MDA 03 017 Low Cost, High Altitude Unmanned Sensor Platform

(1). Identification and Significant of the Problem or Opportunity

The MDA has identified the need for a low cost high altitude sensor platform. Galileo Systems (GS) has significant experience in the field of high altitude ballooning from zero pressure balloon design, analysis and fabrication, to telemetry and imaging package design and fabrication to flight test of above systems. The technology in current use by GS along with some performance modifications specific to defense sector characteristics should fulfill the needs of the MDA. Since successful launch of high altitude balloons are dependant on low wind conditions, some of the offeror's performance enhancements are in the area of all-weather operations and field deployable and tactically responsive characteristics.

(2). Phase I Technical Objectives

The overall objective of Phase I of this research is to design and conduct experiments to refine the trade space of platform design / cost, observation altitude, payload mass and cost for a high-altitude observation platform based on zero-pressure and possibly latex balloon systems.

The company is uniquely positioned to satisfy the requirements of the MDA by applying its extensive experience in

- Design and low-cost fabrication of zero-pressure balloons (highest altitude to date 107,400 ft, largest payload successfully launched 12 lbs, 45 lbs planned for next launch, largest design is 850,000 cu. ft.)
- Design and fabrication of payloads including GPS and RDF (Radio Direction Finding) tracking devices, image sensing and storage, remote control capabilities, and flight termination devices.
- Launch, tracking (fixed, mobile, and airborne), and recovery of flight hardware, including both payload and balloon envelope for post-flight analyses.

In addition, the company subject matter expert / Principal Investigator has supported numerous amateur group launches, including the design of commercial support missions that utilized multiple gas envelopes in unique configurations to support specified altitude, payload, ascent, and descent rates.

Specific supporting objectives of the research will be to

- Define specific quantitative engineering performance requirements and design goals beyond those specified in the SBIR Program Solicitation
- Review company experience and develop lessons-learned and good-practices based on company, subject matter expert, industry and amateur high-altitude balloon research and experience.
- Identify innovative technologies and products available in addition to those the company and its subject matter experts have fabricated and utilized in the past to launch and control high-altitude observation platforms.
- Develop and refine existing analytical models used to forecast and control altitudes and direction of flight; duration payload orientation, sensing and stabilization; and forecast *(If required)* define any additional required technologies and potential development paths that will permit successful vehicle development and subsequent testing, refinement, and deployment
- Further development of existing, in-house proprietary concepts for rapid balloon launch in an expeditionary, tactical environment, either automated or with one or two persons to conduct the launch.

- Further development of existing, in-house proprietary concepts for successful balloon inflation and launch in high winds in an expeditionary, tactical environment. Existing methods of launching balloons are not compatible with strong gusty winds.

The SBIR solicitation described the overall purpose of this proposal as one to

> *With the increased reliance of weapons programs on simulation to support test and evaluation, observation of missile test flights is critical to providing validation of those simulations. This is particularly important in the boost phase of missile flight, where high-resolution data taken at high altitude is very useful. ... This SBIR topic seeks innovative solutions to the problem of lifting a light-weight observation platform to high altitudes using off-the-shelf balloon or airship components.*

The company has accepted this challenge based on an extensive background in design, fabrication, and successful flight and recovery of low-cost high-altitude sensor systems.

The principal investigator has developed low-cost fabrication techniques that permit the fabrication of optimal flight envelopes from readily available materials. In addition, the PI and other members of the company have developed remote-controllable electronics package and devices that have been successfully flown, recovered, and re-flown numerous times.

Experience in high-altitude balloon launches, including tracking and recovery, is critical to developing a reliable system that can be utilized with success. These systems require a careful balance of the variables to ensure flight objectives are met. Once launched, failures cannot typically be overcome until subsequent flights. Representative problems that have been overcome by company staff in the past include:

- Weather Prediction and Data Sources
- Flight Predictions, including ascent, duration, float control, flight termination, descent, and landing location.
- Payload mechanical arrangement and support during launch
- Electronics redundancy, configuration, and electro-magnetic interference issues
- Tracking reliability and diversity
- Regulatory obstacles to flight, e.g. required approvals, etc.
- Elevated wind speeds and launch techniques

The company proposes to apply its experience to develop a reliable high-altitude observation platform. The overall plan will be to refine the understanding of the needs of the MDA, e.g. mass, control, duration, launch environment, etc. To apply these requirements and desires to develop a base design that will satisfy the MDA needs, provide flexibility for future change and growth, and do so at an extremely reasonable cost.

The company will not only perform the above analyses, but proposes to perform suitable demonstration flights that can be used as a basis for future expansion and refinement of MDA goals. For example, payload orientation can be difficult due to the 'free floating' nature of the balloon. The company has researched and can apply technologies such as WAAS enabled, dual GPS position sensing to provide absolute orientation information that can be transferred to MDA instrument packages.

The company believes that the unique combination of experience and capability it can provide will provide a significant technological advantage in developing the desired platforms and capability.

(3). Phase I Work Plan

Phase I.A Requirements and Goals Refinement

The company will develop and refine specific requirements and goals for the system. The solicitation for research provided an overall framework, however to further define the system, its subcomponents and capabilities, specific quantitative requirements and goals must be established.

Requirements will be defined as capability that must exist in the system for it to move forward, while satisfaction of goals may be subject to trade-off or met in more limited means by the need to reconfigure the platform prior to a specific flight. Requirements must be met, while goals will be assigned weighting factors based on input from MDA. A matrix for evaluation and prioritization of features will be developed and utilized to refine the design.

Phase I.B Develop System Specifications Based on Requirements and Goals

This step of the research will consist of translating the requirements and goals document into specific system requirements, e.g. lifting capacity, flight duration requirements in various configurations, special payload issues, etc.

Tradeoff between capabilities directed toward system goals will be established and their basis documented.

Phase I.C System Design

Due to the use of emergent and commercial technologies and the applied research nature of this work, the system design will be developed in an iterative cycle between Phases I.C.1 and .2.

Phase I.C.1 System Design Engineering

This sub-phase will consist of a developing a specific engineering design document that defines the observation system. It will include such things as weights, dimensions, envelope specifications, power and instrumentation and control bus specifications, navigation system requirements and configuration, and base system sensors.

Phase I.C.2 Identify Supporting Technologies

This sub-phase will consist of identifying commercially available technology and products that can be immediately incorporated into the system design. For example, experience indicates that the navigation systems and bus designs will be specified based on existing commercial products and mil-standards with changes and refinements limited to those critical to vehicle design success.

Phase I.C.3 Cost Definition and Management

This sub-phase will consist of iteratively evaluating system component and fabrication cost estimates based on available supplier information. Evaluation of cost-effective alternative technologies against requirements and goals will be documented and an overall proto-type cost

Phase I.D Flight Testing and Qualification

This phase will consist of fabrication/assembly of a flight test vehicle that demonstrates the key parameters defined by the MDA and the earlier Phase I research are met by the proposed design. Depending on the negotiated contract details, this may include demonstration launches at locations other than that of the company, and actual demonstration of capabilities on DOD test or training ranges.

Phase I.E Final Report Preparation and Submittal

The company envisions submittal of a final report that will document all activities and research toward development of a suitable observation platform. The final report will document the requirements and goals utilized during the system refinement. It will also provide the requirements documents and quantitative tools utilized to compare and assess performance trade-offs made during development of the system design. The final report will include an engineered system design that includes the maximum level of detail that can be developed within the time frame and budget of the project. Finally, the report will document the actual test flights conducted, including all pertinent data obtained. The proposal is to provide an overall engineering package and demonstrated design that will permit a transition to developing and proof-testing a reliable flight platform and configuration during Phase II upon approval of MDA.

Optional Phase I.F Design Refinement

If MDA determines that it is likely to pursue the design, the company will initiate actions to further refine the system design based on lessons learned during the initial test flights, as well as emergent commercial and amateur high-altitude ballooning. This research will include such things as expanding the evaluation of available envelopes, launch technology, payload bus configurations, and tracking and recovery methods. This activity would serve as a bridge to maintain company resources as Phase II negotiations and contract issuance is made.

Schedule

As specified in the solicitation, the company plans to satisfy the requirements of any Phase I contract within the six month period specified. To ensure the success of the project, as well as provide appropriate MDA and company management controls, the following schedule is proposed

Phase I.A Requirements and Goals Refinement

This phase will begin immediately with issuance and acceptance of the work contract. It is planned for a three week duration (W1 – W3, approximately 100 person-hours).

Phase I.B Develop System Specifications Based on Requirements and Goals

This phase will overlap somewhat with Phase I.A, and is expected to require approximately 100 hours of effort during the third through fifth weeks (W3 – W5, 100 person-hours)

Phase I.C System Design

The majority of the project work will occur during this phase. The company believes that this can be accomplished in 12 weeks, dedicating approximately 400 hours of effort. (W6 – W18, 400 person-hours)

Phase I.D Flight Testing and Qualification

This phase will actually overlap the System Design phase to a limited extent, and is scheduled to be completed by the end of the 23rd week of the contract (W18 – W23, 300 person-hours).

Phase I.E Final Report Preparation and Submittal

This phase will actually occur from the outset of the project as work documents are generated and incorporated into the overall project report form. In addition, two weeks of dedicated refinement, issue resolution, and final editing and formatting are planned to occur during the final weeks of the project (W25 – W26, 100 person hours)

Optional Phase I.F Resolution of Technology Gaps

As a bridge activity to the Phase II contract, the company will survey commercial suppliers and make contact with suitable vendors that will be able to provide assistance in resolving technology gaps identified in Phases I.D. This activity will be performed in accordance with the plan prepared in Phase I.E of the project.

(4). Related Work

The company principals, including the Principal Investigator, have participated in dozens of high-altitude balloon launches, tracking efforts, and recovery. In addition, they have fabricated approximately one-half dozen flight capable envelopes, and at least as many test fixture sub-assemblies used to validate design choices. The materials and methods for balloon skin fabrication have been validated by sub-scale coupon pull testing as well as sub-scale manometer-quantified inflation and rupture (test to destruction) testing. See Fig 1.

Fig 1. 520 cubic foot 'mini-floater' test inflation.

Company principals have designed and fabricated approximately a dozen electronic packages from circuit level to integrated off-the-shelf commercial devices, that have been successfully tested, flight qualified, recovered, and are routinely used by amateur groups during high altitude flights. Extensive experience has been gained in support technologies such as parachute designs, antenna support and orientation, survivability and payload location identification technologies and techniques.

The company has access to the capability to fabricate low-cost envelopes of basically unlimited size using in-house techniques. Tracking capabilities exist in at least two vehicles owned by company principals, and a long-term relationship with various amateur balloon groups has existed for a number of years that can be used to obtain additional telemetry, tracking and recovery resources.

Additional information regarding details of the company experience with amateur groups can be obtained on the internet at www.eoss.org .

(5). Relationship with Future Research or Research and Development

It is anticipated that the with the issuance and successful completion of this research, the company and government will be well-positioned to continue to explore the possible use balloon based observation platforms. Possible areas for consideration range from emergency radio relay platforms for civilian agencies during times of national emergency to extremely low-cost battlefield observation platforms that can be tactically deployed with few logistical support needs. Commercial endeavors are underway to provide high altitude common carrier communication relay, as well as governmental research into global atmospheric behavior analysis. The company will be well positioned to support these technologies. Finally, the company will be conducting additional research into economical means of fabrication of balloon envelopes using modern technology including digital controls and instrumentation.

Phase I research will provide a basis for expanding the company, MDA, and the DOD overall knowledge of available and basis for high-altitude observation platforms. Phase I will result in a foundation of knowledge that identifies the potential to develop economical lighter-than-air systems that provide enhanced sensor capability and placement at a lower cost. Finally, the Phase I research will position the company and MDA to immediately develop standard high-altitude observation platform technology that can be adapted to meet the future needs of the MDA and nation as a whole.

(6). Commercialization Strategy

The high altitude platform has significant commercial potential for applications currently being served by conventional aerial photography and space based imaging. The extreme altitude possible with the balloon-based high altitude platform makes it more similar to space based than airplane based observations. The high altitude platform could be utilized by users of commercial space based imaging as a competitive source, and/or as a 'gap filler' in the event that a user has a requirement to image a specific geographic area on a time and frequency not served by the limited about of LEO imaging satellites. Additionally, the high altitude platforms make a perfect platform for low power VHF/UHF and higher frequency radio communications. The map below shows the predicted UHF coverage for the upcoming "ES-OS" flight, which is planned for 'only' 85,000 feet.

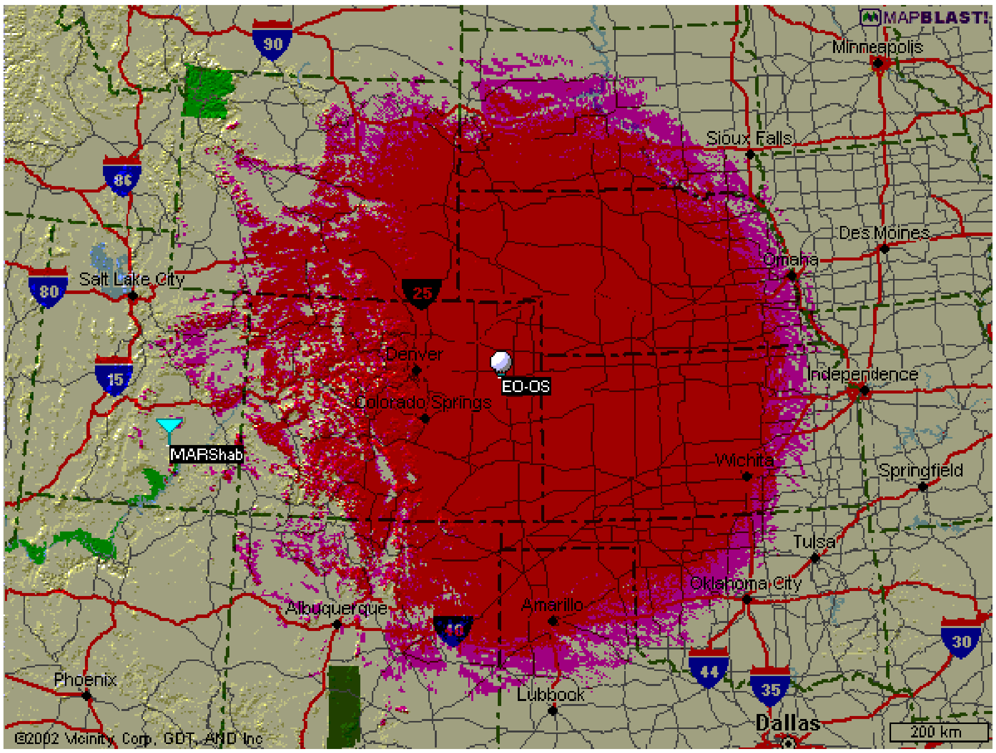

Fig 2. UHF coverage for high altitude balloon over eastern Colorado with balloon at 85,000 feet altitude, red is line-of-sight, magenta includes extended range possible with refraction

(7). Key Personnel

<u>K. Mark Caviezel (Principal Investigator):</u> contact: kmcaviezel@yahoo.com K. Mark Caviezel shall be the principal investigator on this proposed Phase I contract. He has a wide range of experience in the field of stratospheric ballooning, launch vehicles and rocket propulsion. He graduated with a BS degree in Aeronautical and Astronautical Engineering from the University of Washington in Seattle. Subsequently, he worked as a ground test and spacecraft integration engineer for the Boeing Commercial Space Company's Sea Launch program. He was heavily involved in mechanical test of Sea Launch flight hardware and ground support equipment, both mechanical and electrical. He developed and supervised some procedures for preparing the spacecraft processing facility for reception of flight hardware, and transfer of the hypergol-fueled spacecraft to the Sea Launch ship onboard a 257,000 lb, 56 wheel heavy duty transporter, and its integration on to the 1.8 million lb thrust Zenit 3-SL rocket's upper stage. Prior to his departure from the project, the Sea Launch conducted a successful test launch of a 10000+ lb satellite simulator payload into geosynchronous transfer orbit (GTO).

After leaving Boeing, he worked as an engineer at Truax Engineering, Inc., a small rocket technology research and development firm. He was lead engineer on investigational studies and hardware fabrication of innovative space launch technology, and a contributing member of the development team in other areas. During this time, using tools available to him after hours, he designed, built and successfully tested a 1500 lb thrust regeneratively cooled LOX/ethanol rocket engine, and has contributed to the design, construction and flight testing of smaller engines as well. Additionally, he has accumulated over 32 minutes of zero-gravity test time onboard the NASA KC-135 research plane. Mr. Caviezel is a member of the Reaction Research Society (RRS) and the American Institute for Aeronautics and Astronautics (AIAA), and Edge of Space Sciences (EOSS). Mr. Caviezel was recruited to join Pioneer Astronautics and has amassed a significant amount of experience in the design of bi-propellant, mono-propellant and thermal rockets. He served as member of the JPL Phase I Gashopper and Phase II NOBOSS (Nitrous Oxide Based Oxygen Supply System) teams, and as lead engineer for several liquid rocket engine development programs, including Pioneer's in-house proof-of-principle NOMR (Nitrous Oxide Monopropellant Rocket) engine demonstration effort and the COR (Carbon dioxide Oxidizer Rocket) analysis and test program.
During work on Pioneer's MMB (Mars Micro Balloon) and LAISRB (Lightweight Autonomously Inflated Self Rigidizing Booms) program, Mr. Caviezel served as flight director for high altitude zero pressure balloon test-flights as high as 122,000 feet MSL. After preparation and launch of the balloon-borne experiments, tracking telemetry was monitored, enabling 100% recovery of experimental hardware within minutes of landing. Some flights were over 200 miles distance traveled and 4 hours endurance. To pursue his personal ballooning objectives, he formed a new amateur group "ES-OS" (http://groups.yahoo.com/group/ES-OS_Launch) which has conducted flight test of garage-built zero pressure polyethylene balloons to altitudes exceeding 107,000 feet and as large as 28,000 cubic feet. Lateral views in excess of 400 miles are possible from these platforms. See Fig 3.

Publication: High Altitude Ballooning used to Simulate Mars Planetary Entry, ASCE Space and Robotics Conference, Albuquerque, New Mexico, March 2002

Presentation: "APRS Used to Track High Altitude Balloons From Launch to 100,000 Feet and Back" Tucson Amateur Packet Radio (TAPR) Digital Communication Conference, October 2002.

Fig 3. Picture taken by proposed PI via radio remote control from unmanned balloon at 99k feet.

Dr. Gary Snyder Contact: Redyns@ix.netcom.com

Education: B.S. in Electrical and Computer Engineering specializing in VLSI design and computer systems from Washington State University (1989)
M.S. (1991) and
Ph.D. (1994) in Aerospace Engineering, specializing in astrodynamics, from The University of Colorado at Boulder. His Ph.D. dissertation was entitled: “Attitude Determination from a Codeless GPS Signal Processing System

Dr. Snyder has worked on many projects, including: Artificial Intelligence (AI) adaptive electrical power management systems, Capacitive fuel monitoring systems, NASA Ph1 SBIR for codeless GPS satellite yaw sensor, disposable GPS receiver for balloon radiosondes, spread spectrum communications of DGPS on Syledis offshore network, Codeless GPS Application to MultiPath (CGAMP), flight telemetry system for transonic fin flutter experiments. Also: InfraRed TeleRobotic Positioner (IRTRoP), cell phone based, DGPS locator, NASA Ph1 and Ph 2 SBIR Mars Microballoon, NASA Ph2 SBIR Methanol Ejector Ramjet, DoD Ph1 SBIR Solar Sail Microspacecraft, and NASA Ph1 SBIR Mars Gashopper. Dr. Snyder was also head of the electrical department in a small manufacturing company, where he was in charge of industrial control system design, manufacturing and quality assurance for four years.
Dr. Snyder is a pilot, 'extra' class ham radio operator, EMT, scuba DivCon, CDL-A driver, and avid amateur rocketeer with a BATF LEUP.

Karl W. Gross contact: karlg@worldnet.att.net
Mr. Gross has a wide range of experience in the field of defense and commercial nuclear power application and use in the United States. He graduated with a BS degree in Nuclear Engineering from the University of Arizona in Tucson.
Subsequently, he worked as an engineer for Arizona Public Service in the licensing, operations and maintenance of the Palo Verde Nuclear Generating Station. The company initially assigned him to a training program which included assignments in various engineering departments and at a fossil-fired station and 500 kV switchyard. His nuclear project involvement was initially in technical issue resolution with the regulator. He was subsequently provided 12 months of post-graduate industrial training and assigned as a technical advisor to the control room staff of the facility. Finally he was promoted to manage the onsite regulatory interface engineering group, where the initial operating and safety limits for the facility were negotiated with the Nuclear Regulatory Commission, and during the period the operating licenses for the facility were issued. Special projects included participation in industry full-scale multi-phase fluid flow testing of safety and relief valves, radiation effects assessment on structural components, Three Mile Island Lessons Learned integration, Security, and Emergency Planning. Extensive field experience was gained in the operation of complex control systems, heavy mechanical equipment, and high- and low-voltage electrical equipment
Since 1986 Mr. Gross has provided consulting services to many facilities and organizations in the commercial and defense nuclear industry. His focus has been on resolution of lingering issues related to nuclear safety and the management and administrative programs associated with ensuring continued safe operations. Projects have included reconstitution of operating limits, surveillance program assessment and corrective actions, and project management. He has worked in Quality programs management as a subject matter expert as well as provide staff augmentation at facilities under regulatory duress or sanctions. He has also acted as facility nuclear safety manager at a DOE facility during the processing of special nuclear materials.
Mr. Gross has continued his formal education, returning to graduate school as a Ph.D. candidate at the University of Arizona between 1990 and 1996 (degree work not completed) while continuing to provide professional consulting services. He completed all available nuclear engineering coursework at the university, and extensive studies in the minor field of systems engineering. He was appointed assistant reactor supervisor at the university nuclear reactor laboratory where he was licensed as a senior reactor operator by the NRC. He provided laboratory and industrial training for the university, as well as assisted in the day-to-day operation of the department nuclear, radiochemistry, and accelerator laboratories.
Mr. Gross has also pursued other areas of interest germane to this proposal. He is an Amateur Extra licensed radio operator, attaining the highest available licensure in the Amateur Radio service. His interests include UHF/VHF/HF operations, APRS (Automatic Position Reporting System), portable satellite communications, and mobile communication systems. Mr. Gross is an active licensed pilot and aircraft owner with over 500 hours of pilot in command time, including complex aircraft. Recent activities have

included assisting in the construction of, launch, tracking, and recovery of high-altitude balloons, including airborne tracking and location from his personally owned aircraft.

Wil McCarthy contact: wmccarth@sprynet.com

EDUCATION: B.S. Aerospace Engineering, University of Colorado at Boulder. 12 Graduate credits in astrodynamics and life support systems.

LANGUAGE: Member, Science Fiction and Fantasy Writers of America (since 1990) w/ 6 published novels (Penguin, St. Martin's Press, Random House), incl. 1996 Locus Bestseller, 1998 New York Times Notable Book, 2000 Amazon.com "Best of Year". Short fiction and science/technology articles published widely. Bibliography available at http://www.wilmccarthy.com

COMPUTERS & MATH: Extensive experience with high-fidelity simulations, optimizing simulations, computer graphics, user interfaces, language parsers, data reduction, scientific programming on a wide variety of languages and platforms. Linear algebra, covariance analysis, multivariate normal theory, Monte-Carlo techniques, messy trigonometry, strange coordinate systems, restricted 3-body problem, n-body problem. C/C++, Basic, Fortran, MATLAB, JAVA, MS-DOS/Windows, Unix/Linux.

ELECTRONICS: Systems engineering including performance specification, proofing/verification of electrical schematics, troubleshooting/circuit analysis, limited design capability (mainly at the integration level), some 6809 and 8051 assembly language, plus LM628 motion control.

CLEARANCE: DOD SECRET

CURRENT WORK EXPERIENCE:
11/99 - Present Senior Project/R&D Engineer, Omnitech Robotics LLC, Englewood, CO
Concept, development, and testing of autonomous ground vehicle hardware and software subsystems including navigation, laser vision, obstacle avoidance, operator/supervisor interface. 3D simulation of vehicle performance in virtual environments. System development and troubleshooting, including hardware integration and software development for supervised autonomous capability on Skytrak forklift and HMMWV ("Humvee"), teleoperation capability on Caterpillar D7G bulldozer and other vehicles, plus classified work.

08/98 - 10/00: Systems Engineering Manager, Omnitech Robotics LLC., Englewood, CO
Coordination of design & troubleshooting efforts between electrical, mechanical, software, logistics/human factors, and test engineering groups. Performance and physical/electrical/software interface specification for 15 Line Replaceable Units, 30 Shop Replaceable Units, 2 Computer Software Configuration Items, and 7 Firmware Components in design phase of Mark IV Standardized Robotic System (a standard kit to convert land vehicles for robotic operation). Direct supervision of engineers, including hiring and schedule/budget/manpower planning. Proofing/verification of electrical schematics and mechanical assembly drawings. Monitoring and resolution of "big picture" design issues including: audio/video systems, night vision/FLIR, Controller Area Network, High Integration Actuators, RF communications, cable/connector design, CANIO/SIO interfaces to vehicle electrical systems, embedded computer hardware, embedded Ada95 computer software, embedded firmware, inclinometer and compass sensors, power systems, display systems, graphical user interfaces, user controls.

11/97 - 08/98: Senior Engineer, Lockheed Martin Astronautics, Denver CO
Space Based Laser Program: Design of satellite orbits, detailed simulation of laser missile defense systems. Titan Program: Guidance and Navigation analysis, orbital mechanics, algorithm design/ flight software engineering, real-time launch support (Go/No-Go). Lead engineer on several missions.

PRIOR WORK EXPERIENCE:

Software Engineer, Science Fiction Writer, Science Writer, Journalist, Technical Writer, Book Reviewer, Cashier, Night Guard, Information Clerk, Dishwasher, Research Assistant, Computer Programmer, Bartender.

Richard M. Powers contact: Richard.M.Powers@Colorado.EDU

Education B.S. and M.S. in Aerospace Engineering, University of Colorado at Boulder. M.S. in Electrical Engineering, University of Nebraska at Lincoln.

Mr. Powers' specializations include Orbital Guidance, Navigation, and Control, Control Theory, and Kalman Filtering / Sensor Fusion Algorithms.

While at the National Center for Atmospheric Research (NCAR), he was part of the control system design and science instrumentation accuracy verification teams for the High Resolution Dynamics Limb Sounder (Hirdls) Satellite flown as part of Nasa's Earth Observing System. (Publication: SPIE Aquisition, Tracking, and Pointing, Vol. 3086.) This Satellite is scheduled to be launched in January 2004.

Mr. Powers has broad experience consulting on aerospace electronics and control systems, including: Pioneer Astronautics' Mars Micro Balloon (digital and software design, prototyping, and testing of the Balloon Gondola's communications, controls, and camera systems) and Omnitech Robotic's Mark III and Mark IV Robotic Humvees (control system, Kalman Filtering, and sensor fusion design, debugging, and integration).

Mr. Powers is currently completing a Ph.D. in Electrical Engineering, University of Colorado at Boulder. His thesis work is an investigation into the detection and analysis of track loss in Sensor Fusion algorithms.

(8). Facilities/Equipment.

Galileo Systems (GS) is a non-traditional defense and NASA contractor benefiting from the engineering experience of the involved persons in areas as wide ranging as terrestrial robotics to satellite space launch to the nuclear industry.

Most GS personnel have been involved in numerous DOD, DOT, and/or NASA SBIR projects in the past, but GS as a company has not yet received any SBIR awards.

GS is a small operation with only 650 sq. ft. of dedicated facilities, in the form of a dedicated three car garage workshop. However, the space available in the home shops and offices of GS staff is more than adequate for this project. Available tooling includes traditional hand, air, and power tools, mill, lathe, drill press, oxyacetylene torches, MIG and TIG-welders, and materials for working in fiberglass. Automated equipment includes a computer-controlled milling machine, and over a dozen PC-class computers in three separate local area networks, with broadband Internet access, CD burners, analog/digital video capture and editing. In-house electronics capabilities include microcontroller/PIC programming, PROM and EPROM burning, PCB printing, and the usual assortment of electronic test equipment such as multimeters, oscilloscopes, and a spectrum analyzer.

GS typically creates early physical, mechanical, and electronic prototypes using in-house facilities. Fabrication of complex components such as enclosures, larger run circuit boards, cast parts, and oversized milled/lathed steel components, are outsourced through local service providers with rapid turnaround. GS is also has established relationships with more advanced machine-shop, electronics assembly, and environmental test facilities locally, in the event a fabrication is needed that is beyond the scope of our in-house capabilities.

Because GS does not have many dedicated facilities and our overhead rates are low, we are able to turn around products, designs, and projects very rapidly and at low cost.

Zero pressure balloons have been built in the GS workshop. Fig 4 shows a launch photo of a 28,000 cubic foot balloon on it's way to an apogee over 107,400 feet. That balloon was built in the GS workshop.

Fig. 4. 28000 cubic foot balloon which was fabricated in GS workshop. Note, the balloon is 100' tall.

Although not a 'facility' per se, the GS relationship with a 12 year old established ham radio and high altitude balloon club, Edge of Space Sciences, EOSS is a definite asset for the proposed work. See www.eoss.org. Some GS personnel have worked with EOSS during their support of the JPL Mars Micro

Balloon NASA Ph 2 contract (EOSS flights 42, 43, 44, 46, 47 48 and 50). EOSS provided excellent launch support and tracking and recovery of 7 flight tests of the Mars Micro Balloon payload, and also provided similar support for the flight of a zero pressure polyethylene balloon built in the GS workshop. See http://eoss.org/ansrecap/Thirtyone_to_sixty/recap55.htm for some details on the zero pressure balloon test flight.

(9). Subcontractors/Consultants

We do not anticipate a need for outside consultants on this project

(10). Prior, Current, or Pending Support of Similar Proposals or Awards

Although GS is independently pursing development of balloon technology germane to this MDA topic, there is no pending awards at this time for funding of duplicate work.