USLP Proposal

Rocket Design for Exhaust Plume Studies

Submitted by

Harding University
Searcy, AR 72149

20 September 2007

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Section 1
School Information

1.1a Name/Title of Project

- Rocket Design for Exhaust Plume Studies

1.1b School Name/ Address

- Harding University, 915 East Market Street, Searcy, Arkansas 72149

1.2a Project Leader

- Sarah Christensen, Junior Chemistry Major

1.2b Team Official

- Edmond Wilson, Ph.D. Professor of Chemistry

1.3 Bureau of Alcohol, Tobacco, Firearms, and Explosive permit holder

- None, Ammonium Perchlorate Composite Propellant will not be used.

1.4 Safety Officer

- Brett Keller

1.5a Students and Faculty Members Participating

Ten students and two faculty members make up the key personnel. Team members are list below according to their job function:

- Project Leader – Sarah Christensen
- Team Official –Edmond Wilson, Ph.D.
- Co-Sponsor- James Mackey, Ph. D.
- Purchasing and Acquisitions (Budget Plan) – Megan Bush and Erin Fulks
- Model Design (Rocksim, Airframe Design, Motor Selection) – Brett Keller and Pablo Oropin
- Payload Design – Stephen Wagner
- Safety and Regulations – Brett Keller, Megan Bush, James Mackey, Edmond Wilson
- AUTOCAD – Sarah Christensen, Casey Christensen, Dan Sewell
- Recovery/Tracking – Stephen Wagner and Pablo Oropin
- Ground Support (Telemetry) – Stephen Wagner and Pablo Oropin
- Physical Construction Supervisor – Megan Bush
- Web Design – Paul Elliot
- Publicity, Community Outreach (Public Relations, Photographer, Historian, Scrapbooking) – Erin Fulks
- Teleconferencing – James Mackey

1.5b Short Resumes of Key Personnel

Project Leader

Name: Sarah Christensen
Address: HU Box 15295, Searcy AR 72149-5295
Phone: 501 279 7277 FAX: 501 279 4706 E-mail: schriste@harding.edu
Major: Biochemistry Minor: Math
Career Plans: I plan to graduate with a Bachelor of Science in Biochemistry and attend graduate school to obtain a Master of Science or Doctor of Philosophy degree in forensics. After that I plan to work for the CIA or FBI in a forensics lab.
Other: I have a NASA/Arkansas Space Grant Consortium Undergraduate Research Fellowship at Harding University for the summer of 2007 and will be doing NASA supported research. I am a member of the Honor's College at Harding, the GeDanken Society Treasurer, and work as a lab assistant in freshman chemistry labs and organic and biochemistry labs. I serve as the Project Leader for the Harding University USLP Project. I attended the USLP Workshop at University of Alabama Huntsville, Huntsville, AL in August 2006. My current GPA is 3.20.

Team Official

Edmond W. Wilson, Jr.

Harding University
915 East Market Avenue
Searcy, AR 72149-0849
www.harding.edu/wilson

Professor of Chemistry
Department of Physical Science
Tel: (501) 279-4513
wilson@harding.edu

RELEVANT EXPERIENCE

Ten years experience working with open path diode laser spectroscopy systems. Thirty five years teaching and research in applied spectroscopy. Six years experience in emission spectroscopy of hybrid rocket exhaust plumes.

EDUCATION

Ph.D. (Physical Chemistry) 1968 University of Alabama, Tuscaloosa, AL.
M.S. (Physical Chemistry) 1965. University of Alabama, Tuscaloosa, AL.
B.S. (Chemistry) 1962. Auburn University, Auburn, AL.

POSITIONS

1970-Present: **Professor of Chemistry**, Harding University, Department of Physical Science, Harding University, Searcy, AR
1997-1998: **NASA/ASEE Summer Faculty Fellow**, Jet Propulsion Laboratory

PROFESSIONAL ACTIVITIES

American Chemical Society, Councilor 1999-Present, Arkansas Academy of Science, President, Sigma Xi, The Research Society, Secretary, Treasurer, Vice-President, President, The Planetary Society, National Space Society, SETI Institute, American Institute of Aeronautics and Astronautics, American Association for the Advancement of Science. Solar System Ambassador, Jet Propulsion Laboratory, Arkansas State NASA EPSCoR Committee, Arkansas Space Grant Consortium Campus Representative

RESEARCH GRANTS CURRENTLY ACTIVE

NASA ASTID, *Distributed Spectroscopy for Mobile Science Laboratories*, Edmond W. Wilson, Jr., Harding University, P.I., Edward W. Tunstel, JPL, Co-I, Gary Anderson, University of Arkansas, Little Rock, Co-I, Amount $670,000 for 3 years. Start Date: 15 August 2005.

NASA EPSCoR, *Instrumentation for Diagnosis of Chemical Rocket Motors (Instrumentation for Diagnosis of a Hybrid Rocket Motor)*, Andrew B. Wright, Lead Investigator, Edmond W. Wilson, Jr. Co-PI, $862,500 over 3 years, Start Date August 15 2002. Extended to Year 5 ending 14 August 2006.

SELECTED RECENT PUBLICATIONS

Gary T. Anderson, Ray Hashemi, Edmond W. Wilson, Jr. and Murray Clark, "Application of Cooperative Robots to Search for Water on Mars Using Distributed Spectroscopy," *World Automation Congress, Eighth International Symposium on Robotics with Applications*, ISORA034, June 11-16, 2000.

D. Duke, J. Post, J. Mackey and E. Wilson, Jr., "Virtual Open Path Diode Laser," *American Institute of Aeronautics and Astronautics,* AIAA Paper 2000-3889, July 2000.

G.T. Anderson, C. Sheesley, R. Hashemi, M. Clark, E.W. Wilson, Jr., J. Mackey, R. Williams, M. Smeltzer and E. Tunstel, "A Distributed Diode Laser Spectrometer for Mapping Biogenic Gases on the Martian Surface," *Mars Atmospheric Chemistry and Astrobiology Workshop*, Caltech, Pasadena, CA, Dec. 2001.

Andrew B. Wright, Warfield Teague, Ann M. Wright, Edmond W. Wilson, "Instrumentation of UALR Lab Scale Hybrid Rocket Motor," *Proc. SPIE Defense and Security*, Vol. 6222, No. 622202, pp. 1-12, 2006.

Edmond W. Wilson, Jr., James E. Mackey, Brett D. Keller, Elaine J. Goertzen, Sheryl A. Clements, Charles D. Rivenbark and Calvin Cox, "OH Emission Spectra of Hybrid Rocket Motors Using PMMA and HTPB," *American Institute of Aeronautics and Astronautics*, AIAA Paper 2005-3905, July 2005.

Edmond W. Wilson, Jr., Brett D. Keller, Kellen M. Harkness, Christopher S. Smeal, Megan S. Easterly and James E. Mackey, "Ultraviolet-Visible Spectrometry Characterization of Combustion in Hybrid Rocket Motors," *AIAA 2006-4343-258,42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit*, Sacramento, CA, July 9-12, 2006.

Name: Megan Bush
Address: HU Box 11348 Searcy AR 72149
Phone Number: 501-279-5195
Major: Biochemistry and Molecular Biology Minor: Health Missions
Career Plans: I plan to attend Medical School after graduation and specialize in surgery. I want to be a medical missionary.
Other: I am a member of the Honors College and attended the ONE (missions organization on campus) meetings. I maintain a 3.8 GPA on 16 credit hours this semester while working on this project and working for Dr. Wilson. During the summer I attended the USLP workshop in Huntsville, Alabama and now am part of the project team and leader of the construction for the USLP competition.

Name: Paul Elliott
Address: HU Box 11462 Searcy AR 72149
Phone Number: (501) 305-8140
Major: Mechanical Engineering / Vocational Ministry
Career Plans: I plan on working with robotic vehicles, especially those with flight and hovering capability. I also would like to work in the development of alternative sources of non-polluting energy.
Other: I have experience with designing and building solid rocket engines and smoke systems. I also competed with a creative problem solving team that progressed to world finals 2 different years. We placed 13th my senior year in high school at the competition. I am a member of Harding's Honors College, and currently have a GPA of 3.95. I will be designing and maintaining the website for the USLP project.

Name: Erin Fulks
Address: HU Box 12036 Searcy AR 72149
Phone Number: 501-279-5093
Major: Biology Minor: Health Missions and Spanish
Career Plans: I plan to graduate with Bachelors in Biology and then attend dental school. Following graduation I plan to do medical missions in Central America.
Other: I am a member of the Honor's College and will be doing research on the atmosphere of Mars in the spring of 2007 with Dr. Wilson. I work in the admissions off office and maintain a 3.8 GPA while taking 16 credit hours. Several mission opportunities have presented themselves and I have taken advantage of them, such as my most resent medical missions trip to Panama, in Central America.

Name: Aaron Howell
Address: HU Box 13581 Searcy, AR 72149
Phone Number: 901 493 8750
Major: Mechanical Engineering and Math Minor: Physics
Career Plans: To pursue a career in the Aerospace field, in which I will be working with either propulsion or the design of the rockets themselves and the aerodynamics of the flight.
Other: I am a member of the Honors College, I am attending Harding University on a scholarship, and maintaining a GPA of a 3.7. I tutor college students that need help in the math and science fields, while I am taking 20 hours of school. I will be graduating next

spring at the age of 20, since I entered into college at 17 years old. Then I plan to attend graduate school and obtain a masters degree. I will be working on the USLP project under the supervision of Stephen Wagner and help with the electronics, payload, and construction of the rocket.

Name: Brett Keller
Address: HU Box 13543, Harding University
Phone Number: (501) 230-8817
Major: 1) Biochemistry and Molecular Biology, 2) Political Science
Minor: Psychology
Career Plans: MD/MPH, pursuing a specialty in infectious disease epidemiology in order to have an impact on international development and public health policy, with an emphasis on the synergy of changing political, economic, and social conditions on the emergence and spread of infectious diseases.
Other: I have held a NASA EPSCoR Undergraduate Research Fellowship and NASA/ Arkansas Space Grant Consortium Undergraduate Research Fellowship. My research involved the use of spectroscopy as a non-intrusive combustion diagnostic for hybrid rocket motors, developing a hybrid rocket test facility, designing and constructing a rocket test vehicle for in-flight testing of spectrometers. Attending Harding on a National Merit Scholarship and Arkansas Governor's Scholarship. Honors Council member, founded L.C. Sears Collegiate Seminar Series exploring contemporary sociopolitical issues. I have Web design experience and 6 years mid and high power rocketry experience (Level 1 NAR certification).

Name: James Mackey
Address: HU Box 10582 Searcy AR 72149
Phone Number: 501 279 4512
Professor of Physics
Department of Engineering and Physics
Ph. D. in Physics from the University of Mississippi in 1969
Research Topic – Solid state physics
Research Interests – Hybrid rocket plume analysis using laser diodes
Mobile laser diode spectrometry for measuring biogenic gases on Mars
Courses Taught: Calculus based Physics, Mathematical Physics, Electromagnetic Theory, Astronomy and Space Science.

Name: Pablo Oropin
Address: Harding's: Cone Hall Room 213A.
Home Address: Diagonal 14 # 15-39 zona 5 Jardines de la Asuncion sur, Guatemala city, Guatemala, Central America.
Phone Number: 501 305-8378
Major: Computer engineering and computer science.
Career Plans: Work for an engineering-research company. Obtain a master's or Ph.D. in biomedical engineering.
Other: I received the outstanding senior award in my high-school and graduated with

honors. I have done research on redox reactions and build batteries using them. I am part of the honors college at Harding. I am also part of the American Studies Institute Distinguished Student Honor Program. GPA: 3.9. I've done honors contracts for discrete math, software engineering. This semester I am doing an honors contract for microcontrollers/microprocessors class and one for electronics. I work as a lab attendant at the engineering lab. I am involved in Rocksim software, Airframe Design, Motor Selection, Ground Support (Telemetry), and Recovery/Tracking on the Harding University USLP Team..

Name: Daniel Sewell
Address: 3012 E. Moore APT 17 Searcy, AR 72143
Phone Number: 501 593 0979
Major: Mechanical Engineering
Career Plans: My career plans are to develop solutions to technical problems through the use of science and mathematics by studying the applications of mechanical engineering
Other: Member of Honors College, member of Alpha Chi, Kappa Delta Pi, attended leadership training through Harding University, graduated from Harding University with a BA cum laude. I am a member of Honors College, member of Alpha Chi, Kappa Delta Pi, and attended leadership training through Harding University, graduated from Harding University with a BA cum laude.

Name: Stephen Wagner
Address: HU Box 11412 Searcy AR 72149
Phone Number: 408 204 5680
Major: Electrical Engineering
Career Plans: Going to Medical school to enter into the biomedical engineering field. I plan to work designing prosthetics. I plan to lead several mission trips to Africa and other underdeveloped regions.
Other: I am involved in the Honors College and attend Harding University on a Chancellor's Scholarship. My GPA is 3.88. I attended the NASA/USLP workshop at University of Alabama, Huntsville. I am the head of the Harding University USLP team dealing with the electronics and the payload. I did research in Little Rock, Arkansas this summer with EPSCoR funding. I was involved in tracing and analyzing the structure of proteins I also have done research with Raman Spectroscopy. I also tutor students who need help in math or physics.

Section 2
Facilities and Equipment

2.1. Description of Facilities

The planned research and experimentation can be accomplished using existing equipment and facilities available to the key personnel at Harding University. Adequate laboratory space, 1400 sq. ft., is available for the proposed rocket and payload design and assembly. In addition, a 27 ft. by 30 ft. machine shop for construction of the rocket and its payload is at the disposal of the team. Shop equipment includes a 9" x 42" ENCO Turret Vertical Mill with electronic readout, EMCO Compact 10, Swiss made, Lathe, Ramco Vertical/Horizontal Metal Cutting Bandsaw and 18" Vertical Metal-Cutting Bandsaw. Also, a variety of woodworking equipment including a Delta 10" Contractor's Saw with 30" Biesemeyer Fence, Delta 6" Jointer, 14" Craftsman Bandsaw and 15½" Craftsman Drill Press is available for building the rocket airframe.

2.2 Necessary personnel, facilities, equipment, and supplies not provided by the government

In addition to the facilities described in 2.1, Facilities and Equipment, the Harding University Rocket Team has at its disposal a number of computer labs that available to students and faculty. Software needed and available in these computer laboratories are: RockSim, AutoCAD, and CFD*. A recording rocket altimeter is available. All facilities, shops and computer laboratories items are open and available from 7 a.m. to 10 p.m.

2.3. Computer Equipment

The following is a description of the computer equipment accessible to Harding University USLP Team.

- 2.3a Equipment for (1) intra-group communication – a campus wide network available to all faculty and students at Harding University. For intra-group communication, we have access to computer labs, as well as access to a multiplicity of public labs on campus, as well as personal computers, all of which have the capacity for emailing each other.
- 2.3b Communication with our NASA USLP Project Manager -- with access to email, our group has the capacity to maintain communication with our NASA USLP Project Manager.
- 2.3c Designing, building and hosting a team web site – a web page is established at www.harding.edu/engineering/uslp and a portion of the website will include documents available to all team members.
- 2.3d The maintenance of this web site will also be used for the purpose of keeping public the status of the project and a list of needed material or expertise,
- 2.3e Document development to support design reviews – the web site will be used as a central location for document development and aid in the carrying out of design reviews.
- 2.3f Teleconferencing -- Teleconferencing equipment is available. Equipment manufactured by INSORS (www.insors.com), is located in Room 167 of the

Pryor-England Science and Engineering Center. It will provide interactive video/audio feed.

Section 3
Safety and Mission Assurance

3.1a Team Members that are NAR Members and NAR Certified:

- Brett Keller- Level 1 complete, NAR # pending
- Megan Bush- NAR # pending
- James Mackey- NAR # pending
- Edmond Wilson- NAR # pending

(Brett Keller is Level 1 Certified and plans to be Level 2 Certified on 14 October 2006 in Memphis, Tennessee with the Mid South Rocketry Society, NAR Section #550. Megan Bush, Dr. James Mackey, and Dr. Ed Wilson will be Level 1 Certified 14 October 2006.)

3.2 Written Safety Plan

All team members have read and signed a statement acknowledging that they are aware of and will follow the following regulations: NAR High Power Rocket Safety Code, FAA Title 14: Aeronautics and Space code, part 101 – Moored Balloons, Unmanned Rockets and Unmanned Free Balloons, subsection 101.22 Special Provisions for large model rockets, and NFA 1127 "Code for High Power Rocket Motors." All other state and local regulations will be complied with.

3.3 A BATF Low Explosive Users Permit is not required as no Ammonium Perchlorate Composite Propellant will be used in Harding's USLP project. Hypertek Hybrid motors will be utilized.

3.4 Not Applicable

3.5 DOT regulations are not applicable to Hypertek Hybrid motors because the fuel grain is an inert thermoplastic, and all other materials are completely inert. Nitrous oxide will be acquired on site.

3.6 Not Applicable

3.7 Safety Regulations:

7. Safety Regulations:

HARA will provide range safety inspections of each rocket before it is flown. Each school team shall comply with the determination of the safety inspection.

The HARA Range Safety Officer has the final say on all rocket safety issues. Therefore, the HARA Range Safety Officer has the right to deny the launch of any rocket for safety reasons

Any team that is found non compliant with Safety & Mission Assurance (S&MA) will not fly their rocket at the Huntsville launch.

List and signatures of team members that understand and will abide by the above three safety statements.

1. Sarah Christensen
2. Brett Keller
3. Stephen Wagner
4. Pablo Oropin
5. Aaron Howell
6. Erin Fulks
7. Megan Bush
8. Paul Elliot
9. Daniel Sewell
10. Dr. Ed Wilson
11. Dr. James Mackey

Section 4
Technical Design

Proposed and Detailed Approach to Rocket and Payload Design

- 4.1a General vehicle dimensions. The rocket airframe is designed primarily around the propulsion system described in Section 4.1b, necessitating a airframe diameter of 4 inches. To contain the length of the hybrid rocket motor, avionics bay, and dual deployment recovery bays, the rocket will be 96" from tail to nose-tip. Four clipped-delta style fins will be utilized, as well as a boattail to reduce drag. Standard hobby rocketry components and techniques will be used to construct the airframe.
- 4.1b. Motor type and size. Hypertek 54 and 81mm hybrid motors will be used. The primary motor of choice is the Hypertek 835CC172J – J317, with a total impulse of 998.8 Newton-seconds, an average thrust of 317 Newton-seconds, and a total burn time of 3.15 seconds. This J motor will require Level 2 certification, but its lack of APCP and pyrotechnic components makes it completely inert until nitrous oxide is loaded on the launch pad.
- 4.1c. Science Payload and Electronics. The projected electronics of the rocket will include an R-DAS flight computer for recording of measurements, transmission of telemetry, and primary recovery, a GWiz MC 2.0 Recording Flight Computer as a fully independent redundant recovery backup, and a Perfectflite altimeter for the purposes of the competition. A radio locator will be employed for recovery. A Boostervision wireless color 2.4Ghz Wireless Micro Camera will record in-flight video. The R-DAS flight computer will store information from an emission photometer, the specific science payload of the rocket, in order to measure the exhaust plume gradients. Other modular units of the R-DAS flight computer include a 2-axis accelerometer and pressure sensor, a GPS board, and telemetry transmitting and receiving capabilities.
- 4.1d. Primary requirements for rocket and payload. The first goal for this project is to build a rocket capable of reaching the desired altitude of 5280 feet and capable of being reasonably retrieved via standard dual deployment recovery techniques. The second goal is to build a working science package including a photometer that can be used to analyze the plume gradients; once built this photometer will be mounted in conjunction with the R-DAS flight computer and secondary scientific instruments associated with the R-DAS for storage of data and real-time transmission to the ground. If these requirements are met then this project will be a success.
- 4.1e. Major challenges and solutions. We expect to encounter several major challenges during the course of this project. Ignition of non-pyrotechnic hybrid rocket motors such as Hypertek Hybrids requires complex ground support equipment, filling procedures, and launch checklists. The airframe of the rocket will encounter considerable stress and must be designed to avoid premature separation, fin flutter, or zippering upon recovery system deployment. Variable thrusting characteristics of hybrid rocket motors may necessitate lock-out intervals for recovery devices including barometric altimeters. Recovery from high altitude is problematic in traditional rocketry designs, so dual deployment

(using a drogue at apogee and main parachute at 800 ft. altitude) will be employed, along with a radio tracking device for locating the recovered vehicle. Because hybrid motors carry no motor ejection charge for redundant deployment, a completely separate secondary altimeter system will be utilized to eliminate the possibility of non-deployment. Maximizing the payload space of the rocket and mounting the complex electronics package inside the airframe will require careful spacing of various components in an easily accessible avionics bay. Because transmission of telemetry inherently increases the complexity of the project, provisions will be made for on-board storage of photometer and other data in the R-DAS flight computer. Thorough ground-testing of the electronics package, electronically-activated ejection charges, and hybrid ground support equipment will lessen the likelihood of common failure scenarios.

Section 5
Outreach

5.1 Community Support

- Community Outreach will include air rocket launching at Sidney Deener and Beebe elementary schools. We plan to make rockets out of film canisters and two-liter bottles.

- Press releases will be sent to The Arkansas Democrat, The Daily Citizen (Searcy, AR), and the GeDanken Paper (Harding University's Physical Science Newsletter) as well as to hometown newspapers for other project participants; The Daily Herald (Columbia, TN) and The Daily Statesman (Dexter, MO).

- An article will be written in Harding University's school paper, The Bison. Information can also be found on our website www.harding.edu/engineering/uslp.

5.2 Outreach Project

- We plan to attend an elementary school in the local area and present an afternoon program on the science of rocketry. The focus will be on simulating rocket fuel. Film canisters will be used and then fins, that the children design, will be attached to the outside. Acetic acid and Alka-Seltzer inside for fuel, the canister will be turned upside down, and the subsequent reaction will send the canister flying into the air. The active participation in rocketry engendered by this demonstration will increase awareness of and interest in rocketry-related science. An air powered rocket demonstration and model rocket launch will also be performed.

Section 6
Project Plan

6.1 Timeline

- September 25 - Turn in Proposal
- Build rockets for certification
- October 14 - launch rockets in Memphis, TN for certification (Brett Keller certified for Level 2)
- Wed Design and Rocket Drafting for up-coming due dates
- November 6 – Web Presence due
- November 13 – Preliminary Design Review and report due to Marshall Space Flight Center Academics Affairs Office
- Start Construction on Rocket (order payloads and materials needed)
- November 20 – PDR Discussion (tentative)
- January 15 – Critical Design Review and Presentation Slides due to Marshall
- Construction of Rocket
- January 22 – CDR (tentative)
- March 12 – Flight Readiness Review Presentation and Presentation Slides due to Marshall
- March 19 – FRR (tentative)
- Final Preparations for Rocket and Finishing Touches
- Full-up test flight in Memphis, TN
- April 12-15 – Huntsville Launch
- May 11 – Final Report Due

6.2a Projected Budget

Table 1. Projected Budget

Expense		Amount
1. Rocket Airframe Construction		250.00
2. Payload:		1450.00
R-DAS Kompact	280.00	
2-axis Accelerometer and Temperature Sensor Board	110.00	
GPS Unit	245.00	
Active GPS antenna	70.00	
6 Channel Telemetry Transmitter	150.00	
6 Channel Telemetry Receiver	165.00	
3 Element Yagi Antenna	75.00	
GWiz MC 2.0 Recording Flight Computer	195.00	
BoosterVision GearCam Mile High Combo	160.00	
3. Hypertek J Motor system and reloads		400.00
4. Parachutes and Recovery Harness		150.00
5. Safety and L1 & L2 Licensure		300.00
6. Outreach		200.00
Total		**2750.00**

6.2b Source of Funding

Funds in the amount of $2750 are currently available to the Harding USLP team. The source of these funds is from indirect funds generated by a NASA/EPSCoR grant held by Dr. Ed Wilson, Team Leader. A separate proposal is being prepared to ask for these funds from the Arkansas Space Grant Consortium instead of the NASA indirects.

Section 7
Competition Deliverables

Competition Deliverables will include:

7.1 A reusable rocket and science payload (available for NASA/MSFC display) ready for launch in April of 2007 will be produced.

7.2 A scale model of the rocket design with a payload prototype will be flown before Critical Design Review (CDR). A report of the data from the flight as well as the model should be shown at CDR.

7.3 Reports and PowerPoint presentations due on November 13, January 15, and March 12 will be submitted to the Academic Affairs Office. Reports and presentations will also be posted on the team website by the due date.

7.4 A final report for the rocket and payload will be presented to the MSFC Academic Affairs Office no later than May 11th, 2007.

7.5 The team will have a web presence no later than November 6. The web site will be maintained/updated throughout the school year. It will be judged at random times throughout the year.

7.6 Copies of any other products developed (journal, 3-D animation, media coverage, video, scrapbook, etc.) willl be delivered to the NASA/MSFC Academic Affairs Office prior to the final launch. These will be prepared for a public showing at MSFC before the launch in April.

7.7 An electronic copy of the comprehensive report, with results, pertaining to the implemented Outreach activity or activities will be submitted.

7.8 A safety plan outlining how NAR safety requirements will be implemented and how safety will be incorporated into all manufacturing, testing, and launching activities will be produced. The risk assessment will include such things as (but not limited to): risks associated with faculty support, school support, financial/sponsor support, use of facilities, partnering arrangements, schedule risks, risks associated with chosen designs. This will be updated throughout the program and presented at the CDR and FRR. The initial plan will be due with the first report on November 13, 2006. *(This date is tentative.)*

7.9 The team will participate in a PDR (November 2006), CDR (January 2007), FRR (March 2007), and Launch (April 2007). Exact dates and locations will be provided at the time of selection.

7.10 The PDR, CDR, and FRR will be presented to NASA at a time and location to be determined by NASA/MSFC Academic Affairs Office. The presentation will be done using Video Teleconferencing/Web casting capabilities and PowerPoint and will be available on the team website no later than 7 days prior to the review board meetings.