Preliminary Design Review Report
Vehicle and Payload Experiment Criteria

Measuring Radiation as a Function of Altitude Using a Hybrid Rocket Platform

1) Summary of PDR report (1 page maximum)

Team Summary

Ø School name  Harding University
Ø Location  915 East Market Street, Searcy, AR 72143
Ø Mentors  Edmond W. Wilson, Jr., Professor of Chemistry

Launch Vehicle Summary

Ø Size  ï Last year our airframe was 4.00 in diameter x 9.5 ft long, weighed 12.8 lb without the motor and reached an altitude of 4902 ft. The motor used was a Contrail Rockets Certified Hybrid, K-234HP. Our achieved altitude in 2009 was 93% of the goal of 5280 ft. For the 2010 competition we decided to retain the basic airframe size but increase the motor power. Keeping the same airframe size but increasing the motor performance allows us to be able to increase the weight of the rocket slightly and still reach altitude. The additional weight will be taken about by making the airframe substantially stronger. The fins and airframe will be reinforced with Kevlar, fiberglass and epoxy.

For our purposes, a 4.00 inch diameter by 90.3 inch long airframe appears to be ideal. It is large enough to accommodate a powerful motor, give reasonable space for the science payload and be economical in terms of weight.

Ø Motor choice  ï A hybrid motor was chosen for our competition rocket because we have been developing sensors for hybrid rocket motors for several years. The use of hybrid rocket propulsion provides additional opportunities to learn more about hybrid rockets and do a better job of characterizing hybrid rocket exhaust plumes. We believe hybrid rocket propulsion has an important role to play in delivering payloads to low earth orbit. Hybrid rocket propulsion provides economy, storage and safety advantages not equaled with liquid or solid rocket systems. Hybrid rocket use makes for minimal impact on the environment as no perchlorates are needed for propulsion.

The motor we chose is a Contrail Rockets Certified K-888-BM Hybrid Motor. When using a medium nozzle, the motor produces a Total Impulse of 2400 N∙s and Burn Time of 2.67 s.

Ø Recovery system  ï The recovery system uses a PerfectFlight Mini Altimeter flight to record the flight data and deploy the two parachutes. A G-Wiz MC2 flight computer will provide a redundant backup in case of failure of the PerfectFlight MiniAltimeter.
Two parachutes with shock cords will be used to return the rocket to ground safely. A drogue parachute will deploy at apogee. The drogue is a 24'' Classic II Sky Angle Parachute weighing 6.0 oz. The main parachute will be a 60'' Classic II Sky Angle Parachute that weighs 18.2 oz. It will deploy at 800 ft. The descent rate with both parachutes deployed, according to RockSim V9 models is 17 ft per second.

 Payload Summary

The Harding Flying Bison USLI rocket science payload consists of a suite of sensors:
- Geiger radiation sensor
- x-, y-, z- accelerometers
- pressure sensor
- temperature sensor

Science Payload Goal: The goal of our science payload is to measure alpha, beta and gamma radiation as a function of altitude during our competition rocket flight in April 2010, record the measurements and interpret the results. A secondary goal is to measure temperature, pressure and x-, y-, z- acceleration during the flight and relate this to flight trajectory and performance.

Summary experiment: We will measure alpha, beta and gamma radiation as a function of altitude using a Geiger counter in order to have a better idea of the amount of radiation encountered at altitudes as high as one mile.
- The experiment will use a Geiger counter as the sensor.
- A g-switch will initiate data collection at launch.
- Data from the Geiger counter will be digitized and stored in memory using an embedded computer.
- Radiation events closer than 2 ms will not be recorded.
- Alpha radiation is blocked by thin sheets of paper or the top layer skin, we will see only the higher energy alpha particles.
- We should be able to detect most of the beta and gamma radiation.
- The analog to digital converter has a resolution of eight bits making the count range 0 to 255.
- The rate at which data is converted is one reading per 2 ms. Therefore events that occur less than 2 ms apart will be recorded incorrectly.
- Careful calibration will aid in improving the quality of the results.

II) Changes made since Proposal (1-2 pages maximum)

Changes made to Vehicle Criteria: We have added a set of three fins to the mid-section of the launch vehicle for increased stability.

Changes made to Payload Criteria: We have completely abandoned the original science payload which was installation of a spectrometer to measure atmospheric
gases during flight. The reason is two-fold. First, the spectrometer could not be made to fit inside the 4.00 inch airframe shell without doing significant modification to the $3000 spectrometer chassis. This removal of chassis material may have rendered it useless for the competition flight and for other projects. We could have increased the diameter and length of the airframe where the science experiment was mounted. This would require building an airframe with a bulge in it leading to additional problems of flight stability and adverse weight distribution. Secondly, interfacing the spectrometer to an embedded controller and developing all the computer code was too ambitious for the time and personnel involved.

Instead, our science payload will consist of radiation, pressure and temperature sensors as well as accelerometers. These devices are operated by an embedded controller which directs the data obtained to on-board memory for later read-out and interpretation.

Changes made to Activity Plan İ No changes have been made to the original activity plan and the individual activity goals are being pursued.

III) Vehicle Criteria

Selection, Design, and Verification of Launch Vehicle

Mission Statement, Requirements, and Mission Success Criteria

Mission Statement İ Our mission is to design, build, test and fly a high powered hybrid rocket that will reach exactly an altitude of 1.00 mile and carry a science payload to measure alpha, beta and gamma radiation as a function of altitude. A second part of the mission is to measure temperature, pressure and x-, y-, z- acceleration during the flight. This mission will be done safely with no injuries, no damage to property and the entire rocket vehicle will be recovered without receiving any damage that would prevent it from further use.

Requirements İ In order to meet these mission goals, the following systems and plans must be procured or produced:

- Hybrid rocket motor using nitrous oxide oxidizer and hydroxyterminated polybutadiene with a 2400 Ns total impulse
- Nitrous oxide oxidizer supply tank that can deliver 10 liters of liquid nitrous with pressure regulator, fill and dump valves, temperature control to keep pressure between 600 and 900 psi
- Remote battery operated ignition system with 200 feet of cable that can control the fill and dump lines of the nitrous oxidizer supply and set off the electric matches which ignite Pyrodex pellets initiating the hybrid rocket flight
- On-board flight computer with backup computer capable of monitoring and recording apogee altitude and having pre-programmed capability to set of ejection charges to deploy a drogue parachute at apogee and a main parachute at 800 feet. Computers should have separate power supplies and manual switches to turn them on just before flight.
• Drogue and Main parachutes: drogue to deploy at apogee with main to deploy at 800 ft. Parachutes attached to airframe securely with ample shock cord to prevent breaking of shock cord and minimizing collision and entanglement of separated airframe parts

• Airframe that can withstand flight stresses and landing damage and carry the science payload, motor, recovery parachutes, flight recorder safely through the planned trajectory

• Fins that help maintain smooth and stable flight pattern with minimum turbulence

• Science payload with separate power supply to record radiation, altitude, temperature, pressure, x-, y-, z- acceleration. An embedded controller will be required to activate the sensors, record and store their signals and provide interface to retrieve data at the end of the flight

• Portable Launch Stand for holding, aiming and releasing rocket for flight

• Scale drawings of all components, systems and subsystems to be assembled into the final competition rocket including launch stand and fixtures used to construct sub-assemblies

• Inventory Manual of all items needed for successful and safe flight of competition rocket at USLI launch site

• Procedures Manual for preparation of the rocket for flight

• Safety Manual for safety procedures, safety information and best safe practices to be followed including MSDS sheets of all chemicals used

**Mission Success Criteria**

The mission will be a success if the following objectives are met:

• Pre-Launch
  • Complete assembly
  • Electronics activated and responsive
  • Full battery Charge
  • Establish RF connection
  • Proper Motor preparation

• Launch
  • Motor Ignition
  • Rocket successfully leaves launch pad
  • Correct thrust to weight ratio
  • Stable flight by guidance rail
  • Stabilization by fins
  • Maintains integrity despite (LAUNCH) forces
  • Motor burns completely

• Flight
  • Barometrics Locked
  • Thrust launches rocket to 5280 feet altitude
• Apogee reached
• Gauged by accelerometers/barometer
• Drogue parachute launched
• Rocket successfully separate
• Drogue Parachute Successfully deploy
• Rocket begins descent
• Barometer detects altitude of 800 feet
• Main parachute deploys
• Rocket successfully separates again
• Main parachute successfully deploys
• Rocket decelerates to 17 feet per second
• Rocket Lands

• Recovery
  • Power maintained throughout flight
  • GPS sends coordinates
  • Rocket recovered
  • Data retrieved within 30 minute window

• Integrity
  • Airframe integrity maintained
  • Electronics functionality maintained
  • Rocket remains in reusable condition

• Major Reports
  • Proposal submitted on time
  • Web Site Active
  • PDR submitted on time
  • CDR submitted on time
  • FRR submitted on time
  • Final Report submitted on time

• Safety and Environment
  • No injuries to life forms
  • Environment not affected

δ Major Milestone Schedule (Project Initiation, Design, Manufacturing, Verification, Operations, and Major Reviews)

The major milestone schedule section is found in the Major Milestone Schedule Table in the Timeline Section of this report.
Review the design at a system level, going through each system's functional requirements. (Includes sketches of options, selection rationale, selected concept and characteristics.)

A 4.00 inch diameter airframe appears to be ideal. It is large enough to accommodate a powerful motor, give reasonable space for the science payload and be economical in terms of weight. Last year our 4.00 inch by 9.5 ft competition rocket reached an altitude of 4092 feet. It seemed sensible to us to use approximately the same size rocket airframe but increase the power of our hybrid motor.

The motor we chose is a Contrail Rockets Certified K-888-BM Hybrid Motor with a Total Impulse of 2400 N\(\cdot\)s and Burn Time of 2.67 s. The 3.00 in diameter motor is composed of two chambers: a 2050 cm\(^3\) nitrous oxide chamber, 30.00 in long, bolted to a 10 inch combustion chamber. This configuration comes with a "medium speed" nozzle. The Coaxial Vent Assembly allows for the vent to be routed through the combustion chamber. This eliminates the need for a top vent on motors, a distinct advantage over previous designs. These Contrail 75mm Motors fit Standard Aero Pac Motor Retainers another advantage when constructing the rocket.

The rocket motor is 40.00 in long and 2.95 in. in diameter. It has four 3/16 in injectors plus a 1/8" vent. The empty motor weighs 4173 g and has an Average Thrust of 896, Peak Thrust of 3024.8, Total Impulse of 2400 N\(\cdot\)s and Burn Time of 2.67 s. when using a "Medium Black" fuel grain.

Describe the subsystems that are required to accomplish the overall mission.

Subsystems are:
- Aft airframe consisting of
  - Boat tail
  - Motor mounting tube
  - Tail cone motor connector
  - Aft fins
  - Mid-rocket fins
  - Motor
- Forward airframe consisting of
- Science payload consisting of
  - Flight computer number 1
  - Flight computer number 2
  - Embedded micromputer system
  - Radiation counter
  - Temperature sensor
  - Pressure sensor
  - X-, Y-, Z- accelerometers
  - Battery power supply
- Drogue parachute compartment
- Main parachute compartment
- Nose cone
Describe the performance characteristics for the system and subsystems and determine the evaluation and verification metrics plan and its status.

Performance characteristics have not yet been determined. This will require laboratory and field tests that will be done later. We do not understand the terms “evaluation and verification metrics plan and its status.”

Define the risks and the plans for reducing the risks through analysis or testing for each system. A risk plot that clearly portrays the risk mitigation schedule is highly encouraged. Take all factors that might affect the project including risks associated with testing, delivery of parts, adequate personnel, school holidays, budget costs, etc. Demonstrate an understanding of all components needed to complete the project and how risks/delays impact the project.

We are unfamiliar with “risk plots.”

Demonstrate planning of manufacturing, verification, integration, and operations. (Include component testing, functional testing, or static testing.)

These items are included in other sections of this report.

Confidence and maturity of design

We do not understand the meaning of confidence and maturity of design. Is there some reading materials that would help us with these concepts?

Include a dimensional drawing of entire assembly, such as a RockSim graphic.
SolidWorks Drawing of Harding University Flying Bison Competition Rocket.

Harding Flying Bison Competition Rock Minus Airframe Skin to Show Detail.

Airframe System

- **Nose Cone** -- Composed of plastic to minimize cost and weight. Aerodynamic ogive shape. The base of the nose cone will be cut off to fit part of the folded main parachute inside the hollow nose cone, thereby maximizing the usable volume and minimizing the length of the rocket. The nose cone will be 4.09\(\text{in}\) outer diameter and 16.8\(\text{in}\) length.

- **Body Tubing** -- Composed of pre-glassed phenolic which, unlike quantum tubing, will not expand significantly as temperature increases. Pre-glassed phenolic will also be easier to accurately machine than quantum tubing. The uniform cylindrical body tubing will have an outer diameter of 4.09\(\text{in}\) and an inner diameter of 3.9\(\text{in}\). It will be divided into three sections, which will be held together by coupler sections inside the rocket body. The total length of the body tubing will be 66.0\(\text{in}\).
• **Coupler Sections** -- Composed of phenolic tubing to minimize cost. The uniform cylindrical coupler sections will have an outer diameter of 3.9\(\text{in}\) and an inner diameter of 3.78\(\text{in}\). Each coupler will have a bulkhead at each end, composed of one 3.78\(\text{in}\) diameter plywood circle centered and attached with epoxy to one 3.9\(\text{in}\) diameter plywood circle.

• Avionics Section -- will have two .25\(\text{in}\) threaded rods bolted to both bulkheads to provide integrity to this section when each parachute is opened, putting strain on the airframe.

• **Boattail** -- Composed of plastic to minimize cost and weight. Aerodynamic ogive shape. The purchased boattail will be modified to fit the specifications of the rocket, resulting in a front outer diameter of 4.09\(\text{in}\), a rear inner diameter of 3.13\(\text{in}\) and an approximate length of 7.5\(\text{in}\).

• **Motor Mount** -- Composed of phenolic tubing. The motor mount will have an outer diameter of 3.13\(\text{in}\) and a length of 36\(\text{in}\).

• **Fins** -- Composed of G-10 fiberglass. The rocket will have two sets of three fins (spaced evenly at 120° angles): one set attached through slots in the body tubing onto the motor mount with epoxy, and the other set attached through slots in the body tubing onto slotted plywood pieces with epoxy. These three slotted plywood pieces will be fixed to the inside of the body tubing in the drogue parachute bay section. The fins of the drogue parachute bay, which are required to stabilize the rocket, will be right triangles with a length of 6.5\(\text{in}\) and a semispan of 4\(\text{in}\). The fins of the motor section will be trapezoidal with a root chord length of 8\(\text{in}\), a tip chord length of 4\(\text{in}\), a semispan of 4\(\text{in}\), and a sweep length of 4\(\text{in}\).

**Recovery Subsystem (Highlighted Because of Criticality)**

• Demonstrate that analysis has begun to determine size for mass, attachment scheme, deployment process, test results with ejection charge and electronics.

**Primary Altimeter** For the recovery sub-system, we have chosen a PerfectFlight MiniAltimeter as the primary altimeter. This is required by the USLI committee. It will also serve as the backup flight computer. Specifications for the PerfectFlite MiniAltimeter are available from the PerfectFlite website: [http://www.perfectflite.com/](http://www.perfectflite.com/).

• Dimensions: 0.90"W x 3.00" L x 0.75"T

• Weight: 20 grams (without battery)

• Operating voltage: 9V nominal (6V - 10V)
- Default low battery alarm: 8.4V
- Operating current: 8 ma typical
- Firing current: 27 A peak, 190 mJ energy
- Continuity check current: 8.9 uA/V
- Serial data format: 8 data, no parity, 1 stop, XON/XOFF
- Serial data rate: 38,400 bps (commands, data), 9.600 bps (telemetry)
- Maximum altitude: 25,000 feet MSL
- Launch detect: 160 feet AGL
- Event 1 output: apogee

Event 2 output: selectable 300 - 1,700 feet AGL. Altitude accuracy: +/- 0.5% typical. Operating temperature: 0C to 70C

**Primary Flight Computer** For the primary flight computer, we will use a G-Wiz MC2 flight computer. It also serves as the backup recording altimeter (Specs for the Flight Computer from G-Wiz Flight Computer, Website: http://www.gwiz-partners.com/html/g-wiz_mc2.html)

- Pyro output 1 - Jumper select between Launch detect (for clusters) and Burnout detect (for staging). When Staging, 1st, 2nd, or 3rd stage selectable. Optional timer as well.

- Pyro output 2 - Fires at Apogee detect. Apogee detection is generally based on Accelerometer data, but Barometric Apogee can be selected, and is not subject to problems with Mach transition. Also with optional timer.

- Pyro output 3 - Fires at a programmable low altitude, settable in 10 (foot or meter) increments. Also, may be configured to fire a given number of seconds after Apogee instead. Also with optional timer.

- Pyro output 4 - User programmable. May be turned on with one event, and off with another. Or with an event plus a time delay in both cases.
- Status LED / Speaker shows and beeps readiness at launch, and maximum altitude plus optional maximum speed upon landing. Readiness consists of Continuity checks, and both CPU and Pyro battery voltage levels.

- Arming jack provided on board, and via terminal block for external placement. Not vibration sensitive, and continuity checks work even when disarmed.

- Analog to Digital converter reads accelerometer and barometric sensors to 12 bit precision. Equivalent to about 7 ft/count barometric, or .03 G per count acceleration.
  - Acceleration and Barometric data sampled and recorded 33 times per second along with all detected events. Enough memory on board for up to 18 min of flight (128k), and can record multiple flights. More memory available as an option.

  - Barometric altitude to 70k+ feet
  - Altitude selection, and readout in English (feet) or Metric (meters) units.
  - USB or RS-232 connection.
  - Graphing software provided works on PC/Windows, Mac
  - High performance processor uses proprietary techniques to calculate altitude properly. It does not rely on linear simplifications, but follows atmospheric pressure to altitude models very closely.

  - High current FET driven pyro outputs are capable of delivering up to 15 amps for a full second, each. Outputs capable of delivering up to 50 amps are available on request.

  - Can use 2 batteries to ensure that the battery driving the pyro output does not interfere with the computer.

  - Optional low current mode (jumper selected) allows use of one battery by limiting current draw. Works with DaveyFire 28B and Pratt Hobbies WEC-1A. May work with other low-current matches as well.

    - Reverse voltage protection on all connections.

    - Positive retention header is standard.

    - MC HiG has a 100g sensor. Unit dimensions: 4.9"x 0.9"


    - Main - 60"Classic II Sky Angle Parachute - Weight: 18.2 oz
Mission Performance Predictions *(Highlighted Because of Criticality)*

- State mission performance criteria.

Mission performance criteria were listed in the Mission Success Criteria section above.

- Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve.

<table>
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<tr>
<th>Simulation</th>
<th>Results</th>
<th>Engine</th>
<th>Max altitude Feet</th>
<th>Max velocity Feet/sec/sec</th>
<th>Time to Apogee</th>
<th>Velocity at deployment Feet/sec</th>
<th>Altitude at deployment Feet</th>
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Critical Data for Rocket:

- Length: 90.30 in
- Diameter: 4.09 in
- Span Diameter: 12.09 in
- Mass: 249.10 oz
- Center of Gravity: 40.70 in
- Center of Pressure: 58.16 in
- Margin: 4.36 overstable
Experimentally determined thrust curve for our motor by outside agency.
● Show Stability margin, simulated CP: Center of Pressure/CG: Center of Gravity relationship and locations.

These values are listed in the section above.

**Payload Integration**

● Describe integration plan with an understanding that the payload must be co-developed with the vehicle, be compatible with stresses placed on the vehicle and integrate easily and simply.

The payload, flight computers and batteries will fit inside a 12.0 in long phenolic coupler that is 3.78 in. i.d. with a wall thickness of 0.062 in. It will have plywood end caps. Electrical connections will be made to the ejection charges from the flight computers through plywood end caps with screw type connectors. Power switches, LED indicators and connectors to the various computers will be through the middle of the coupler tube wall. A ring of airframe tubing glued to the middle of the coupler will reinforce this connection area. The layout and connection design of the payload has not been done at this time. It will be completed for the CDR on January 20, 2010.

**Launch Operation Procedures**

● Determine what type of launch system and platform will be used.

As his NASA Workforce Undergraduate Fellowship at Harding University, Matt designed and built a portable launch stand that uses a one inch as the guide rail. This rail is 8 ft long and can be extended up to 8 additional feet. The length requirement for the guide rail has not yet been determined and its dimension will be known for reporting in the CDR on January 20, 2010.

● Develop an outline of final assembly and launch procedures.

The outline of final assembly and launch procedures will be prepared for the CDR on January 20, 2010.

**Safety and Environment (Vehicle)**

● Identify Safety Officer for your team — Edmond W. Wilson, Jr.

● Provide a Preliminary analysis of the failure modes of the proposed design of the rocket, payload integration and launch operations, including proposed and completed mitigations.

• Design failure modes of rocket design

• Airframe fails to hold motor in place causing motor to tear through the airframe. We will reinforce the hardware which holds the motor casing thrust ring in place.
Motor falls backwards out of motor housing tube during flight. We will use a commercial motor retainer to prevent this failure.

Airframe fails to separate with ejection charges at the designated couplers. We will use sandpaper or paper masking tape to adjust the fit of the coupler tubes to the airframe so that the fit is neither too tight nor too loose.

Fins become separated or tear through the airframe upon hard landing. We will reinforce attachment of the fins to the airframe and to the motor housing tube with Kevlar or nylon using epoxy adhesive.

Shock cords separate when deployed. We will perform tensile strength measurements on the shock cords to pick the minimum size cord that will be strong enough and increase the size to twice tensile strength specified.

The primary flight computer will malfunction. We have a second flight computer that will provide the same functions and sensors to the rocket as the primary.

Design failure modes of payload integration

Batteries will fail during launch. We will install brand new fresh batteries as part of the rocket preparation. Each electronic system will have its own battery supply.

Circuit boards and batteries will break off their mounting boards and devices at launch. We will pay special attention to making these mounting boards and battery holders as robust as possible.

Cables will detach during pre-launch or launch. We will attempt to reinforce the connections with tape to prevent separation.

Design failure modes of launch operations

Cable connecting rocket ignition box at the rocket launch pad with the operator controls at least 200 feet away fails. We can test the connectivity prior to launch and correct any problems.

Battery failure in control box that controls rocket motor ignition and nitrous oxide filling/dumping. We will bring a back-up battery and make sure the original battery is charged and tested just before launch.

Nitrous oxide cylinder too warm or too cold producing pressures below 600 psi or greater than 900 psi. We will keep the nitrous in a thermal container that can be filled with either ice water or hot water to adjust the temperature. In April one usually needs to cool the nitrous cylinder.

Provide a listing of personnel hazards, and data demonstrating that Safety Hazards have been researched (such as Material Safety Data Sheets, operator’s manuals, NAR regulations), and that hazard mitigations have been addressed and mitigated.

Personnel Hazards

Exposure of skin and eyes to epoxy resins. Exposure of hands to epoxy adhesive materials will be minimized by the use of protective eyewear and gloves.
- Exposure of skin and eyes to fiberglass fibers and Kevlar™ fibers
- Exposure of hands to fiberglass fibers and Kevlar™ fibers will be minimized by the use of protective eyewear and gloves.
- Exposure of eyes and lungs to acrylic spray paint
- All painting will be done with doors to shop opened and vent fan on. Protective eyewear and a mask covering nostrils and mouth will be worn.
- Trauma to body from improper use of hand tools
- Proper use of hand tools will be explained as needed for each process undertaken.
- Trauma to body from improper use of metalworking machines
- All will wear protective eyewear and instruction on preventing injury to the body during work periods will be conducted repeatedly for each phase of the work.
- Proper use of the nitrous oxide cylinders, regulators and controls will be explained before use. The Safety Officer will supervise launch activities dealing with nitrous. Pressures between 600 and 900 psi will be maintained on the nitrous storage cylinders by surrounding them in thermal jackets in which ice water or warm water can be added as needed. Personnel will be at least 200 feet from the launch area while loading the nitrous into the rocket motor. This will prevent anyone from receiving frostbite from an uncontrolled leak. All operations for the nitrous will be done by electrical valves except for initial turn-on of the main cylinder valve during initial launch setup and after launch. A dump valve is part of the equipment in case of failure to launch. Once a rocket is launched or aborted, the main cylinder valve will have to be manually turned off.
- Discuss any environmental concerns
- Our plan would pose no damage to the environment. We will use a flash arrestor on the bottom of our launch stand to protect the surrounding grass and weeds from catching on fire.
- A clean-up of the site after each launch will be conducted to remove trash and debris from the launch and recovery area.
- Only two to three people will enter the field to recover the rocket and they will be respectful of the crops in the launch field.
- The oxidizer is nitrous oxide. A small amount of this will be leaked to the atmosphere where it will be quickly dispersed. The amount will not contribute in any measurable way to the greenhouse effect.
- The fuel is hydroxyterminated polybutadiene, HTPB, which is essentially rubber. The spent fuel grain will be disposed of in a landfill where it will degrade back to carbon dioxide and water eventually.
IV) Payload Criteria

Selection, Design, and Verification of Payload Experiment

- Review the design at a system level, going through each system’s functional requirements. (Includes sketches of options, selection rationale, selected concept and characteristics.)

The science payload will be contained on three printed circuit boards as shown in the figure below. In addition a g-switch will be used to turn on the system at launch thereby saving power for use during the flight only. The system is powered by 2 nine volt batteries.

Components of science payload
Describe the payload subsystems that are required to accomplish the payload objectives.

- **Radiation Subsystem** -- the Geiger counter kit used is GCK-05 from Images SI, Inc. The Geiger-Mueller Tube is neon plus halogen filled with a 0.38 in effective diameter mica end window of 1.5 to 2.0 mg per cm². It will detect the following radiation:
  - Alpha particles above 3.0 MeV
  - Beta particles above 50 KeV
  - Gamma particles above 7 KeV.

- **Temperature Subsystem** -- the temperature transducer will be measured with a National Semiconductor LM50CIM3 transducer. This temperature transducer reads directly in Celsius degrees (10 mV/°C). The nonlinearity is less than 0.8°C over its temperature range of -40°C to +125°C. The accuracy at 25°C is ±2% of reading. It operates with any single polarity power supply delivering between 4.5 and 10 V. Its current drain is less than 130 mA.

- **Pressure Subsystem** -- the pressure transducer is a ASDX015A24R Honeywell device with a pressure measuring range of 0 to 15 psi and a burst pressure of 30 psi. It is powered by voltages in the range of 4.75 Vdc to 5.25 Vdc and has a current consumption of 6 mA. It will operate in the temperature range of -20°C to 105°C. It is survive 10 gram vibrations from 20 Hz to 2000 Hz and can survive a 100 g shock for 11 ms. Its lifetime is 1 million cycles minimum.

- There is one 1-axis low-range accelerometer, ADXL103CE, and one 2-axis low range accelerometer, ADXL203CE from Analog Devices. There is one 1-axis high-range accelerometer, AD22279-A-R2, and one 2-axis high range accelerometer, AD22284-A-R2. All of these devices have an output full-scale range of 37 g. All have a non-linearity of approximately 0.2% of full scale. They require a power supply capable of producing 4.75 Vdc to 5.25 Vdc and at least 3.0 mA. The operational temperature range is -40°C to +105°C. Their maximum rating is 4000 g acceleration for any axis.

Describe the performance characteristics for the system and subsystems and determine the evaluation and verification metrics.

Performance characteristics are listed in the subsystem description immediately preceding this entry.

Describe the verification plan and its status.

We do not understand what these terms mean, verification plan and status.
● Describe preliminary integration plan

Preliminary and final integration plan are the same i mount the printed circuit boards, g- switch and batteries in the payload bay and attach on-off switches, indicating LEDs and computer cable interfaces to the outside world through the end caps and walls of the payload bay.

● Determine the precision of instrumentation, repeatability of measurement and recovery system

We will test the ability of our Geiger counter sensor to measure alpha, beta and gamma radiation while mounted within the competition rocket. The Geiger counter will be calibrated with alpha, beta and gamma radiation laboratory standards to improve the quality of the measurements. Likewise, the accelerometers and pressure and temperature sensors will be calibrated in the laboratory before deployment on the competition rocket. A final science report section will be included in the final USLI report after the April 2010 competition.

Payload Concept Features and Definition

● Creativity and originality

Radiation consists of three major types: alpha, beta and gamma particles

• Alpha Rays are high speed helium nuclei. They are the least penetrating type of radiation. They can be stopped with a single thickness of paper or a few centimeters of air.
  • Beta Rays are high speed electrons. They are more penetrating than alpha rays.
  • Gamma Rays are particles of energy and are the most penetrating. Gamma rays can penetrate several centimeters of steel or hundreds of meters of air.

Cosmic and terrestrial radiation is of concern in everyday life on the surface of the Earth. It is more of a concern when moving to higher elevations, such as high mountainous elevations, traveling in jet aircraft or rocket travel to low Earth orbit. It is a serious problem for travel to other Solar System bodies such as the Moon or Mars. Radiation is not only harmful to humans; it is also damaging to electronic equipment, science experiments and spacecraft components. Single Event Phenomena, SEP, can cause burnout of electrical circuits or cause bit flips in logic circuits.

There is little data available for suborbital space. An average value for radiation on the surface of the Earth is in the range of 14 counts per second. This level can increase many fold due to environmental factors such as building materials containing radioactive materials, smoke detectors, medical x-rays, lantern mantles, etc. Cosmic radiation is
particularly troublesome, especially from events happening on our Sun. Major Solar emissions can affect power grids and communication satellites.

Radiation levels roughly double every 5000 feet in altitude. Sea level dosage is roughly one-half the level observed at one mile high, the target altitude of our rocket.

○ Uniqueness or significance

More information is needed at various locations and under various conditions about radiation at different altitudes. This small scale effort can lead to performing these same measurements on sounding rockets and high altitude balloons.

○ Suitable level of challenge

This is a very appropriate project for college science and engineering students, CAD design, metal and electronic fabrication, tensile strength machines, presses and wind tunnels will be used. There will be lots of testing done and calibration. Finally, reports such as this one plus posters and oral presentations will all help to enhance the education of participants with real-world, hands-on activities.

Science Value

○ Describe Science Payload Objectives.

- Test and calibrate a Geiger-Mueller radiation counter
- Interface the Geiger counter to an embedded controller that will operate the instrument and collect and store the data.
- Test the complete, computer integrated instrument after mounting in the airframe using laboratory alpha, beta and gamma radiation standards.
- Test and calibrate a pressure sensor that will record pressure at constant intervals over the rocket trajectory
- Test and calibrate a temperature sensor to be used to record temperature as a function of altitude
- Test and calibrate a low sensitivity and a high sensitivity 3-axis accelerometer that will record the acceleration throughout the flight trajectory.

○ State the payload success criteria.

Payload success will be achieved if all the sensors perform satisfactorily and data from each is collected and stored in the on-board computer memory.

○ Describe the experimental logic, approach, and method of investigation.

The logic, approach and method of investigation are listed in the Science Payload Objectives.
● Describe test and measurement, variables and controls.

Variables are ambient pressure, humidity, temperature and radiation density. All of the sensors’ operating ranges are well within those that might be encountered in northern Alabama in the spring unless there were at 3 sigma weather or radiation deviation. In the case of a 3 sigma deviation from the norm, the range officer would not allow the rocket flights.

● Show relevance of expected data, accuracy/error analysis.

Data collected will be compared to that anticipated when possible. Accuracy can then be estimated. Error analysis will be made during laboratory testing once the payload is complete and testing begun.

● Describe the Preliminary Experiment process procedures.

All the test equipment and radiation standards are in place waiting for testing to begin.

Safety and Environment (Payload)

● Identify Safety Officer for your team  Edmond Wilson, Team Official, is the Safety Officer for the Harding Flying Bison 2010 USLI Rocket Team. He holds a NAR Level 2 Certification.

- We have met with Searcy Fire Inspector, Phil Watkins, City of Searcy Fire Department, 501 W. Beebe Capps Blvd., Searcy, AR 72143, PH 501 279 1075, FAX 501 279 3892, EMAIL pwatkins@cityofsearcy.org. to go over our handling of solid rocket motors and electrical matches with him to insure that we were in compliance with all local, state and federal regulations.

● Provide a Preliminary analysis of the failure modes of the proposed design of the rocket, payload integration and launch operations, including proposed and completed mitigations.

The payload fits completely inside a coupler on the rocket airframe. The integration of the payload has been described above in the section entitled ‘Payload Integration.’ Launch operations were addressed in the section entitled ‘Launch Operation Procedures.’ Proposed and completed mitigations have not been addressed and will be in the CDR on January 20, 2010.
○ Provide a listing of personnel hazards and data demonstrating that Safety Hazards have been researched (such as Material Safety Data Sheets, operator’s manuals, NAR regulations), and that hazard mitigations have been addressed and mitigated.

Personnel hazards include:

- Injury to eyes or hands while machining payload parts. All will wear protective eyewear and instruction on preventing injury to the body during work periods will be conducted repeatedly for each phase of the work.
- Proper use of hand tools will be explained as needed for each process undertaken.
- Instruction on how to solder properly will be given when electrical circuits are being assembled.
- No chemicals are used in constructing or operating the payload.

- Discuss any environmental concerns — All payload work will be done in the laboratory under air-conditioning. No chemicals will be used. Other than brief smoke from the soldering process, there are no chemical hazards. Burns from inadvertently touch heated portion of soldering iron are virtually unknown and the small areas affected can easily be treated with burn ointment and band-aids.
- No electrical voltages high enough to cause shock are encountered with the equipment used.

V) Activity Plan

Show status of activities and schedule

○ Budget plan — A proposal was submitted to the Arkansas Space Grant Consortium requesting $9800.00 on 20 November 2009 for funding the activities of the Harding University Flying Bison 2010 USLI Rocket Team. The status of this request is not known at this time. Our budget, which is the same as the request, is itemized below.
## Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocket Airframe</td>
<td>1100.00</td>
</tr>
<tr>
<td>Parachutes and Safety Harness</td>
<td>200.00</td>
</tr>
<tr>
<td>Construction Hardware and Consumables</td>
<td>800.00</td>
</tr>
<tr>
<td>Perfect Flight MAWD &amp; G-Whiz Flight Computers</td>
<td>200.00</td>
</tr>
<tr>
<td>Materials for Science Payload</td>
<td>500.00</td>
</tr>
<tr>
<td>Contrail Rocketry Hybrid Motor System and Reloads</td>
<td>1200.00</td>
</tr>
<tr>
<td>Nitrous Oxide, Motor Fuel Grains, Launch Consumables</td>
<td>1000.00</td>
</tr>
<tr>
<td>Travel Expenses, Meals for Travel to Memphis to Carry out Required</td>
<td>600.00</td>
</tr>
<tr>
<td>Test Flights</td>
<td></td>
</tr>
<tr>
<td>NAR Level 1 and Level 2 Licensure</td>
<td>300.00</td>
</tr>
<tr>
<td>Outreach</td>
<td>200.00</td>
</tr>
<tr>
<td>Travel to Competition Launch at Marshall Space Flight Center (10</td>
<td>3700.00</td>
</tr>
<tr>
<td>Travelers)</td>
<td></td>
</tr>
<tr>
<td><strong>Total Estimated Expense</strong></td>
<td><strong>9800.00</strong></td>
</tr>
</tbody>
</table>

**Travel Expense Budget for USLI Competition, 14 -18 April 2010, at MSFC Huntsville, AL**

<table>
<thead>
<tr>
<th>Travel:</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Passenger Van for 5 Days</td>
<td>550.00</td>
</tr>
<tr>
<td>Gasoline for Trip, 350 miles one way</td>
<td>150.00</td>
</tr>
<tr>
<td><strong>Hotel:</strong></td>
<td></td>
</tr>
<tr>
<td>10 Students at $100/night including tax for 4 nights/double occupancy</td>
<td>2000.00</td>
</tr>
<tr>
<td><strong>Meals:</strong></td>
<td></td>
</tr>
<tr>
<td>10 Students for 5 days at $20/day</td>
<td>1000.00</td>
</tr>
<tr>
<td>**Total Estimated Travel Expense for USLI Rocket Competition in</td>
<td>3700.00</td>
</tr>
<tr>
<td>Huntsville, AL</td>
<td></td>
</tr>
</tbody>
</table>
- **Timeline** Our timeline is listed in the Major Milestone Schedule below which lists each activity and the date by which it is to be accomplished.

<table>
<thead>
<tr>
<th>Major Milestone Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task</strong></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td><strong>Project Initiation</strong></td>
</tr>
<tr>
<td>Recruitment of Team Members, Goal Setting, Organization</td>
</tr>
<tr>
<td><strong>Major Reviews and Deadlines</strong></td>
</tr>
<tr>
<td>Proposal to USLI Due 8 October 2009</td>
</tr>
<tr>
<td>Web Presence Established 12 November 2009</td>
</tr>
<tr>
<td>Preliminary Design Report Due 4 Dec 2009</td>
</tr>
<tr>
<td>Preliminary Design Review, PDR, 9:00 am, Tue, 8 December 2009</td>
</tr>
<tr>
<td>Critical Design Report Due 20 Jan 2010</td>
</tr>
<tr>
<td>Critical Design Review, CDR</td>
</tr>
<tr>
<td>Flight Readiness Report Due 17 Mar 2010</td>
</tr>
<tr>
<td>Flight Readiness Review, FRR</td>
</tr>
<tr>
<td>USLI Launch Competition, 14-19 Apr 2010</td>
</tr>
<tr>
<td>Post Launch Assessment Review, PLAR, 7 May 2010</td>
</tr>
<tr>
<td>Test Launch of Scale Model with Science Payload Prototype</td>
</tr>
<tr>
<td><strong>Airframe Division</strong></td>
</tr>
<tr>
<td>Final Design of Airframe</td>
</tr>
<tr>
<td>Order Materials for Airframe</td>
</tr>
<tr>
<td>Conduct Testing of Airframe and Airframe Components</td>
</tr>
<tr>
<td>Build and Paint Airframe</td>
</tr>
<tr>
<td><strong>Motor Division</strong></td>
</tr>
<tr>
<td>Order Motor and Ignition Hardware and materials</td>
</tr>
<tr>
<td>Prepare Detailed Procedure for Motor Preparation and Flight</td>
</tr>
<tr>
<td>Prepare Safety Document for Motor, fuel and oxidizer transportation, flight preparation, ignition, flight, maintenance, stowage</td>
</tr>
<tr>
<td>Static Testing of Rocket Motors</td>
</tr>
<tr>
<td><strong>Science Payload Division</strong></td>
</tr>
<tr>
<td>Integrate Science Payload and Controller into Airframe Coupler</td>
</tr>
<tr>
<td>Laboratory Test and Calibrate Science Payload</td>
</tr>
<tr>
<td>Prepare Operations Guide for Science Payload</td>
</tr>
<tr>
<td><strong>Avionics Division</strong></td>
</tr>
<tr>
<td>Laboratory Test of Avionics Computers</td>
</tr>
<tr>
<td>Install Flight Computers into Airframe</td>
</tr>
<tr>
<td>Prepare Operations Guide for</td>
</tr>
<tr>
<td><strong>Launch Operations Division</strong></td>
</tr>
<tr>
<td>Prepare Inventory of Materials, Equipment, Supplies</td>
</tr>
<tr>
<td>Order Needed Materials and Supplies</td>
</tr>
<tr>
<td>Prepare Detailed Procedure for Launch of Rocket with Safety</td>
</tr>
<tr>
<td>Test Launch Rocket in Memphis</td>
</tr>
<tr>
<td>Prep and Launch Rocket at USLI Competition</td>
</tr>
<tr>
<td><strong>Recovery Division</strong></td>
</tr>
<tr>
<td>Use RockSim to Choose Recovery Parachutes and Supplies</td>
</tr>
<tr>
<td>Purchase Parachutes and Supplies</td>
</tr>
<tr>
<td>Integrate Recovery Hardware into Airframe</td>
</tr>
<tr>
<td>Monitor Flight and Recover Rocket at Memphis</td>
</tr>
<tr>
<td>Monitor Flight and Recover Rocket at USLI</td>
</tr>
<tr>
<td><strong>Outreach Division</strong></td>
</tr>
<tr>
<td>Design and Implement Harding Flying Bison USLI Website</td>
</tr>
<tr>
<td>Outreach Project at Westside Elementary</td>
</tr>
<tr>
<td>Outreach Project with Girls Scouts and Brownies</td>
</tr>
<tr>
<td>Prepare Safety Manual for Flying Bison USLI Rocket Team</td>
</tr>
<tr>
<td>Carry Out and Record Publicity Projects</td>
</tr>
<tr>
<td>Seek External Funding</td>
</tr>
<tr>
<td>Recruit New Team Members</td>
</tr>
</tbody>
</table>

TBD (To Be Determined)
• Educational engagement

1. Provide a written plan for soliciting additional “community support,” which could include, but is not limited to, expertise needed, additional equipment/supplies, monetary donations, services (such as free shipping for launch vehicle components, if required, advertisement of the event, etc.), or partnering with industry or other public, private, or parochial schools.

We have solicited the support and help of Mr. David Stair, a retired NASA model maker who has created some fabulous models as a NASA contractor when he was active in his profession. David has donated time and talent to help us maximize our design and construction projects. He has created several devices and jigs to help us. For example he designed and built a rotating device to allow us to evenly coat epoxy-fiberglass on our airframes. He also designed and built fixtures to allow us to glue the fins at exactly 120 degrees on the airframes and to mark and drill holes in the airframe at evenly spaced intervals.

We plan to ask BEI Systems and Space Division, a premier aerospace company in Little Rock, Arkansas to Sponsor us and give us technical support. One of their Vice-Presidents, John Beasley, was very impressed with our participation in the USLI program.

Also, we have sought to get to know the key scientists and engineers at NASA centers who are involved in rocket research. In June of 2009, I took several of our team members to visit with the rocket scientists and engineers at Marshall Space Flight Center and at University of Alabama at Huntsville. We met with Dr. Robert Frederick, Jr. and toured the facilities at UAH. We also met with Robert H. "Bobby" Taylor, Jr., Branch Chief, Solid Launch Systems and Analysis Branch, Patrick S. McRight, Branch Chief, Spacecraft Propulsion Systems Branch (ER23), George T. Story, J. Andrew Ridnour, Ph.D. at MSFC and they, in turn, introduced us to many other hybrid rocket researchers and engineers and facilities. This past year, I and some of our team visited with Dr. Greg Zilliac, Research Scientist, at NASA Ames Research Center. Dr. Zilliac is a hybrid rocket expert and conducts hybrid rocket research with people at Stanford University.

2. Include plans for at least two educational projects that engage a combined total of 75 or more younger students in rocketry. Comprehensive feedback on the activities must be developed.

• Westside Elementary School, Searcy, AR; Ms. Sherry Wilson, Teacher, 1st Grade Class 1 bottle rocket building, flight, lecture. We met in late October with the first graders and gave a lecture about NASA and rockets. This Friday, 4th December 2009, we will conduct the water rocket launch. A final meeting will be held later to make awards and present certificates of participation. The number of students is 25 plus some parents will be involved.
- Arkansas Space Grant Consortium, ASGC, Dr. Keith Hudson, Director. Provided funding for this project; Harding Flying Bison 2010 USLI Team participants will present oral or poster presentations of their rocket team projects at the Arkansas Space Grant Annual Symposium in April 2010. Attendance at this meeting is generally 100.

- Ouachita Council of Girl Scouts of America 1-800 632 6894 or 501 758 1020 and Girl Scouts of America, Batesville, AR. We will work with GSA Troop 76 in Bradford, Arkansas. An estimate of 10 - 15 girls will be involved in our outreach.

- Quapaw Area Council of the Boy Scouts of America 1 800 545 7268 or 501 664 4780. We plan to contact some of the local Boy Scout troops to see if we can enhance their program as regards STEM projects, especially those related to NASA's mission.

- Mid-South Rocket Society NAR Section #550, Marie Holyfield, Secretary-Treasurer. Ph: 901 340 8586, meholyfield@att.net, 9180 Fletcher Trace Pkwy, Lakeland, TN 38002. This NAR Section is our mentoring, sponsoring section. They provide the location and expertise to conduct rocket launches according to all local, state and federal laws.

- Jack Frederick/Raytheon/Rockets; Principal Systems Engineer; Raytheon IDS Headquarters; Tewksbury, MA; 978 858 9897 office; 781 710 9370 mobile. Dr. Frederick spends a great deal of time helping young people out of the mainstream to get interested in STEM topics. I hope to meet with Dr. Frederick this Thursday to explore ways to teach STEM topics to young people throughout the local area.

- We have received approval to present a Rocket Display in Harding University Library sometimes in February. This display will be seen by hundreds of students and faculty that visit the library each day.

- Rocket Team Chapel: Our University has a daily chapel program that all 6500 students attend. We are planning to ask for a chance to introduce our Flying Bison Rocket Team in Chapel in April just before we go to the contest at MSFC.

- Poster Session in Science Building: We are planning on having a poster session for our science, math and engineering students in the Pryor Engineering Building Main Lobby in April. All of our team members will be encouraged to present a poster at this event.

- Matt: NASA Workforce Development Undergraduate Researcher designed and built the portable and fixed launch stands for our rocket team and for our research as his undergraduate research project. Matt is a team member.
V) Conclusion

- The preliminary plan for the design of the hybrid rocket, launch stand, and payload has been proposed and agreed upon by team members.
  - Much of the detail drawings of the payload have not been made yet.
  - The launch stand has been built and ready to use.
  - The plans are complete enough to build the rocket airframe
  - The payload electronics and embedded controller, along with the avionics need to be mounted in the payload bay. Once they are securely mounted in a flight ready position and the battery powered supply installed they will be ready for laboratory testing.
- Detailed documents need to be prepared for:
  - Pre-launch
  - Launch
  - Payload
  - Payload deployment
  - Safety Procedures
- Testing needs to be done on airframe components
- Calibration and testing of all payload components and avionics needs to be done.
- Rocket needs to be flown before FRR on March 17, 2010.