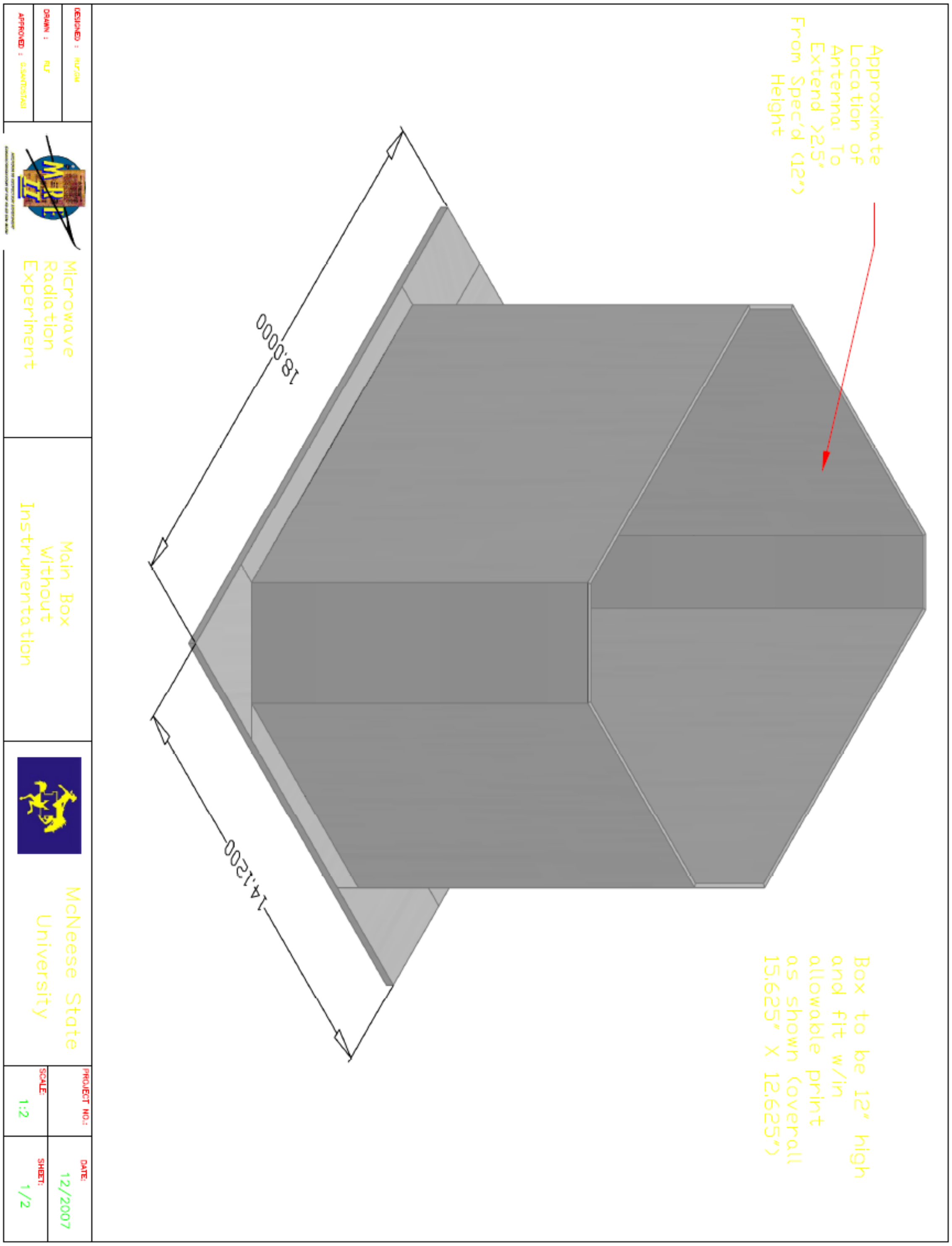

Fig. 3: Overall schematic of the payload. The drawing shows the size of our box that will contain the electronics of our receiving apparatus, the thermal control system and data storage device. A feed horn antenna (not shown in this preliminary drawing) will protrude from the top of the box and oriented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

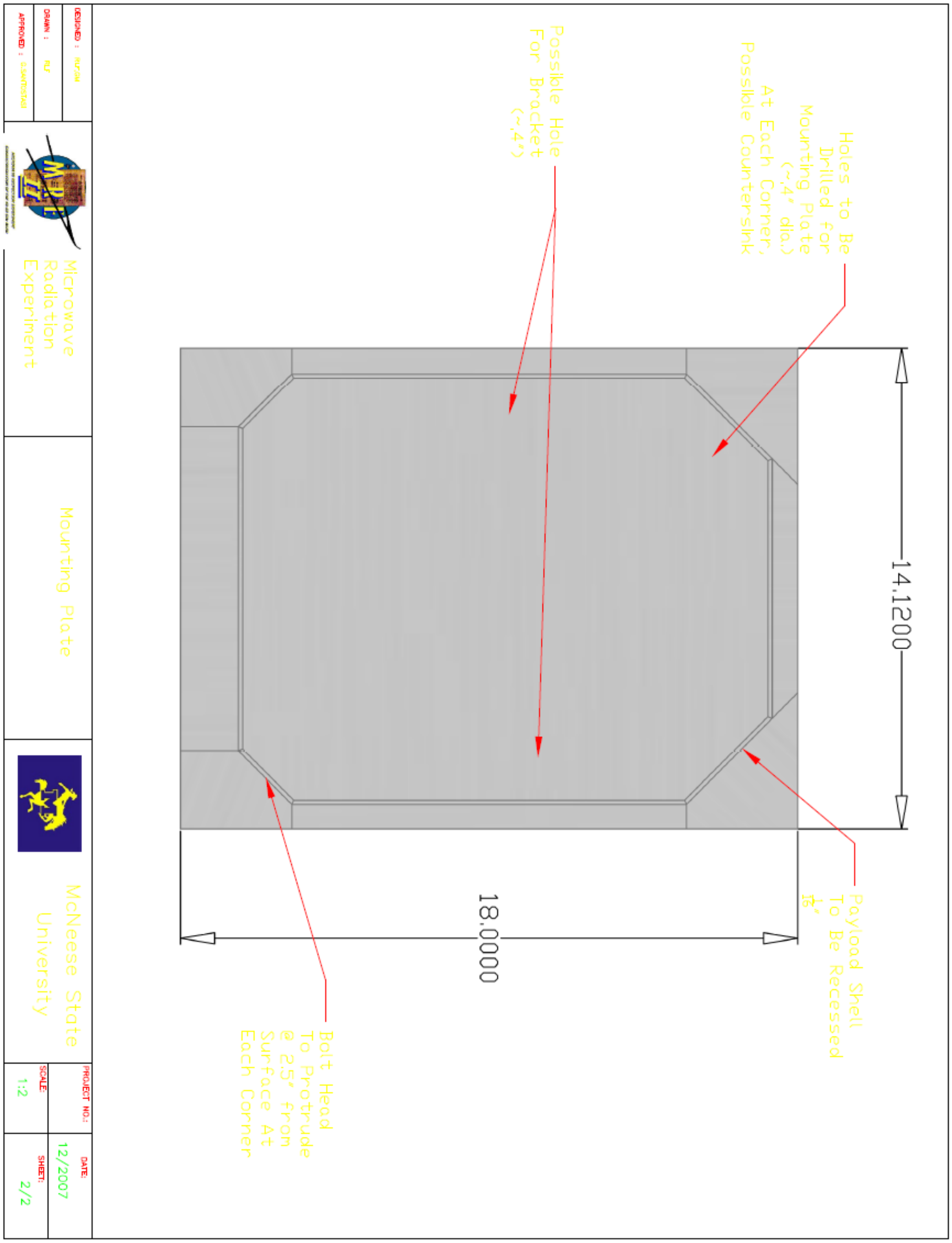

Fig. 4: The mounting plate modifications to which attach the box illustrated in Figure 1.

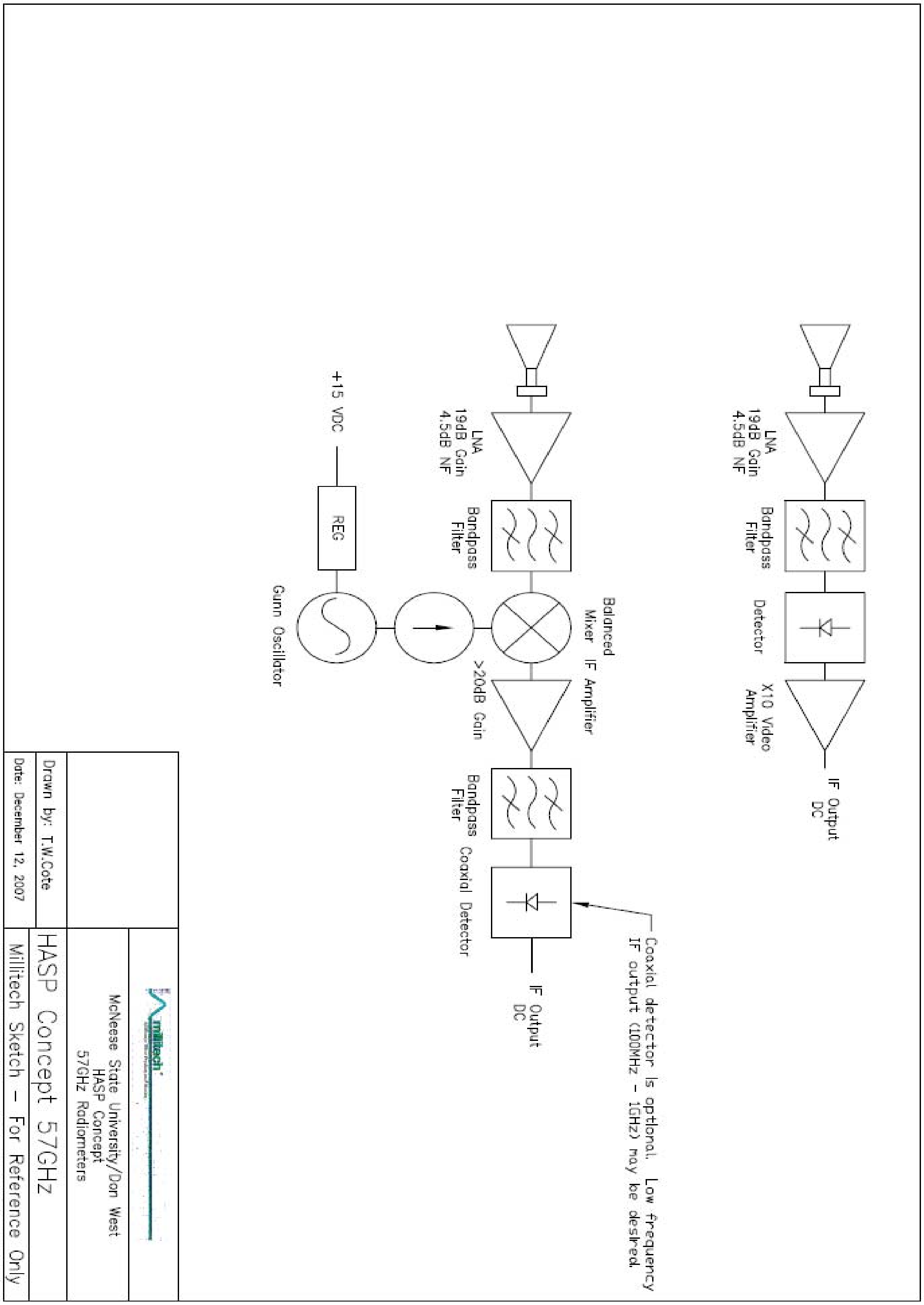

Fig 5: Schematic diagrams of two possible radiometers to measure the microwave radiation in the sky at around 57 GHz. The top design is for a simpler, less expensive but less precise radiometer. The lower diagram represents a more precise and flexible instrumentation. This is our favored setup if budget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

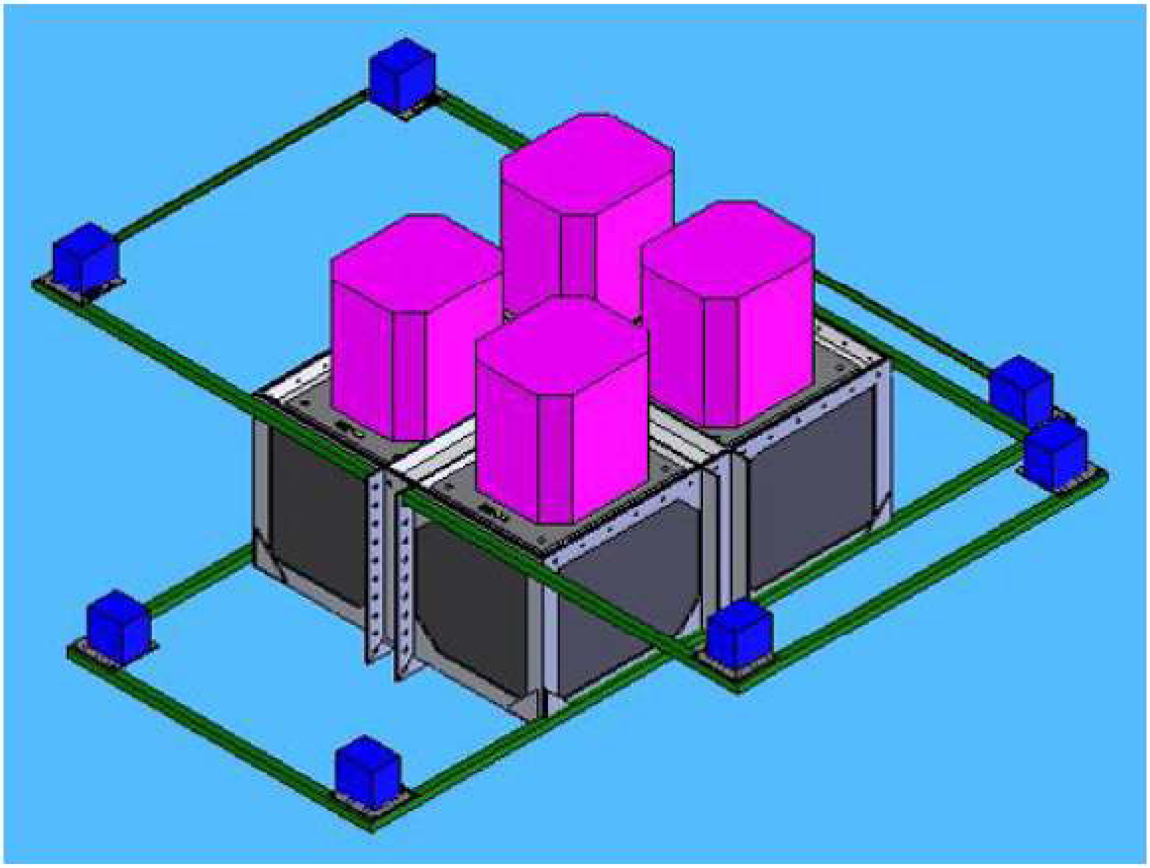

Fig 6: 3-D view of HASP platform with payload configurations from (Note: located opposite of cosmocam, because of possible interference.)

GANTT CHART

HASP – McNEESE '08/'09																	
				2008					2009								
SN	Task	Start time	End time	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep
1.	Planning and Organization	09/01/08	12/03/08														
2.	Research, Brainstorming and Tranning	09/15/08	04/10/09														
3.	Data Acquisition	15/10/08	03/30/09														
4.	Documentation and Project Registration	11/10/08	12/14/08														
5.	Company Visit	01/04/09	01/07/08														
6.	First Phase Design	01/20/09	04/09/09														
7.	First Phase Design Test	04/20/09	05/07/09														
8.	Test in Columbia Scientific Balloon	05/09/09	05/20/09														
9.	Second Phase Design Test	06/10/09	08/30/09														
10.	Final Demonstration (Mexico)	09/05/09	09/15/09														

Ramji Neupane 11/11/08