Report of the

Senior Review of

Astronomy and Physics

MISSION OPERATIONS AND DATA ANALYSIS (MO&DA) PROGRAMS

June 11-13, 2002

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Introduction

The Astrophysics Senior Review panel met June 11-13, 2002 to review requests from seven missions for MO&DA funding for the fiscal years FY03-FY06. The missions differed significantly in their fields of exploration, their relative maturity, and the size of their constituencies. Nevertheless, the panel found all seven to be of compelling overall scientific value, particularly when considered in a "science per dollar" metric. All seven missions addressed one or more focus areas in the Space Science Enterprise strategic plan (2000).

Like previous senior review panels, we struggled to achieve the correct funding balance between relatively large missions with broad scientific programs and the smaller (lower funded) missions with significantly more focused and unique science objectives. This quandary was made more difficult by the fact that several of the smaller missions were nearing the end of their productive lives. Nevertheless, the panel was uniformly impressed and fascinated by the progress shown by all the missions. As indicators of the health of space science, all of these missions are fully operational and, even for those that have already met their mission goals, continue to provide important data and new discoveries.

The Review Process

The panel endorses the process developed by previous senior reviews. The missions provide written materials highlighting their scientific achievements and potential and uniformly formatted budget tables. Importantly, representatives of the missions have the opportunity to provide an update of the mission status and address questions from the panel. In turn, the panel recommends to NASA the scientific priorities for the succeeding four fiscal years. A written poll of the panel revealed near unanimity for the priority rankings of the seven missions. Similarly, all votes regarding recommendations for specific mission funding showed strong panel consensus.

The panel particularly appreciated the strong emphasis on scientific achievement and potential and the corresponding page limits on the materials provided for review. Although a few missions disregarded or misinterpreted the instructions in this regard, we found that the more concise documents and tighter presentations were sufficient and made stronger cases. The Education and Public Outreach portions of the proposals were reviewed separately by Larry Cooper and Rosalyn Pertzborn of NASA HQ. Relevant portions of the evaluations from that review appear in an appendix to this report.

For future senior reviews, the panel recommends extending the period allowed for presentations and questions and answers and requesting the presenters to remain available to answer questions after the executive session. This would permit the panel to caucus before each presentation or resolve questions that may arise in executive session. In addition, presenters should be requested to bring copies of their presentations. However, the distribution of ancillary data that are not timely (e.g. testimonial letters, books, etc.) is not useful and should be discouraged. Finally, NASA should encourage the missions to provide clear and consistent explanations of the staffing levels requested in the standard budget submissions. Discrepancies between the prose and the budgets in several mission proposals fueled long and unnecessary discussions during the mission evaluations.

Related suggestions for the Astronomy and Astrophysics MO&DA management

The panel was gratified to find explicit recommendations for funding guest investigators within many of the missions. This is a welcome change to the policy of having successful proposers for time submit new proposals to the Astrophysics Data Program (ADP) program. However, the panel noted a wide range in the average funding for science data analysis per guest investigator among the missions. A single value may not be appropriate. Data complexity, experience within the user community, and mission phase may call for different levels of funding. We encourage NASA to provide guidelines for establishing levels of guest investigator funding.

Several members of the panel expressed concern about the relative funding among extended missions and cross mission programs such as the ADP and Long Term Space Astrophysics (LTSA). While the panel found that the funding of extended missions was appropriate and capable of supporting vigorous science programs in the operating missions, the panel understands that the cross mission programs have over-subscription rates exceeding 5 to 1. Such rates are greater than those for many of the extended missions and may be unhealthy for the future of space astronomy and astrophysics.

MISSION ASSESSMENTS (in rank order)

MAP: Microwave Anisotropy Probe

MAP is designed to provide a full-sky map of the cosmic microwave background with high accuracy and precision. MAP will produce maps at five frequencies, from approximately 20 GHz to 100 GHz. At present (June 2002), the MAP mission has

completed its observations for the 6-month data release, scheduled for December 31, 2002.

Extended Mission Strengths:

MAP addresses very fundamental scientific questions, and will yield crucial information about cosmological parameters and the origin of structure in the universe.

The spacecraft is functioning well; for the next several years, there are no known lifetime limits for spacecraft components.

MAP's extended mission will provide unique results, unavailable from ground-based or balloon-borne experiments or from the future Planck mission. MAP, by detecting large angle polarization, will directly detect the signature of re-ionization.

The extended mission will permit a better understanding of systematic errors in the data, and should constrain the Gaussianity (or non-Gaussianity) of the temperature fluctuations in the cosmic microwave background.

The MAP website, which receives over 1 million hits per year, is regarded by the Senior Review panel as a particularly effective example of education and public outreach.

Extended Mission Weaknesses:

The mission is particularly sensitive to minor spacecraft anomalies.

Some (but not all) of the questions addressed by MAP can also be addressed by ground-based and balloon-borne missions.

The funding level for the Extended Mission does not drop much below that for the Approved Mission (even when the "Data Services" costs are excluded).

Recommendation:

The Senior Review strongly recommends that MAP operations be extended for an additional two years (extending mission operations until September 30, 2005). On the basis of available information, we recommend termination of the mission after the two-year extension.

XMM-Newton: X-ray Multiple Mirror-Newton Mission

The X-ray Multi-Mirror Observatory (XMM-Newton) is a European-led X-ray observatory, a cornerstone in the Horizon 2000 program, with US participation in hardware and software support and with an active Guest Observer program. NASA supports the instrument teams and the US Guest Observer Facility at Goddard Space Flight Center, which is the interface for the US astronomical community.

XMM-Newton provides complementary capabilities to the Chandra X-ray Observatory: large field-of-view; large collecting area; high spectroscopic sensitivity; and ability to obtain spectra for extended sources while maintaining good spectral resolution. A good index of these capabilities is the over-subscription rate (requested time to available time), which is about a factor of eight.

The Instrument Teams are responsible for calibrations as the instruments age. The US participation has also contributed processing and analysis software that benefits the broader XMM-Newton user community.

Strengths:

The US community enjoys the benefits of access to a major observatory with small initial investment.

Several important discoveries have been made, with promise of many more to come. Among these are the measurement of temperatures and abundances in intracluster gas to large radius, showing the need to revise models for the evolution of the physical state of these baryons; the measurement of model-independent metal abundances for hot gas in elliptical galaxies; the demonstration that AGN spectra show a variety of Fe line profiles; a determination of abundances in the coronae of stars, showing surprising departures from patterns observed in the Sun; and possible X-ray lines indicating a supernova origin of a GRB.

Weaknesses:

The flow of scientific results from XMM-Newton, especially from a US perspective, has been hampered by inefficiencies in the proposal submission process, the proposal evaluation process, scheduling of observations, and delivery of processed data. However, the Guest Observer Facility is working to ameliorate these problems in subsequent proposal cycles.

Because of the delay in the delivery of processed data, there have not been a large number of US-led publications using XMM-Newton data. We anticipate that this situation will improve dramatically in the next two years.

The Optical Monitor has a field of view of 17 arc minutes (much larger than HST's FOV) with sensitivity within the range 1600 A – 6500 A. It provides a capability for simultaneous measurements of transients, but the scientific returns from this instrument have been modest.

Recommendation

For a modest investment in the mission, US astronomers have access to an exceptionally powerful observatory. We strongly recommend continued support for this mission, including an augmentation to the Guest Observers grants program.

FUSE: Far Ultraviolet Spectroscopic Explorer

FUSE is a high spectral resolution (R ~20,000) far ultraviolet (FUV) spectroscopic mission covering an important wavelength region of 910–1190 A. This wavelength region contains a number of strong, critical diagnostic spectral features that are sensitive to plasma temperatures from ~8,000K to 10MK: the H I Lyman series, C III (977/1175 A), O VI (1032/1038 A), and Fe XVIII 975 A. Numerous strong lines of molecular hydrogen are present in the FUV and provide important information on cool hydrogen gas.

FUSE has been operating for about 2.5 years (mainly as a Primary Investigator (PI) Explorer mission) and over 1500 objects have been observed. FUSE has made a number of important discoveries in a wide variety of astrophysical problems that include resolving the He II Lyman-alpha forest, detecting H_2 in the atmosphere of Mars and in the Large Magellanic Clouds, measuring hot coronal gases and fountains in galaxies, and constraining the baryonic matter density traced by hot intergalactic O VI plasmas.

Extended Mission Strengths:

FUSE is proving to be a powerful and versatile instrument that is addressing a broad range of cosmological, astrophysical and solar system problems. Considering the extended mission, the panel expects FUSE to yield important science returns on solar system objects (planets and comets), hot stars (both inside and outside the Galaxy), young stars, protoplanetary disks, solar analogs, compact binaries, novae, supernova remnants, local interstellar medium (LISM) and the intergalactic medium (IGM), as well as on galaxies, active galactic nuclei, and quasars.

During the extended mission FUSE will be a 100% Guest Investigator (GI) mission. The GI program will be important for building on previous results and also for introducing new ideas and new science into the FUSE science program. Like Chandra and HST, FUSE will be accessible by the entire astronomy community and involve more people and students in NASA space research.

FUSE has science program compatibility and synergism with other operating missions (Chandra, XMM and HST) and, in the near future, with GALEX and SIRTF. Many new FUV sources will be found with the upcoming GALEX mission. Observations of these new objects with FUSE with its unique spectroscopic capabilities will be invaluable in determining the properties of these new sources. Some of the GALEX sources will provide new sight lines for studying the ISM and IGM.

Canada and France will continue their participation in the FUSE during the extended mission.

Extended Mission Weaknesses:

The mission is vulnerable to any failures in the remaining reaction wheels and to additional gyro failures.

The FUSE data products are complicated and sometimes difficult to use (improvements are being made in the FUSE pipeline reductions).

The EM proposal exceeded the page limit of 15 pages by a factor of two.

Comments On Operations:

The panel congratulates the FUSE mission team on the rapid recovery of the FUSE spacecraft after the failure of pitch and yaw reactions wheels in late 2001 December. Technical evaluations of the reaction wheel failures indicate that there is little likelihood for catastrophic failure of the remaining roll and skew wheels. The mission is on schedule to resume nearly full sky coverage by the end of 2002. One of the six gyros has failed. The mission is modifying the attitude control system to handle additional failures. Testing of this system will be carried out during 2002.

Recommendations:

The Senior Review recommends that FUSE operations be continued for an additional two years of the extended mission. During the extended mission all of the observation time is allocated to the Guest Investigators program and sufficient funding should be maintained for the associated data analyses. The costs of operating the mission are relatively high and the panel recommends maintaining the "In-Guide" mission budgets for FY03 and FY04.

The panel recommends the continuation of the mission through FY05 and FY06 but with the somewhat reduced budget amounts that have been requested. With mature missions cost savings could be made in further streamlining operations or with small reductions in the funds from the data analysis budget.

Also, the panel recommends implementing Key Project / Legacy Programs during FY05 and FY06 to permit a number of interesting and important astrophysical problems to be tackled. This should greatly enhance the enduring scientific value of the mission.

Every effort should be made to calibrate carefully the FUSE observations. The final data products should be available in a fully reduced form with convenient and easy to use formats similar to those now available in the archives for IUE and EUVE.

RXTE: Rossi X-ray Timing Explorer

The Rossi X-ray Timing Explorer (RXTE) is a mission comprised of three non-imaging instruments which together span the energy range 2-200 keV. RXTE has many capabilities that make it unique among past, current and foreseen X-ray telescopes: an enormous collecting area, all-sky monitoring capability, sensitivity above 10 keV, very high time resolution, and great flexibility and speed of scheduling. RXTE's main research areas are in accretion-powered compact objects including black holes (both stellar mass and supermassive), neutron stars and white dwarfs. Fundamental astrophysical issues addressed include gravity in the strong-field regime, physics of ultradense matter, ultrastrong magnetic fields and accretion disks. In the most recent years of the mission, observing priorities have switched to increased Target of Opportunity (TOO) observations and more long-term monitoring programs.

Extended Mission Strengths

RXTE was launched in 1995 and has been in its Extended Phase for several years. Nevertheless it continues to produce impressive science results. The superb and accelerating rate of refereed publications based on RXTE results, the consistently high number of IAU telegrams, and the increase in the number of new users since the last Senior Review, demonstrate that RXTE results have a very high level of relevance and interest in the astrophysical community.

The number of major scientific discoveries made since the last Senior Review is still high, so the scientific justification for a continued Extended Phase is strong. These include the recent discoveries of neutron star "superbursts" (likely due to carbon thermonuclear burning events), quasi-periodic oscillations in accreting black hole systems, effective simultaneous studies of blazars with ground-based very-high-energy gamma ray observatories, and long-term monitoring projects on a variety of source types.

The extended mission allows coordinated observations with Chandra, XMM, Integral, and ground-based TeV telescopes. The RXTE team is taking advantage of these opportunities.

Extended Mission Weaknesses

With an older mission such as this, there is concern that most of the forthcoming science will be very similar to that of past years such that the rate of improvement in theoretical understanding may be diminishing with time.

Some of the science being produced by RXTE has a purely phenomenological flavor, lacking successful detailed theoretical interpretation. Scientific understanding of some critical issues may need a new, more powerful facility.

The requested funding level does not diminish with time as expected for a mature mission. In particular, the request for Full-Time Equivalents (FTE) not directly related to Missions Operations was not well justified.

There has been some loss of sensitivity in the proportional counter detectors.

Recommendations

We feel that the scientific productivity of RXTE, both in empirical results and astrophysical interpretations, continues at a high level. The Senior Review particularly applauds the increased priority for TOO observations, as well as large projects.

Nevertheless, the likelihood for diminishing returns seems significant; the Senior Review finds it unclear whether an extension beyond FY05 will produce new science that is worth the cost. We therefore recommend support at the current level, or the somewhat increased In-Guidelines level subject to review by NASA, through FY05. However, we recommend termination in FY06, though this question should be revisited by the 2004 Senior Review. Funding for the Guest Investigator program should be included for all years of operation.

2MASS: The Two-Micron All Sky Survey

2MASS is an all-sky survey in three near-infrared (1.2, 1.6, and 2.2 micron) wave bands. 2MASS has successfully completed its primary mission and has been widely used by the astronomical community. It has exceeded its required sensitivity, going 0.1 to 0.3 magnitudes deeper; its astrometric accuracy of ~0.15" exceeds its requirement by a factor of 3. The data are now being prepared for final delivery to the astronomical community in summer 2002.

The extended mission is aimed at providing a number of ancillary products that will enable additional science investigations beyond those of the basic all-sky catalog. Some of these come from co-adding data from regions that were viewed more often than typical. This will permit going deeper and producing more sensitive maps over portions of the sky from multiple exposures as well as lower-significance sources over the entire sky. Additionally, variability and proper motions can be investigated from multiple epoch observations. Technical support will also be provided for the scientific community. Validation of the data is an important aspect of this extended phase of the mission.

Extended Mission Strengths:

The proposed activities will make the mission significantly more powerful than originally conceived. Deeper-reaching maps and the prospects of determining the proper motions of faint nearby stars will considerably enrich our understanding of local regions within the Galaxy.

The speed of ramping down manpower seems reasonable. The 2MASS record of on-time/on-budget performance speaks well for the likely success of this ancillary data phase. The additional science capabilities of the ancillary data sets are likely to be very extensive; the combination of large area, deep, and multiple epoch surveys of selected

regions will result in a database that can be mined for years. The collection of "working-database" objects of lower signal-to-noise will also provide a catalog of infrared objects that will likely contain a very large number of relatively unique and important sources for follow-up. The deeper observations of the Magellanic Clouds will be of significant value as well.

The Sloan Digital Sky Survey and 2MASS beneficially complement each other. The Sloan covers shorter wavelengths, going to the U band, and reaching deeper. Both surveys provide proper motions. 2MASS, however, has the benefit of being less affected by extinction and includes the Galactic plane.

Extended Mission Weaknesses:

The overlap of celestial maps for 30% of the sky that the extended mission proposes to provide is likely to yield only modest additional information on stellar variability.

The cream of the program from the all-sky survey is already in hand. Accordingly, the extended mission will largely produce incremental advances. However, most of the requested funding is properly going into enriching the database, while continuing support for the user community is being appropriately phased out and amounts to only ~9% of the total requested.

Recommendations:

The review recommends that the 2MASS Extended Mission be funded at the requested level to be completed in the next two years.

HETE-II: High Energy Transient Explorer II

HETE-II is a small, low-cost mission devoted to the detection, localization and study of gamma-ray bursts in the 1-500 keV spectral band. Gamma-ray bursts rank among the most intriguing phenomena discovered in recent years, and HETE-II is capable of moving this rapidly developing field forward. Although the satellite suffered hardware and operational difficulties during its first year, it now appears to be proceeding with its scientific investigation in a smoother fashion.

Extended Mission Strengths

HETE-II fills a gap in the gamma-ray burst detection studies between the recent end of operations of the Italian SAX mission and the beginning of science from NASA's Swift mission in 2004. This is particularly important for continuity in the worldwide ground-based burst follow-up enterprises, and was emphasized by the 2000 Senior Review.

There is a good expectation that HETE-II will produce scientifically valuable and new insights into two classes of bursts: X-ray rich bursts and short-hard bursts.

The HETE-II satellite and ground-based Burst Alert Network typically notify the worldwide community via Internet within 30 seconds of the arrival time (but not location) of a burst. This rapid response is critical for investigation of burst behaviors and physics with ground-based robotic telescopes.

Extended Mission Weaknesses

At its current level and over a 2-year Extended Phase, about 200 bursts are expected to be detected with the FREGATE instrument; 40 will be roughly (typically 10'-20') localized with the Wide-Field X-ray Monitor; 6-10 will be finely (<1') localized with the Soft X-ray Camera. This performance means that only a modest number of bursts can be confidently identified and studied at optical wavelengths.

With the exception of interesting constraints on the properties of the soft gamma-ray repeater 1900+14, the level of new scientific results that has emerged from the first 17 gamma-ray bursts detected with HETE-II has been limited. Much of the phenomenology derived from HETE-II data is comparable in quality to existing data.

Recommendation

Qualitatively new advances in our understanding of gamma-ray bursts will require coordinated space- and ground-based efforts, and realistically this goal will take a commitment to HETE-II until the start of the Swift mission. Despite the relatively small, expected number of well-localized bursts, HETE-II provides a bridge to the Swift mission. Specifically, we recommend funding of the HETE-II mission at the In-Guideline levels until January 31 2004, with inclusion of the proposed Education and Public Outreach effort.

SWAS: Submillimeter Wave Astronomy Satellite

SWAS was designed specifically to observe five important spectral lines in the submillimeter region, originating from H_2O, $H_2{}^{18}O$, O_2, ^{13}CO J=5-4, and atomic carbon. The H_2O, $H_2{}^{18}O$, and atomic carbon transitions have the ground state as the lower level, so that these lines can be observed in absorption as well as in emission.

Extended Mission Strengths:

The mission has performed well since launch in December 1998. On-orbit performance meets or exceeds design specifications in all respects. The only significant hardware degradation involves a laser diode; the failing diode has been replaced by a backup diode, which is now operating according to specifications.

SWAS has achieved or exceeded its original scientific goals, having obtained measurements or strong upper limits on the gas phase abundances of H_2O and O_2 in a number of different interstellar regions. The radiometric performance of SWAS has

substantially exceeded specifications, allowing long integrations to be made on weak lines.

SWAS has found high H_2O abundances in warm gas, and very low H_2O abundances in cold dense gas. The H_2O and O_2 abundances are inconsistent with the predictions of pure gas-phase chemical models, but appear to be consistent with models which allow for growth of frozen H_2O mantles on the surfaces of cool dust grains.

SWAS discovered H_2O in the outflow from IRC+10216, indicative of a population of icy comets around that star. SWAS has likely obtained the first detection of O_2 in the interstellar medium (confirmation is needed). In addition to observations of the interstellar medium, SWAS has carried out observations of H_2O in 4 comets, and has observed the atmospheres of Mars, Jupiter, and Saturn.

The SWAS team is to be commended for carrying out a highly successful observational program despite a very limited budget in FY01 and FY02

Extended Mission Weaknesses:

SWAS has already achieved most of its original science goals. While significant scientific questions can continue to be addressed by SWAS, the panel did not feel that the additional science was sufficient to justify the requested 2 full years of additional mission operations. Nevertheless, additional observations have some value since SWAS serves as a pathfinder for the future NASA submillimeter missions (SOFIA in ’05, and Herschel/HIFI in ’08).

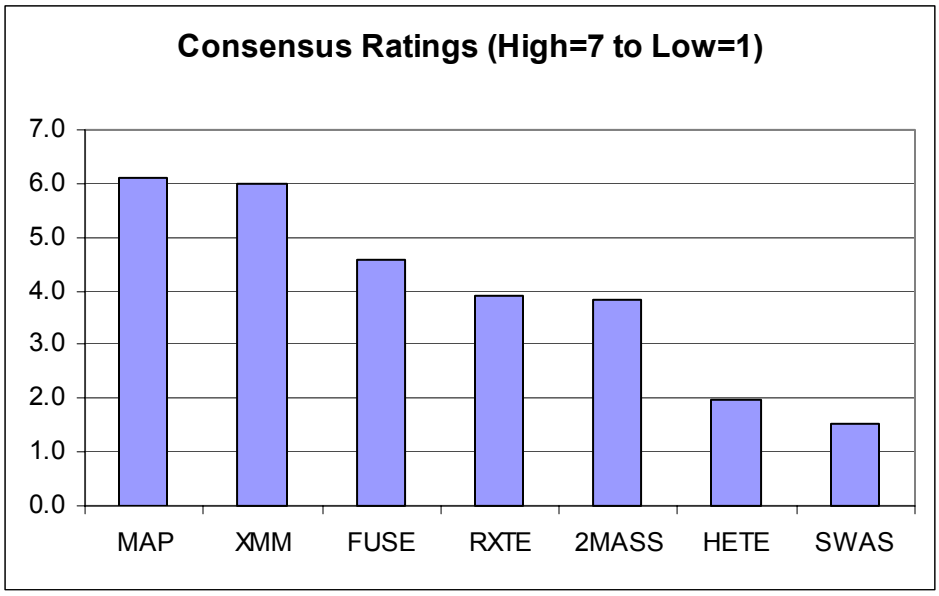
Recommendations:

We recommend that SWAS be funded to carry out mission operations through the end of FY03, plus funds for data analysis and archiving efforts in FY04. The additional year of mission operations should be used to carry out the highest-priority observations distilled from the program proposed for FY03+FY04.

Science Ratings for Missions
2002 Senior Review

Consensus Ratings (High = 7 to Low = 1)

MAP	6.1
XMM	6.0
FUSE	4.6
RXTE	3.9
2MASS	3.8
HETE	2.0
SWAS	1.5



Appendix A

Education and Public Outreach (E/PO)

Larry Cooper and Rosalyn Pertzborn

MAP

The requested funding would support the following activities:

1. Support the Adler Planetarium and Rose Center to incorporate MAP science and new advances in cosmology into their planetarium shows.
2. Develop electronic display materials for the Adler's electronic exhibit space and the traveling exhibit kiosk on Space Science Updates.
3. Continue collaboration with Old Bridge High School through scientist visits.
4. Develop new educational materials for the classroom
5. Continue to upgrade MAP web site

XMM-Newton

Proposed E/PO activities for the US part of the XMM-Newton mission include:

1. Continuation of teacher workshops.
2. d\Development of a script and a scenario for a Space Mysteries inquiry-driven web based interactive game.
3. A first draft of a planned planetarium program to be adopted for the Star Lab portable planetariums.

FUSE

The proposal narrative indicates that the "In-Guide" effort will be very modest and will support the maintenance of the FUSE web site and continued local volunteer efforts by the FUSE science team.

RXTE

The RXTE E/PO program demonstrates a thorough understanding of the requirements for an effective E/PO program that is consistent with the OSS E/PO policy. It is well focused and effectively leverages existing resources. Strong emphasis is placed on active involvement of the RXTE team to support teacher professional development opportunities such as workshops and partnerships with teacher interns to develop educational products (teacher guides, CD-ROMS, etc) that are linked to the parent research program science. Scientist participation in educator workshops emphasizes authentic partnerships to achieve the objective of developing products that are scientifically accurate and standards-based. The targeted audience (Grades 9-12) is also ideal for the scientific subject matter and continuing partnerships with teachers should insure appropriate evaluation for the effectiveness of the materials developed. Both national and local training sessions are envisioned

2MASS

The team's dedication to E/PO is commendable. 2MASS did not request any Education and Outreach (E/PO) funding. However, they did indicate they would "continue to provide content for, and leverage in all ways possible, the existing infrastructure of the IPAC E/PO activities." The planned IPAC E/PO efforts provide an excellent framework for a 2MASS contribution.

HETE-II

The HETE-II project proposes to focus on offering a 5 day teacher workshop for ~30 middle through high school teachers. Scientists from HETE will provide the main contribution to the workshop in addition to those from the Chandra and RXTE missions.

They will also develop a variety of informal education products including a HETE fact sheet and a litho on the electromagnetic spectrum and possible sources of GRBs. They will coordinate with the Swift mission to avoid duplication of similar products. Materials will be disseminated through the SEU Education Forum folder set and the CSR initiatives in Boston.

SWAS

SWAS did not request any E/PO funding.