USLI Proposal

Hybrid Rocket Design for In-Situ Exhaust Plume Spectroscopy

Submitted by

Harding University Flying Bison USLI 2009 Rocket Team
Searcy, AR 72149
20 October 2008

Gregory W. Lyons
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Section 1
School Information

1.1 Name and Title of Project

- Hybrid Rocket Design for In-Situ Exhaust Plume Spectroscopy

1.2 Team Official

- Edmond Wilson, Ph.D. Professor of Physical 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

- Greg Lyons, Project Leader

1.5a Students and Faculty Members Participating

Nine students, two faculty members, and a retired NASA engineer make up the key personnel. Team members and responsibilities are:

- Greg Lyons, Project Leader
- Edmond Wilson, Ph.D., Team Official
- James Mackey, Ph. D., Senior Scientist
- David Stair, Senior Engineer
- Paul Elliott, Design and Simulation
- Megan Bush, Exhaust Plume Studies/Outreach
- Steven Barber, Microprocessor Programming and Interfacing
- Nathan Smeal, Avionics and Telemetry
- Jon Langford, Avionics and Telemetry
- Matt Goodhart, Motor Testing
- Taylor Durham, Website Design
- Jonathan Freese, Website Design

1.5b Short Resumes of Key Personnel

Project Leader

Name: Greg Lyons
Address: HU Box 12323, Searcy, AR, 72149
Phone Number: (616) 914-6779
Major: Physics, Mathematics
Career Plans: Doctorate in astrophysics; Tenure at a modern research university; Experimental and observational research in astrophysical and planetary sciences.
Other: NASA/ASGC Undergraduate Research Fellowship Recipient. I have been involved in the Flying Bison team since 2007, and have developed a strong knowledge of high-powered rocketry and a good set of organizational skills. Outside of the USLI project, I am involved in the Honors College Council, research assistantships with Edmond Wilson, Ph.D. and Lambert Murray, Ph.D., tutoring of high-school and college students, and lab assisting for the Physics department. I maintain a GPA of 4.00 with 18 credit hours in progress.

Team Official

Edmond W. Wilson, Jr., PI

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915 East Market Street
Searcy, AR 72149-0849
www.harding.edu/wilson

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

RELEVANT EXPERIENCE

Ten years experience working with open path diode laser spectroscopy systems. Thirty eight 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-Pres.: *Professor of Chemistry*, Department of Chemistry, Harding University

1995-2000: *Dr. Robert Roy and Dr. Callie Mae Coons Endowed Chair* of Biomedical Sciences

1997-1998: *NASA/ASEE Summer Faculty Fellow*, Jet Propulsion Laboratory
Worked with Dr. W. DeMore, Chair of NASA Panel for Data Evaluation and Editor of Chemical Kinetics and Photochemical Data for Use in Stratospheric Modeling.
Made laboratory measurements of importance to understanding Earth's atmosphere.

1990-1994: *Research Associate*, University of Arkansas Department of Chemistry and Biochemistry, summers. Research Studies in inorganic biochemistry, developed machining skills, electronics skills, chemical synthesis skills.

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 Space Grant Consortium Campus Representative, Optical Society of America

RESEARCH INTERESTS

- Application of diode laser technology to the development of new measurement techniques
- Characterization of hybrid rocket exhaust plumes using diode laser spectroscopy
- Measurement of atmospheric lifetimes of substances that pollute the atmosphere

RECENT PUBLICATIONS

Edmond W. Wilson, Jr., Edward W. Tunstel, Gary T. Anderson, *BioGAS Spectrometer for Biogenic Gas Detection and Location on the Surface of Mars*, Infotech@Aerospace 2007 Conference and Exhibit, 7 – 10 May 2007, Rohnert Park, CA, AIAA 2007-2726-837, pp. 1-15.

Gary T. Anderson, Edward Tunstel and **Edmond Wilson**, *A Robot System to Search for Signs of Life on Mars,* IEEE Aerospace and Electronic Systems Magazine, Vol. 22, No. 12, 2007, pp. 23-30.

Tunstel, E., Anderson, G. T., **Wilson, E. W**., *Autonomous Mobile Surveying for Science Rovers Using In Situ Distributed Remote Sensing*, Systems, Man and Cybernetics, 2007. ISIC, IEEE International Conference, 2007, pp. 2348-2353.

Edward Tunstel, Gary Anderson and **Edmond Wilson**, *Motion Trajectories for Wide-Area Surveying With a Rover-Based Distributed Spectrometer,* 11th International Symposium on Robotics and Applications, World Automation Congress, Budapest, Hungary, 24-26 July 2006, Paper ISORA-220, pp. 1-8.

Gary Anderson, Chris Sheesley, Jay Tolson, **Ed Wilson** and Edward Tunstel, *A Mobile Robot System for Remote Measurements of Ammonia Vapor in the Atmosphere,* 2006 IEEE International Conference on Systems, Man and Cybernetics October 8-11, 2006 Taipei, Taiwan, Paper SMC2006-0966, pages 241-246.

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.

G.T. Anderson, R. Hashemi, **E.W. Wilson, Jr.** and M. Clark, "Application of Cooperative Robots to Search for Water on Mars Using Distributed Spectroscopy," *World Automation Congress, 8th International Symposium on Robotics with Applications*, ISORA034, 2000.

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

Edmond W. Wilson, Jr., Wesley A. Hamilton, Hillary R. Mount, and William B. DeMore, *Rate Constants for the Reactions of Hydroxyl Radical with Several Fluoroethers by the Relative Rate Method* J. Phys. Chem A., 2007, 111(9), 1610-1617.

Edmond W. Wilson, Jr., Wesley A. Hamilton, Hillary R. Mount, Bill Evans, III, Nathan R. Scott, William B. DeMore, *Measurement and Estimation of Rate Constants for the Reactions of Hydroxyl Radical with Several Alkanes and Cycloalkanes,* J. Phys. Chem. A, 2006, 110(10), 3593-3604.

Edmond W. Wilson, Jr., Brett D. Keller, Kellen M. Harkness, Christopher S. Smeal, Megan S. Easterly and James Mackey, *Ultraviolet-Visible Spectrometry Characterization of Combustion in Hybrid Rocket Motors,* AIAA 2006-4343-258, July 2006.

Andrew B. Wright, Warfield Teague, Ann M. Wright, **Edmond W. Wilson**, *Instrumentation of UALR labscale hybrid rocket motor,* Proc. of SPIE, Vol 6222, 622202-1 through 12, 2006.

E.W. Wilson, Jr., J.E. Mackey, B.D. Keller, E.J. Goertzen, S.A. Clements, C.D. Rivenbark and C. Cox, "OH Emission Spectra of Hybrid Rocket Motors Using PMMA and HTPB," *American Institute of Aeronautics and Astronautics*, AIAA Paper 2005-3905, July 2005.

E.W. Wilson, Jr., A. M. Jacoby, S. J. Kukta, L. E. Gilbert and W. B. DeMore, "Rate Constants for Reaction of CH_2FCH_2F (HFC-152) and CH_3CHF_2 (HFC-152a) with Hydroxyl Radicals," *J. Phys. Chem. A,* **107**(44) 2003, pp. 9357-9361.

James E. Mackey
Professor of Physics
Department of Engineering and Physics
Harding University

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jmackey@harding.edu

EDUCATION

University of Mississippi, University MS, PhD in Physics, May 1969
University of Mississippi, University, MS, MS in Physics, May 1965
Tulane University, New Orleans, LA, BS in Physics, May 1962

PROFESSIONAL EXPERIENCE

Professor of Physics (1978 - present), Associate Professor (1971 - 1978), Assistant Professor (1968 - 1971), Harding University

Physicist (Westinghouse-Hanford Corporation, Summer 1981), Analysis of Positron-Annihilation Techniques for Defect Analysis

Physicist (US Naval Weapons Lab, Dahlgren,Va, Summer 1963), Interior Ballistics

COURSES TAUGHT

Electromagnetic Theory
Applied Mathematics for Science and Engineering
Microcomputer Interfacing
Basic Electronics
Engineering Physics
Astronomy and Space Science

RESEARCH INTERESTS

Autonomous Mobile Robots
Diode Laser Spectroscopy
JOVE Research Project, "MaxEnt Image Restoration"
Hybrid Rockets
Energy Conservation

SAMPLE PUBLICATIONS

J. Mackey, *Analysis of Passive Attic Ventilation Methods*, Private Report for Lomanco, Inc., Jacksonville, AR, (1980)

Mackey, J., Wilson, E.W., and Thompson, D., "*Construction and Software Design for a Microcomputer Controlled pH/Ion Titrator",* **Ark.Acad.Sci.Proc.38,** 74-80 (1984).

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

Amanda Gerlach, Edmond W. Wilson, Jr., and James E. Mackey, Proceedings Journal of the 2004 Arkansas Undergraduate Research Conference p230, *"Near Infrared Emission Spectrum of a Lab-Scale Hybrid Rocket Motor"*

Philip A. Ashley, Edmond W. Wilson Jr., and James E. Mackey, Proceedings Journal of the 2004 Arkansas Undergraduate Research Conference p199, *"Measurement of Diatomic Oxygen in the Exhaust Plume of a Mini-Hybrid Rocket*"

Edmond W. Wilson, Jr., Brett D. Keller, Kellen M. Harkness, Christopher S. Smeal, Megan S. Easterly and James Mackey, American Institute of Aeronautics and Astronautics AIAA, Paper 2006-4343-258, July 2006, *"Ultraviolet-Visible Spectrometry Characterization of Combustion in Hybrid Rocket Motors"*

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

Name: David W. Stair
Address: Suite 102, Mayfair Hotel, 101vNorth Spring Street, Searcy, AR 72149
Phone Number: (501) 593 5161
Other: David is a native of the Searcy area who has worked many diverse jobs, from being Silver Dollar City's "Resident Artist" in the mid 70's, to owning and operating his own company in Houston, Texas where he built many technical models for industrial equipment. Over two years of his time in Houston were spent working for a company contracted to NASA where he was Project Engineer for the CCTII, a full-scale crew compartment trainer for the astronauts. David lives in Searcy where he does odd (and usually difficult) technical projects and computer graphics. He tries to put his design expertise to good use as a consultant to the Harding Flying Bisons Rocket Group.

Name: Paul Elliott
Address: HU Box 11463, Searcy, AR, 72149
Major: Mechanical Engineering
Career Plans: Doctorate in Mechanical Engineering specializing in alternate and renewable energies, followed by work in applied engineering for international development.
Other: NASA/ASGC Undergraduate Research Fellowship Recipient.
Involvement in the Flying Bison team since 2006.
I maintain a GPA of 3.87 on 139 credit hours.

Name: Megan N. Bush
Address: HU Box 11348, Harding University, Searcy, AR 72149-1348
Phone: 573 421 7887
Major: Senior Biochemistry and Molecular Biology Major
Career Plans: Medicine
Other: NASA/ASGC Undergraduate Research Fellowship Recipient. I have been involved in the Harding University Flying Bison USLI Rocket Team since its inception two years ago. I have served as the Outreach Coordinator and the Secretary for the past two years. This year I will again be the Outreach Coordinator. I will also be conducting the static tests of the rocket motors at our Hybrid Rocket Test Facility. This complements my NASA research which is to measure the concentrations of chemicals in the exhaust plumes of hybrid rocket motors by spectroscopy. My GPA is 3.5 and I will graduate in May 2009.

Name: Steven Barber
Address: HU Box 10355, Searcy, AR 72149-0355
Phone Number: (870) 612-0821
Major: Physics
Career Plans: What I do immediately after obtaining a doctorate in physics will depend on what catches my interest, but I ultimately intend to become a professor, with my focus on teaching.
Other: This is my first year on Harding's USLI team, and because I am a senior, it is also my last. My interest and contribution to the team lies primarily in the rocket's payload, specifically the means of processing data. I completed a NASA/ASGC undergraduate

research fellowship this summer with Dr. Edmond Wilson, during which we attended a workshop on rocket payloads that will be useful for this project. I have served as a physics tutor and lab assistant, as well as a chemistry stockroom assistant. I have a minor in math and am also interested in computer science.

Name: Nathan Smeal
Address: HU Box 14316, Searcy, AR 72149
Phone Number: (256) 436-0136
Major: Computer Engineering
Career Plans: Considering graduate work in electrical engineering and working in the private sector
Other: NASA/ASGC Undergraduate Research Fellowship Recipient. Currently involved in undergraduate research with Edmond Wilson Ph. D. I am a senior with a 3.24 GPA taking 14 credit hours.

Name: Jon Langford
Address: HU Box 13347, Searcy, AR, 72149
Phone Number: (404) 406-3941
Major: Electrical Engineering
Career Plans: Possible MS and PhD in Electrical Engineering; attempt and pass the F.E. and P.E. exams.
Other: Over the last 4 years I have been involved in implementing electronic medical records for Georgia Urology. I am also the tutor for the Engineering Department at Harding University. I tutor Circuits 1 and 2, Digital Logic Design, and Signals and Systems. I am also the lab assistant for the classes that use the Analog Circuit Lab. Besides tutoring for Harding University, I privately tutor many students from Harding Academy in mathematics and science subjects. I maintain a GPA of 3.7 with 15 hours in progress.

Name : Matt Goodhart
Address: HU Box 13861 Searcy, AR 72149
Phone Number: 240-285-6697
Major: Mechanical Engineering
Career Plans: Masters in Mechanical Engineering; focus on robotics and nanotechnology in medicinal or military research.
Other: I tutor physics and higher mathematics to high school and college students. I maintain a 3.7 GPA with 14 credit hours in progress.

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. Available for sheet metal work is an ENCO 48" Sheet Metal Pan & Box Brake and a Jet Bench Model Sheet Metal Roller, 2" x 48". The Harding team also has access to a hybrid rocket test stand that has been used for static firings of motors up to J impulse, which is currently under redesign to allow for greater motor capability. In this new tripod frame design, the motor will be held into place by two interchangeable clamped semi-rings, specially cut to the diameter of the desired motor. The entire stand will be made from of ¾" and ½" Electrical Metallic Tubing, typically known as conduit tubing. The redesigned test stand will be roughly four feet in height, three feet in width, and have a top extension for larger engines. 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, SolidWorks, and Visual Studio. All of the rocket components, excess building supplies, and related materials from previous competition years are available for team use. All facilities, shops and computer laboratories items are open and available from 7 a.m. to 10 p.m.

2.2 Necessary personnel, facilities, equipment, and supplies

In order to design and build the competition rocket, personnel with expertise in the following areas have been acquired: Electrical engineering, computer engineering, mechanical engineering, computer science, physics, chemistry, web design, machining, CAD, and laser optics. General facilities required will include a machine shop for construction of the rocket body, as well as clean laboratory space for electronics and payload assembly, both of which have been described above. Equipment required beyond standard tools and electrical equipment includes a rocket test stand, a milling machine, a band saw, a belt sander, a drill press, and an ignition system, all of which are possessed. The payload itself will rely heavily on a locally-owned laser cutting machine for its construction. Supplies required are too extensive to list, but the large quantities of epoxy used for bonding the rocket are currently possessed, as well as fiberglass cloth and carbon fiber for reinforcement. The airframe supplies will be purchased from

Public Missiles, except for the fins, which will be hand-made from layers of aircraft plywood. For verifying the final altitude of the rocket, a PerfectFlite MAWD Barometric Altimeter will be flown in the competition rocket, per competition rules.

2.3. Computer Equipment

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

- 2.3a Equipment for 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 NASA USLI Project Manager – with access to email, our group has the capacity to maintain communication with our NASA USLI Project Manager.
- 2.3c Designing and hosting a team web site – a web page is established at http://www.harding.edu/wilson/usli.html and a portion of the website will include documents available to all team members. It will be used as a central location for document development and aid in the carrying out of design reviews.
- 2.3d Maintaining web presence – 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 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. The computer equipment available for videoconferencing meets the minimum requirements indicated.

Section 3
Safety and Mission Assurance

3.1 Team Members that are NAR Members and NAR Certified:

- Paul Elliott – NAR #88015; Level One Certified
- Edmond Wilson, Ph.D. – NAR #86424; Level One Certified
- Greg Lyons – NAR # 88751

(Both Edmond Wilson, Ph.D. and Paul Elliott will attempt Level Two certification before the end of 2008; Greg Lyons will attempt Level One certification in the same manner.)

3.2 Written Safety Plan

Two of the members of the team plan to receive their NAR Level Two certification which includes a test on various rocketry safety issues.

All of the physical materials used in rocket construction will be plastic or plywood, with the exception of metal screws, I-bolt, and the motor casing.

The use of a hybrid rocket system is advantageous for safety, because there is no legal requirements for the handling of the inert fuel grains. The components of the hybrid motor system are completely inert by themselves, and will only ignite when placed in the hybrid motor system. The oxidizer will be nitrous oxide, and we have obtained the proper valves and regulators to control nitrous flow from a distance of 200 feet. Ignition of the motor can be effected from the same distance.

We will produce a risk assessment document to be included with the Preliminary Design Review. We will identify risks involved in the process of constructing and launching the rocket.

3.2a The Harding University USLI team has understood and will comply with the NAR High Power Safety Code requirements [http://nar.org/NARhpsc.html]. We will follow all known safety guidelines for the use of ejection charges and the hybrid motor system, which will include a briefing of the entire team on the construction and operation of a hybrid rocket motor.

We will comply with any and all environmental laws and regulations.

3.2b Before each construction procedure, the team members will be briefed on hazard recognition and accident avoidance. This procedure will be conducted for pre-launch briefings, including action for misfires, non-firing motors, ballistic landing, etc.

3.2c A safety and operational checklist will be created that includes cautionary and safety statements for each applicable procedure. This checklist will be posted in plain sight and will be read by each team member. MSDS safety

sheets will be included in the safety and operational checklist for nitrous, epoxy, and any other chemical substances used in the project.

3.3 Regulation Awareness

All team members have read and signed a statement acknowledging that they are aware of and will follow the following regulations: Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Code of Federal Regulation Part 55; and NFPA 1127, "Code for High Power Rocket Motors." All team members will comply with any and all other state and local regulations.

3.4 A BATF Low Explosive Users Permit is not required as no Ammonium Perchlorate Composite Propellant will be used in Harding's USLI project. Contrail Rockets hybrid motors will be utilized.

3.5 Motor casings and hardware manufactured by Contrail Rockets have been purchased previously; any fuel grain reloads can be purchased from the Contrail Rockets webstore and shipped via US Mail. Nitrous oxide will be acquired through the chemistry department.

3.5 DOT regulations are not applicable to Contrail Rockets hybrid motors because the fuel grain is an inert thermoplastic, and all other materials are completely inert. Nitrous oxide will be acquired through the chemistry department.

3.6 Not Applicable, see above sections.

3.7 Safety Regulations:

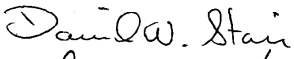
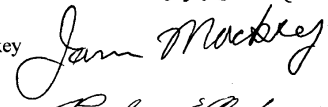
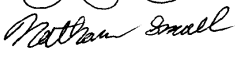
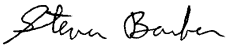
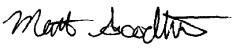
Safety Regulations:

HARA (Huntsville Area Rocketry Association) will provide range safety inspection 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 issue. Therefore, the HARA Range Safety Officer has the right to deny the launch of any rocket for safety reasons.

Any team that does not comply with Safety & Mission Assurance (S&MA) will not be allowed to launch their rocket.

The following is a list of names and signatures of team members that have understood and agreed to abide by these safety statements.

1. Greg Lyons 
2. Ed Wilson 
3. David Stair 
4. James Mackey 
5. Paul Elliott 
6. Jon Langford 
7. Nathan Smeal 
8. Steven Barber 
9. Megan Bush 
10. Matt Goodhart 

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, using an inner airframe diameter of 3.9 inches. To contain the length of the hybrid rocket motor, avionics bay, scientific payload bay, and dual deployment recovery bays, the rocket will be approximately 96" in length. Four delta fins constructed from aircraft plywood will stabilize the rocket in flight, as well as a boattail to reduce drag. Standard hobby rocketry components and techniques will be used to construct the airframe. The outer airframe will be constructed from Public Missiles Quantum Tubing, which is a strong, lightweight polymer alternative to phenolic tubing.

- **4.1b. Motor type and size.** Contrail Rockets 54mm hybrid motors will be used. Depending on the final weight of the rocket, either a J or K impulse configuration will be used (further simulation is necessary). In fact, the only difference between the two likely configurations in the amount of nitrous oxide stored in the motor, which simply translates to a longer burn for the K impulse motor. These motors will require Level 2 certification, but the lack of APCP and pyrotechnic components makes them 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 Atmel 8-bit AVR Microprocessor for data acquisition, an Emhiser Research Model ETT-01DEA Series Telemetry Transmitter for telemetry of data and tracking of the rocket, a GWiz MC 2.0 Recording Altimeter and a PerfectFlite miniAlt/WD Barometric Altimeter as a redundant avionics and recovery system. The PerfectFlite MAWD will also serve as the official altitude recording system for the competition. On the ground, an Emhiser Research Model ETRC-09DEA Series Telemetry Receiver will collect the telemetry from the rocket, operating in the 1.435 GHz – 2.4 GHz signal range. The transmitter will be placed in the same section as the scientific payload. The receiver will be interfaced with a laptop that will format, analyze, and store the data from the rocket. The avionics and recovery subsystem will be physically and electronically separate from the data acquisition, telemetry, and payload subsystems. The AVR microprocessor is an 8-bit, 16 MHz microcontroller with 32 kilobytes of in-system programmable Flash program memory, 2 kilobytes of internal SRAM, and 32 general-purpose working registers. It supports 10-bit successive approximation ADC with 8 single-ended channels, and will collect data from our diffraction grating spectrometer. The emission spectrum of the rocket exhaust plume will be captured by a one-meter fiber optic cable and presented to the entrance slits of this mini-emission spectrometer. The light from the exhaust plume is dispersed inside the spectrometer by means of an optical grating and detected by a photodiode array.

- **4.1d. Primary requirements for rocket and payload.** The first goal for this project is to build a rocket capable of flight to the desired altitude of 5280 feet and safe, reusable-state recovery via standard dual deployment recovery techniques. The second goal is to construct a scientific payload subsystem for the in-situ study of the exhaust plume gradients. This spectrometer interface with the microprocessor and the telemetry system for collection, storage, and safe transmission of spectra collected in flight. If these requirements are met, 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 Contrail Rockets hybrid motors, while surprisingly simple, required skilled understanding of this unusual launch system. 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, as we have observed from our failure at last year's competition, 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. Because hybrid motors carry no motor ejection charge for redundant deployment, two redundant avionics systems will be used to ensure drogue and main parachute 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 spectra in the Flash memory of the AVR microprocessor. Thorough ground testing of the data acquisition, avionics, scientific payload, and hybrid ground support subsystems will lessen the likelihood of common failure scenarios.

Section 5
Outreach

5.1 Community Support

We are negotiating with Captain Warner to have our team flown to the USLI competition in April 2009 in a C41 Air Force plane. Also, we are working with Captain Warner to allow us to use part of Camp Robinson in Little Rock to fly our rockets. This will save us from having to drive to Memphis to use the facilities of the Memphis NAR Rocket Club at Shelby Farms. The trip to Memphis is 2.5 hours each way. Camp Robinson is just under one hour away.

Dr. Keith Hudson, Director of the Arkansas Space Grant Consortium and avid ham radio expert will be enlisted to help us with our telemetry operations. We will ask BEI, a world class provider of positioning equipment to the aerospace industry, located in Little Rock, Arkansas to help us both financially and with expert advice on our science payloads.

We will also solicit help and funds from two Searcy businesses.

5.2 Outreach

We have contacted the Arkansas Wing of the Civil Air Patrol and are working with them to develop a high school rocket program for them which would lead to their competing in the high school rocket competition at Marshall Space Flight Center. Our contacts are Captain Frank Warner, Director of Aerospace Education (fcwmjw@msn.com) and Morris Middleton, 42nd Composite Squadron, Little Rock (mhmiddleton@gmail.com). We are planning to provide a demonstration and workshop to the Little Rock squadron on how to build and fly a high power rocket. This will involve a minimum of twenty-five students. We will develop a feedback document for the student participants to help in evaluation of our educational outreach. A separate document will be requested from the Wing commander to help assess the impact of our interaction with the Wing.

We are involving the Third Grade Class at Westside Elementary in a water bottle rocket launch. The students have been given instructions on building water bottle rockets. We will return on November 20, 2009 to help them launch their vehicles. There are twenty-five students in the class. Awards will be given for various categories. Ms. Sherry Wilson (wilsons@searcyschools.org) is the teacher of this class. A feedback form will be developed for each student to fill out as well as forms for the parents of the students. A separate report will be asked from the teacher of the class.

We will contact the Girls Scouts of Ouachita Council, 100 S. Spring Street, Searcy, AR 72143, phone: 501 279 3085 and offer to provide low power rocket or water bottle rocket programs for the local area Girl Scout troops. We will also offer to help with the scouts to complete requirements for science merit badges. Again, assessment forms will be developed and given to the various participants to get feedback on the program.

We will engage at least one other K-12 school in a rocket activity during the period of this USLI 2009 project.

Press releases will be sent to the *Arkansas Democrat* (Little Rock), *The Daily Citizen* (Searcy) and the Journal of the Gedanken Society (Harding University Chemistry Department) as well as hometown newspapers of the participants.

An article will be submitted to Harding University's school paper, *The Bison*, for publication.

Section 6
Project Plan

6.1 Timeline

October 8
- Proposal Due

October 20
- *Proposal Submitted Late*

October 24
- Notification of Selection

October 29
- Finalize Rocket Design and Drawings
- USLI Teams Teleconference

November 12
- Establish Web Presence
- Select Scientific Payload Design; Signal Type

Late November/Early December
- NAR Level Two Certification Flight Attempts
- Scale Model Flight

November 28
- Finalize Telemetry and Data Acquisition Scheme
- Preliminary Design Review Report Due

December 10
- Complete Rocket Motor Test Stand Rebuild
- Complete Rocket Airframe Construction
- Interface Microprocessor and Scientific Payload

January 22
- Fire Competition Motor on Test Stand
- Successfully Transmit Signal with Telemetry System
- Complete Electronics and Scientific Payload Bay Construction
- Complete Test Flight of Competition Rocket with Minimum Systems
- Critical Design Review Presentation Slides and CDR Report Due

January 28 – February 6
- Critical Design Review

February – March
- Test Flights of Competition Rocket
- Phasing In of Systems as they are Completed

March 18
- All Subsystems Independently Operational
- Complete Test Flight of Rocket in Competition Format
- Collect Data from Rocket Motor on Test Stand with Payload Spectrometer
- Finalize Report on Motor Thrust Studies
- Flight Readiness Review Presentation Slides and FRR Report Due

March 25 – April 3

- Successfully Interface All Subsystems
- Flight Readiness Review

April 17
- Flight Hardware Check

April 18
- Launch Day

May 8
- Post-Launch Assessment Review Due
- Finalize Report on Exhaust Plume Studies

May 25
- Announcement of Winning USLI Team

6.2a Projected Budget

Item	Amount
Rocket Airframe	300.00
Parachutes and Safety Harness	100.00
Construction Hardware and Consumables	200.00
Perfect Flight MAWD	100.00
Materials for Science Payload	600.00
Contrail Rocketry Hybrid Motor System and Reloads	500.00
Nitrous Oxide, Motor Fuel Grains, Launch Consumables	300.00
NAR Level 1 and Level 2 Licensure	200.00
Outreach	100.00
Travel to Competition Launch at Marshall Space Flight Center (10 Travelers)	2600.00
Total Estimated Expense	**5000.00**

6.2b Source of Funding

A proposal to the Arkansas Space Grant Consortium for $5000.00 will be submitted at the November Meeting requesting funds for the Harding University Flying Bison USLI Rocket Team to participate in this year's competition. The committee has enthusiastically supported this competition for the past two years. It is anticipated that our request will be funded for the full amount.

Section 7
Sustainability and Proposal Nature

7.1 Sustainability

The USLI program at Harding University has shown to be sustainable due in part to the large interest among the student body. In fact, this season, more students expressed interest in the competition than could be utilized at current program size. Most of the students that are recruited come to the team based on the strengths of the various research projects that the team official, Edmond Wilson, Ph.D., supervises. Our major source of funding, the Arkansas Space Grant Consortium, has shown great interest in the USLI program at Harding; we anticipate funding to be available for the next two to three years, at the least. There are almost no aerospace industries in the State of Arkansas to approach for funding and support, and certainly none in the local region, which is primarily an agricultural center.

7.2 Proposal Nature

For this season, a vehicle has been proposed that is larger in all aspects than the previous season's vehicle, along with several design changes to minimize weight, drag, and pressure differentials inside the rocket body. Although the science payload will be essentially the same as the previous two years, none of the students currently on the team have worked personally on this payload design at any point. Unfortunately, in the past two years of competition, a working model was never produced for testing before it was installed in the competition rocket itself. There are only three returning students from last year's team, and the remaining six students have no experience with high-powered rocketry, so significant time will be required to train and educate them. This regrettably limits the amount of time available for developing more advanced projects.

Section 8
Competition Deliverables

Competition Deliverables will include:

8.1 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.

8.2 Reports and PowerPoint presentations due on November 28, January 22, and March 18 will be submitted to the Academic Affairs Office. Reports and presentations will also be posted on the team website by the due date.

8.3 A Post-Launch Assessment Review (PLAR) for the rocket and payload will be presented to the MSFC Academic Affairs Office no later than May 8th, 2009.

8.4 The team will have a web presence no later than November 12, 2008. The web site will be maintained/updated throughout the school year. It will be judged at random times throughout the year.

8.5 Copies of any other products developed (journal, 3-D animation, media coverage, video, scrapbook, etc.) will 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 on April 18, 2009.

8.6 An electronic copy of the comprehensive report, with results, pertaining to the implemented outreach activity or activities will be submitted by May 8, 2009.

8.7 A safety plan outlining how NAR safety requirements will be implemented and how safety will be incorporated into all aspects of team activity will be produced This will be updated throughout the program and presented at the CDR and FRR. The initial plan will be due with the PDR on November 28, 2008.

8.8 A reusable rocket and science payload, available for NASA/MSFC display, will be ready for launch in April of 2009.