H. SMART EDUCATION AND PUBLIC OUTREACH, NEW TECHNOLOGY, AND SMALL DISADVANTAGED BUSINESS PLANS

H.1 E/PO

Abstract. The SMART E/PO program will combine new initiatives with proven techniques—inquiry-based and aligned with national science standards—to communicate SMART results to the public and incorporate SMART science in learning activities on various educational levels. Prof. Patricia Reiff, a leader in space physics E/PO, will direct the program. Student modules, museum exhibits, and planetarium and television shows will be disseminated through an existing network of teachers and museums in coordination with ongoing, successful programs. A unique aspect of SMART E/PO will be the development of resources accessible to the visually impaired. A number of the Co-I institutions will have teacher or student programs. Evaluation for content and accessibility will be performed as part of the program.

H.1.1 Teacher Training and Resources

A major emphasis of the SMART E/PO program is on teacher training. We will develop two inquiry-based modules that use SMART science to explore key concepts in math and science. A third module employs “data sonification” as an innovative way of visualizing certain physical phenomena. We will also include research on SMART core science and other SMART E/PO-related activities as for-credit options in Rice University’s Master of Science Teaching program.

Micro to Macro Institute. Over the past four years Rice University has offered a summer Micro to Macro institute for middle school science and math teachers, stressing the fundamentals of measurement as applied to biochemistry. This institute has demonstrated gains in student performance on standardized tests due to teacher participation in the workshop and follow-up activities during the school year. Problem-solving skills are developed using hands-on learning and inquiry-based modules, and the program qualifies for professional development training hours.

We propose to create a new space physics edition of the course, emphasizing national science and math standards on Motions and Forces, Measurements, and Predictions from Data [NAS, 1996, 2000]. Each summer (after Year 1), up to 24 teachers will analyze data sequences from the four MMS spacecraft to learn about correlations, boundary shapes and motion, and fields of force in key regions of the Earth’s magnetosphere. We will create and test inquiry-based modules in time series analysis, Fourier transforms, and boundary normal determination. Most teachers have a very modest understanding of the basics of statistical analysis and of the electric and magnetic fields that influence particle motion. We have found from previous workshops, however, that teachers increase their confidence in discussing these topics, using our space examples in their math and science courses (“I use these examples nearly every day” one algebra teacher reported), and we expect that the new workshop will yield similar results.

What Changed? To help teachers understand why multiple spacecraft are needed to unfold spatial versus temporal changes, we will create a special module called What Changed? This module will begin with an analogy from weather: Did it start to rain everywhere all at once or did we just drive into it? It will then expand into magnetospheric physics, with examples of current sheets, boundaries, and reconnection-induced changes in ambient fields. We will create versions of this new module in PDF form, in video, and in immersive theater, allowing us to judge the effectiveness of the various venues in creating effective learning. The module will also be used for the Micro to Macro institute. This inquiry-based activity will be strongly aligned with the middle school Motions and Forces science objective and the Analyze Change and Predictions from Data mathematics objectives [NAS, 1996, 2000].

Songs of Space. A common complaint about bringing space physics to the public is that the data are often “just squiggly lines.” To captivate and educate the public, we must make those squiggly lines come alive. We propose to create a new sound-based module, Songs of Space to help auditory and visually impaired learners visualize orbital dynamics and magnetic field changes by means of tonal information.

Radio spectrograms at audio frequencies have frequently been translated into sound by a straightforward use of the wideband signal. We will do the same for SMART data, but we will go further by encoding the magnetic field strength data from the four spacecraft into

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sound using a logarithmic scale with low field strengths creating low notes, and higher field strengths creating high notes. Each decade of field intensity will correspond to an octave. “Data sonification” [Smith et al., 1990] has been shown to be an effective learning experience, and sonification tools are available [e.g., Wilson, 1996]. The range of strengths expected should be quite comfortable to the ear.

Each of the four spacecraft will create a tonal sequence over the course of several orbits, with obvious quavers in regions of field-aligned currents or MHD waves. Spacecraft location information will be encoded into the stereo sound, so that if the spacecraft is traveling earthward, it is heard mostly in the left channel and if traveling outward, in the right channel; thus the orbit is heard stereoscopically. The fact that the orbits turn into a “string of pearls” at perigee will be obvious from the sound, as will the Keplerian result of faster spacecraft speeds at perigee.

To further illustrate orbital dynamics, we will create an exploratory module that allows a user to change orbital parameters (semi-major axis, eccentricity, argument of perigee) and listen to how changes in orbit result in changes in sound pitch. We will also create a sound-based magnetic merging module, using the data from a well-observed event. The users will be able to hear the magnetic fields decreasing and moving away as they watch the model-based animations. Sound, being a left-brain/right-brain activity, is stored in two different areas, making the memory much more lasting. We will work with the Accessibility Institute at the University of Texas in Austin and the Texas School for the Blind and Visually Impaired (TSBVI) to make these modules accessible to the visually impaired community (over 5 million Americans; over 200,000 students).

**Master Teacher Program.** Rice University’s Master of Science Teaching program is a professional degree program administered by the Physics and Astronomy Department. It provides an excellent venue to expose teachers to the detailed science of MMS-SMART. The program trains master teachers, who in turn teach other teachers at national and regional teacher meetings. The master teachers will participate in research associated with the core MMS science of reconnection. We expect that, as has occurred in the past, this work will reported at the AGU, AMS, and other national meetings. The teachers will also participate in field-testing the *Songs of Space* and *What Changed?* modules, help with teacher workshops, and test the effectiveness of the planetarium show modules.

**H.1.2 Student Activities**

To give promising high school students the opportunity to experience reconnection research first-hand, we will collaborate with the effective Young Engineers and Scientists (YES) program in San Antonio, sponsored by SwRI, and Project SMART (Science and Mathematics Achievement through Research Training) at the University of New Hampshire (UNH). The YES program brings students from south Texas to SwRI for lectures, demonstrations, and laboratory experiences. Each summer, Project SMART brings together 15-20 mostly rural high school juniors to work in small teams on active space science research topics supervised by faculty and staff at the UNH Space Science Center. Two or three high school science teachers are chosen to participate with the students and continue working with them into the school year. These programs are supported by local and Space Grant funds, and have a positive impact on changing student attitudes towards a career in science.

In addition to the student activities provided for in our E/PO program, we note that university students will be extensively involved in SMART science operations, working alongside professionals as fullfledged members of the SOC team. They will undergo an intensive summer-long training course, testing, and certification and will be involved in all SOC activities. As an additional student activity, a small (<200 g, <1 W) high-energy solid state detector (SSD) could, with some adjustment to planned E/PO activities, be developed by students and added to the SMART payload. (A precedent for this activity is the development of the Student Dust Detector for the New Horizons Pluto mission.) The feasibility of this activity will be evaluated during Phase B.

**H.1.3 Planetarium Modules**

The most exciting development in planetariums in the past six years has been the growth of immersive theater—a computer graphics-driven multi-media setting combining passive and interactive sensory devices to enhance a participant’s sense of realism. Studies that we have conducted on student learning from specific immersive experiences indicate that im-
mersive experiences make abstract 3D concepts more understandable, resulting in significant gains in understanding.

Our prior experience with the immersion technology (we created the world’s first space physics fulldome digital shows Force 5 and The Night of the Titanic with over half a million viewers) will allow us to use this technology to illustrate the use of multiple spacecraft to investigate reconnection and other processes.

In addition, we propose to use SMART science and immersive technology to attack the well-known problem of the “private universe”—the set of misconceptions that many students have about how the universe works [Schneps and Sadler, 1985]. Traditional classroom lectures have only a limited effect in correcting deeply rooted misconceptions. New experiences from different reference frames or vantage points allow students to form correct conceptions. Each year SMART E/PO will research different misconceptions and identify the experience that can remove the misconception. Video sequences will be designed to demonstrate the relationship that has been misunderstood. Through student immersion, concepts such as forces and motions can be more readily experienced, thus retained. Student misconceptions will be tested before and after experiencing the video treatment, and changes in misconceptions will be measured.

For SMART we will use our new, already developed, low-cost, single-projector, inflatable dome system to bring immersive theater to an increasing number of towns and schools. Our productions will be playable on all digital domes, large and small. Our planetary network members have agreed to show the new products and report metrics at no cost to the project: Carnegie Museum of Natural History in Pittsburgh, Lodestar Planetarium in Albuquerque, OMNI in Oregon, and Louisiana Science Center in Baton Rouge.

H.1.4 SMART Web site
The SMART E/PO team will create a web site with up-to-date mission information, webcasts of major events, and educational broadcasts. Rice University’s Center for Technology in Teaching and Learning is a leader in educational web-casting (e.g., of lectures such as PI James Burch’s The Fury of Space Storms). The Songs from Space will be available to blind and visually impaired learners through the SMART web site, which will be created in consultation with UT’s Accessibility Institute and TSBVI to ensure accessibility.

H.1.5 Distribution Mechanisms
We will distribute the E/PO products using our existing distribution network for space physics educational materials and exhibits. This network has been developed through longstanding partnerships with museums, teacher organizations, and television producers. We will also work closely with NASA’s SECEF, LWS, and STP outreach programs.

For several years, we have produced an annual Space Weather CD. Like a digital encyclopedia, it includes movies, images, and illustrations of space weather topics; daily updating images; and recent results. We will upgrade the disk to include the new SMART modules. The new activities created for middle school science and math teachers through the Micro to Macro academy will also be incorporated into the disks and distributed as part of the SECEF. The CD has been highly effective, receiving Exemplary ratings by NASA review panels as well a positive review in the December 2003 Sky and Telescope. The CD is distributed free at teacher meetings (e.g., NSTA, AAPT, SACNAS) as part of the Sun-Earth Connections packet and has reached over 50,000 teachers so far.

We also propose to develop video programming based on the Sounds of Space. We have an established relationship with Passport to Knowledge (P2K) through programs such as the January 17, 2004 First Look – LIVE from Mars program featured live on PBS as well as Live from the Sun and Live from the Aurora. We will continue our productive relationship with P2K to bring the exciting science of MMS to a broad audience at minimal cost.

H.1.6 Metrics and Evaluation
Development efforts will be monitored via presentations at science team meetings and via written reports to the SMART PM. Usage metrics appropriate for each of these efforts will be tracked: numbers of web users, CD’s distributed, teachers in 1-hour workshops, teachers in 3-hour credit courses, students in one-week or hour-long experiences. Software and programs will be externally evaluated. Formative and summative evaluation of the sound-based modules will be performed by Jim Allan of TSBVI, who will test the modules with his students both in Austin and at Space Camp before
materials are placed on the web for general use, and by John Slatin, director of UT’s Accessibility Institute. Dr. Sumners will evaluate the museum kiosk modules. CD-ROM and other written materials will be submitted to NASA OSS product review.

H.1.7 Management, Budget, and Personnel
The SMART E/PO program will be managed by Patricia Reiff, Rice University, who will coordinate activities, collect and report metrics, and arrange duplication and distribution of educational products. She will manage the subcontracts to the UT Accessibility Institute and TSBVI and will work with the Houston Museum of Natural Science on the development of digital renderings for planetarium shows. She will also coordinate activities conducted at other sites, for which funding will come directly from the Project. The major E/PO initiatives will be phased, with each running for six years. (See Section G.2.8 for more information on SMART E/PO management.)

The SMART project is committing $2,533K, just over 1.8% of the project resources, to E/PO. Detailed in Section J.4, the E/PO budget includes, but is not limited to, $220K for six years of the SMART project at UNH, $186K for sonifications and visualizations at GSFC, $223K for six years of “YES” activities at SwRI, $140K for digital renderings and a dedicated portable planetarium to show them, $180K for Micro to Macro institute costs, $300K for web programming and webcasting expenses, $146K at UT and $178K at TSVBI for accessibility testing and evaluation, and over $120K for materials to distribute to teachers at national and regional workshops. The remaining funds are for management, student assistants, travel, and minor expenses.

**Dr. Patricia Reiff**, the SMART E/PO lead, has over 15 years of experience in funded teacher training and informal science projects. A member of the LPI Broker/Facilitator team, she assists other scientists in creating E/PO programs. She is involved in creating fulldome planetarium shows under NASA and outreach projects in Earth science, space science, and the NSF-funded Center for Integrated Spaceweather Modeling. She typically contributes more than half of her time during the school year to educational projects.

**Dr. James Burch**, SMART mission PI and Vice President of the Space Science and Engineering Division of SwRI, will provide overall coordination of science team and E/PO efforts. He will be directly involved in outreach activities by selecting web content, meeting with students, and giving public lectures.

**Dr. Jim Allan**, Director of the Texas School for the Blind and Visually Impaired, will consult on the development of accessible web pages and sound-based modules, and field-test the products with his K-12 students and at the session of the Huntsville Space Camp especially for vision impaired students.

**Dr. Dan Boice** will lead the YES activity at SwRI, organizing the summer program for minority students in Years 2-5 of the program.

**Dr. Geoffrey Haines-Stiles** is Director of Passport to Knowledge, which creates live educational television programming that reaches millions each year. He will work with us to include our animations and sonifications in upcoming productions.

**Ms. Debbie Jensen** will lead the *Micro to Macro* institute. A leader of teacher training programs for over 8 years, she creates, field tests, and uses teacher modules aligned with both federal and state education standards.

**Dr. Ramona Kessel**, head of the space physics visualization group at GSFC, will lead the sonification effort. A 20-year space physics research veteran and 10-year veteran of outreach efforts, she will also guide the development of planetarium visualizations.

**Dr. John Slatin**, Director of the Accessibility Institute of the University of Texas at Austin, will consult on development of accessible web pages and sound-based modules, and will conduct testing for accessibility and educational effectiveness of the sound-based modules with both sighted and vision-impaired students.

**Dr. Carlos Solis** will head the Learning Technology effort. A member of Rice’s Center for Technology in Teaching and Learning, he creates web-based modules and webcasts, both live and archived.

**Dr. Carolyn Sumners**, head of Astronomy at the Houston Museum of Natural Science, has taught teachers for over 30 years, and is a leader in creating fulldome planetarium shows. She will lead the planetarium development as a contribution to the project.

**Prof. Roy Torbert**, FIELDS lead and director of the UNH Space Science Center, will lead outreach at UNH. Prof. Torbert coordinates many outreach activities related to space science within and outside UNH.
H.2 New Technology

Nearly all of the technology for the SMART payload is flight proven with deep heritage from previous similar missions. However, several improvements are being made to ensure the best possible measurements. These improvements are scientifically important, but are not expected to result in significant commercialization opportunities.

A new approach to time-of-flight (TOF) mass spectrometry is essential for MMS. In all previous missions, such instruments have been unable to detect minor ion species such as O\(^+\) in the presence of high fluxes of protons. This problem is caused by accidental coincidences between unrelated start and stop pulses that fall within a minor species’ TOF window. Such coincidences may make up only a small percentage of the proton signal, but for minor species (especially O\(^+\)), the real signal is completely masked by protons. SwRI has modified our flight-proven TOF mass spectrometer by applying an RF signal (~900 V and 5 MHz) to part of the analyzer’s inner deflection electrode. At a given energy, a large fraction of the higher velocity H\(^+\) ions (compared to O\(^+\)) are deflected by the oscillating voltage, causing them to be absorbed by the electrode. Oxygen ions are only minimally affected. The transmission ratio of O\(^+\) to H\(^+\) is of the order of 1000, sufficient to prevent masking of the oxygen signal. This technology has been proven in the laboratory. A significant investment is being made with internal SwRI funds to assure that the technology is qualified to TRL-5 by November, 2004 and to TRL-6 by the end of Phase B. To increase performance at lower mass, there is a new development of the JHU-APL time-of-flight chip for HPCA. Based on a flight-proven design, this new chip is now undergoing flight qualification.

Our Swedish partners at KTH are engaged in a new, evolutionary design, called SCALE, to reduce mass and increase reliability of the wire-boom deployers used for the SMART double probe electric field instrument. An engineering model has undergone vibration, thermal, and deployment tests and computer simulations compare successfully with MMS vibration specifications. A thermal-vacuum capable mechanical deployment test simulator, is under development. Although a space-flight demonstration is possible before FY 2006, a full thermal-vacuum ground test will achieve TRL-6 by December 2004.

H.3 Small Disadvantaged Business and Other Minority Institutions Plan

SwRI will involve both Small Disadvantaged Businesses (SDB) and Minority Institutions in support of the SMART program. SwRI will take steps to assure that the tasks delegated to each are meaningful and relevant to their business, science, or engineering interests. SwRI has started the process in the Phase A Concept study and expand the roles as the MMS Project progresses through all phases of the mission from hardware to data analysis.

H.3.1 Small Disadvantaged Business. As the prime contracting institution for SMART, any subcontracts awarded by SwRI to SDB organizations count toward meeting the NASA goals. SwRI will also work with its instrument subcontractors at universities and government centers to ensure active participation of SDB’s in their subcontracts. Based on their excellent work in support of the IMAGE mission, SwRI expects to award further contracts to several SDB’s. Jackson and Tull performed admirably in support of SwRI in a systems-engineering role, and VX Works was a key member of the operating system development team. In addition, SwRI expects to identify other potential SDB candidates to implement tasks for all phases of the mission. Other potential areas of support are in PC-board and harness manufacturing, thermal covers, integration and test support personnel, instrument calibration and shipping container fabrication.

H.3.2 Minority Institutions. Summer, part time, or semester-long work experiences at SwRI for students from minority institutions will allow these students to work directly with scientists, engineers and managers to acquire hands-on experience while completing their education. Students will be involved from concept to development, launch and mission operations. They will work side-by-side with their mentors, participating in the daily activities of the SMART program. There are several candidate institutions in the San Antonio area with appropriate programs in science and engineering such as St. Mary’s University and St. Philips College. However, a nationwide program is envisioned.