

Report of the
Senior Review of
Astronomy and Physics
MISSION OPERATIONS AND DATA ANALYSIS (MO&DA) PROGRAMS
April 27-30, 2004

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Introduction

The 2004 Senior Review of Astronomy and Physics Division Mission Operations and Data Analysis (MO&DA) Programs was conducted April 27-30, 2004. The Panel considered operating missions, reviewed every two years, and data archives and service centers, reviewed every four years. Proposals from eight currently operating missions, four data archives and two service centers were reviewed for continued operations during fiscal years FY05-FY06. Rankings were difficult since all missions and data/service centers were carrying out high quality programs fully consistent with NASA goals and yet a tight funding climate allowed only the highest priority ranked programs to be awarded their optimal-request levels of support.

The eight missions encompassed the maximum range of mission size and complexity; from the Observatory class ESA-NASA missions XMM-Newton and INTEGRAL to two small UNiversity Explorer (UNEX) class missions, CHIPS and HETE. The remaining four missions reviewed were FUSE, GALEX, RXTE and WMAP. The four data archives spanned the original multi-mission data archive, HEASARC, to the most recently established data archive, LAMBDA. The other two data centers reviewed were IRSA and MAST. The two services, ADS and NED, have the largest numbers of users.

The final ranking of missions and of data archive and service centers was based on the combined criteria of scientific impact, both achieved and expected over the FY05-06 period, and science per dollar. Among the missions, the UNEX mission CHIPS was extreme in its requested very low cost for an additional year of operations, whereas the cost for INTEGRAL was relatively high for the science results obtained this early in its mission and the number of US investigators. The Panel debated separate rankings for science and science per dollar but finally decided to present a single combined ranking.

The Review Process

As with previous Senior Reviews, the missions submitted proposals describing their scientific accomplishments and goals for operation over the FY05-06 period as well as possible extension to FY07-08. The Panel was charged with recommending a program for the upcoming two year period as well as guidelines for the following two, which will be reconsidered at the next Senior Review in 2006. For the data archives and service centers, the Panel considered proposals for operations over the next four years.

The eight missions were reviewed on the first and second days, with presentations from the mission science teams summarizing mission science and needs projected for the upcoming two to four years. Proposals from the four mission data archives and two data services were considered on the third day. All projects were requested to present concise summaries of their proposed operations and plans without describing their full proposals. Budgets were considered in detail, and follow-up questions were asked of several teams following their presentations for additional details and clarifications. We note below that future Senior Reviews should include more precise instructions for budget presentations, with a summary of personnel requirements clearly given by task.

A preliminary ranking of the eight missions based on science achieved and projected was conducted after their presentations. This initial ranking was done with secondary attention to cost issues. Next, data archives and services were ranked, with attention to cost and schedule. A final mission ranking was then done with both science and science per dollar as the ranking criteria. The E&PO programs of all projects received independent assessment by a team led by Dr. Larry Cooper, NASA HQ. The findings of this team are presented in an appendix to this Report; additional comments on the E&PO programs of some missions/archives may be found within the main body of the Report.

Detailed comments on each mission and recommendations for its operation over the coming two fiscal years are provided in the Mission Assessments below. Missions were ranked on a scale of 1-10, with typical dispersions of ~ 1.5 in the final ranks after the top two ranked missions. The CHIPS mission had a larger dispersion (3.1) in its rank which likely reflects the greater uncertainty on the science it will achieve in its very low cost extended mission. The data archives and services are then separately described in the Data Archives and Services Assessments. Their rankings are again on a scale of 1-10, with dispersions again generally ~ 1.5 .

For future Senior Reviews, the Panel supports the previous guidelines for the proposal content but recommends in addition that budgets for missions, archives, and services include breakdown by FTEs required to accomplish their "in guide" and optimal programs. For data archives and services, input from User Committees for the proposed activities should be summarized in the proposals. Both missions and archives/services must provide more accurate in guide budgets, since in several cases these were discrepant from in guide budget levels provided to the Panel by NASA HQ.

The Panel was disappointed that several projects failed to implement the recommendations of previous Senior Reviews, and did not acknowledge these recommendations in their proposals. Projects should be required to address their response to previous Senior Reviews, as well as other direction from NASA, in their proposals to future Senior Reviews.

MISSION ASSESSMENTS (in rank order)

GALEX

GALEX is a SMEX mission that is mapping the sky in two ultraviolet bands with imaging and low-resolution grism capabilities. The main thrust of the mission is to characterize star formation processes in galaxies. This goal is being accomplished with a number of surveys with varying areas and depths. GALEX is still in its prime mission, with a proposed extended mission.

Spacecraft/instrument health & status:

No major problems have occurred after one year in orbit. Inefficiency issues are being addressed, specifically related to elevated count rates on the FUV detector. Sky coverage near bright stars is limited by an amount that is significant but still being determined.

Science strengths:

The mission is producing a huge amount of data that is providing a critically important new window on the Universe. The archives will have enormous legacy value. The discovery of ultraviolet-bright sources will greatly increase science efficiency of STIS and FUSE.

Since the hardware is perceived to be robust, the project has elected to initiate the Guest Investigator program now, even prior to the achievement of the baseline science goals.

Relevancy strengths:

The scientific program addresses very directly NASA's Structure and Evolution of the Universe (SEU) theme because of the central role that star formation plays across astrophysics.

Data accessibility:

The first public release will be 1 October 2004, coordinated via a powerful interface at the MAST archive site. A number of early science results have already been submitted for a dedicated issue of the Astrophysical Journal Letters.

Proposal weakness(es):

The observing efficiency has been lower than anticipated. This has had the effect of stretching out the interval the prime mission will take. Increasing the efficiency will require additional staff.

Overall assessment and recommendations:

The GALEX mission is opening a new window on the sky related to star formation in galaxies and many other topics enabled by wide-area surveys in the ultraviolet. In addition, the synergy with such missions as FUSE and HST, as well as longer-wavelength surveys including SDSS and 2MASS, promises to make the GALEX survey one of the most important data sets in astrophysics in this decade.

The proposal for the extended mission includes the plan to increase time allotted to GI's from 1/3 to 1/2 of the total. The oversubscription rate for Cycle 1 is about a factor of 2.3. This can be expected to increase in later cycles as the "black-out" restrictions are lifted and as the proposal preparation and submission process becomes easier for uninitiated users. An "observatory" style of operations is unprecedented for a SMEX mission, and this aspect needs to be supported. For example, tools should be made more useful to Guest Investigators for planning observations.

The Panel recommends completion of the prime mission in FY05 and FY06, with an extended mission covering the FY07-FY08 interval.

XMM-Newton

XMM-Newton is a Cornerstone ESA mission for X-ray astronomy with a high throughput set of three telescopes and reflection gratings (partly supplied by NASA) for high resolution spectroscopy and intermediate resolution imaging. US investigators participate in ~2/3 of all XMM observations with ~half of these having US PIs.

Spacecraft/instrument health & status:

XMM Instrumentation is, by and large, now operating satisfactorily and should do so for the foreseeable future. Initial changes in performance occurred early in the mission when two of 18 RGS CCDs failed, and it was learned that the Optical Monitor (OM) has somewhat reduced sensitivity due to a larger than expected stray light problem and reduced sensitivity to the UV. None of these technical difficulties has any significant impact on the capability of the observatory to carry out its scientific mission.

Science strengths:

An ESA mission, XMM is a Great (X-Ray) Observatory with great demand for its scientific capabilities (7:1 oversubscription). With large throughput, moderate spatial resolution, and the capability to simultaneously observe with both moderate spatial and spectral resolution with the EPIC CCD cameras, high spectral resolution from the RGS grating spectrometer, and some limited capability for simultaneous optical observations provided by the OM, XMM-Newton complements the Chandra X-Ray Observatory and thus can extend the scientific return from the Chandra mission. From comets to planets, quasars to clusters of galaxies, XMM-Newton has provided important and scientifically useful data applicable for a variety of astronomical and astrophysical questions. In the future, we look forward to science observations that make more use of XMM's spectral and temporal resolution.

Relevancy strengths:

XMM-Newton directly addresses several SEU objectives. In particular, it enables the study of physics in extreme magnetic and gravitational fields. Astronomers will use XMM to find and understand the presence of dark matter in clusters of galaxies.

Data accessibility:

The data are readily accessible in user-friendly formats through the HEASARC. Data access has improved substantially since the 2002 Senior Review. Archival data access for the OM remains awkward

Proposal weakness(es):

The community appears not to make adequate use of the OM data, a point recognized in the proposal. It is not clear, however, that the proposed approach to attacking this problem is adequate. The Panel did not find that the justification for the modification of the OM readout time scientifically compelling, in view of the limited use (thus far) of the OM data. The proposal also requested the addition of an archive program (which we feel should exist) and a theory program (which we do not recommend) on very little justification and without finding resources within the existing program to accomplish these objectives.

Overall assessment and recommendations:

XMM-Newton is a scientifically valuable resource which is very productive and highly utilized and has a vigorous Guest Investigator program with significant US participation. Use of this observatory complements and enhances the scientific productivity of NASA's Chandra X-ray Observatory. We strongly recommend that this program continue for at least 2 years at the minimum level proposed for FY05 and FY06. We recommend that the Guest Investigator program be enhanced in order that proposals with US Co-Is have increased budgets. We recommend that the Astrophysics Data Program be augmented by \$500 K for which the next solicitation will explicitly invite XMM-Newton archival research. We recommend that the XMM-Newton Project urge theorists to make use of the Chandra (if relevant to Chandra science) and/or ATP theory programs to fund their research.

In anticipation of future reviews we recommend that the Project prepare a plan for operating the program with significantly reduced budgets in later years (FY07-FY08) with little or no impact to the Guest Investigator Program.

FUSE

FUSE is a MIDEX class UV telescope for spectroscopy in the line-rich band just longward of the Lyman limit. It is a general purpose Observatory able to study a broad range of objects, from cool stars to QSOs as well as the hot interstellar and intergalactic medium.

Spacecraft/instrument health & status:

The Panel was uniformly impressed with the project's recovery from a near-death experience, maintenance of a respectable observing efficiency despite the loss of gyros, and the longevity shown by the detectors at essentially full sensitivity. Recent improvements in sky accessibility promise considerable gains as to which targets can be observed.

Science strengths:

O VI absorption, tracing the intergalactic medium at low redshifts, has emerged as a unique contribution of FUSE. The availability of new targets suitably bright for absorption measurements, found from the GALEX data, could give significant improvements in the depth of the mission legacy in this area.

The newly-derived gyroless capability for rapidly targeting Swift (and perhaps HETE) GRB counterparts within the FUSE beta-angle range is exciting, even if the probability of seeing any suitably located, bright, and low-redshift bursts is small.

Beyond these programs, FUSE supports a broad range of investigations spanning galactic and extragalactic astrophysics, as well as solar-system studies.

Relevancy strengths:

FUSE makes important contributions to both the Origins and SEU themes.

Data accessibility:

Search and retrieval are well-handled through MAST. With specialized data formatting and extraction routines, data access for analysis is adequate (although it could be more straightforward, for example in comparison with HST spectroscopic pipeline products).

Proposal weakness(es):

The GRB connection is likely to be disruptive to scheduled observations. The Panel found continuation of FUSE work on the IGM more interesting, especially with even a modest increase in suitable sight lines from the GALEX surveys. The detectability of GRB afterglows beyond $z=0.3$ will depend entirely on such sources lying behind negligible amounts of H I, which seems unlikely given the significant H I column densities detected in the host galaxies of many identified GRBs.

The Panel was concerned by the declining totals for GI funding.

Overall assessment and recommendations:

The Panel was enthusiastic about the continuing science potential of extended FUSE operations, and hence the proposed extension of FUSE operations. Such a mission extension should be further evaluated at the next Senior Review, by which time the impact of GALEX source lists should be important.

The Panel also recommends a continuation of the FUSE legacy and survey classes of program, which make a substantial contribution to the overall productivity of the mission, and that adequate GI funding be maintained as long as possible.

WMAP

The Wilkinson Microwave Anisotropy Probe (WMAP) was designed to provide all-sky maps at five microwave frequencies with high sensitivity and precision. The WMAP project released the results of its first year of CMB temperature anisotropy observations in February 2003, exciting considerable media interest. In addition, WMAP is polarization sensitive.

Spacecraft/instrument health & status:

The spacecraft and instrument appear to be performing nominally, with no noticeable degradation over time.

Science strengths:

WMAP addresses very fundamental scientific questions in a way that is, at present, uniquely complementary to other observations. It has already firmed up the emerging cosmological standard model and refined the measurement of its parameters. Improved measurements from the extended mission, particularly of polarization, will complement smaller-scale CMB experiments and other cosmological observations to help address exciting open issues such as the nature of dark matter, dark energy, reionization and fluctuation-generation in the early universe.

By probing structure and evolution of the universe and cosmic origins, WMAP is highly relevant to NASA's core mission, and has given NASA large impact far beyond the astronomy community. WMAP was highlighted as a key part of Science Magazine's "Breakthrough of the Year 2003", and this broader impact is particularly notable among physicists and the general public.

WMAP has an excellent management track record, being on schedule, on budget and on specification. Prompt public release of its first year's data has enhanced WMAP's science return.

The extended WMAP mission will enhance the science return of the Planck mission by mapping polarized foregrounds at 23 GHz, below the lowest Planck LFI frequency. It will also provide crucial input for NASA's decisions regarding a next-generation CMB polarization mission (CMBPOL), both by quantifying polarized foreground contamination and regarding systematic error control.

Relevancy strengths:

WMAP makes fundamental contributions to both Origins and SEU objectives.

Data accessibility:

Data are archived and distributed through LAMBDA, which was established to be the CMB data archive and distribution center.

Proposal Weakness(es):

Much (but not all) of the extended-mission WMAP science may be done better by Planck, officially scheduled for launch in 2007.

Given the extremely low level of CMB polarization signals, it is difficult to evaluate at this time the extent to which WMAP observations complement Planck without having detailed knowledge of the foreground contamination levels and the systematics of both instruments. Although the extended WMAP mission will contribute to measurements of foregrounds and systematics, it is not clear how these will compare with those for Planck.

The funding level for the Extended Mission does not drop much below that for the Approved Mission.

The calibrated time-ordered data were not included in the public data release except in pre-whitened form, limiting the opportunities for analyses of these data.

Overall assessment and recommendations:

We recommend continued funding of WMAP at the requested level in FY05 and FY06, with a potential final extension to two additional years of observation if the 2006 Senior Review finds that the quality and rate of improvement of the polarization results (not yet released) justify it. This recommendation is contingent on annual public releases of calibrated time-ordered data and polarized and unpolarized sky maps at the five observing frequencies within one year of data taking, i.e., a 2-year release by September 2004, a 3-year release by September 2005, etc.

These public data releases are the equivalent of a GI program since they allow community access to the data. Thus the WMAP team should not be required to reduce all relevant systematic uncertainties to negligible levels before data release, but instead to identify and, to the extent feasible, quantify these errors.

RXTE

RXTE's primary scientific objective is to investigate the nature of accreting compact sources: black holes (galactic and extragalactic), neutron stars and white dwarfs. In the most recent years of the mission there has been an increase in the number of TOO observations. RXTE combines the unique capabilities of broad energy coverage, large collecting area, and rapid timing that are not duplicated by any present or future mission.

Spacecraft/instrument health & status:

The spacecraft and instruments are stable and should continue to be so well past the end of FY08. The PCUs are now usually operated with any two (of the five) "resting" to maximize instrument lifetime.

Science strengths:

RXTE continues to produce new and exciting scientific results, particularly in the areas

of investigating the kilohertz QPOs, millisecond pulsars, LMXBs, coordinated multifrequency studies of blazars, and the power spectra of Seyfert Galaxies. The discovery of the twin kHz QPO, SAX J1808.4-3658, has demonstrated that the QPO frequencies are commensurate with the neutron star spin frequencies. The study of the Seyfert PSDs has demonstrated a correlation of the “knee” frequency with mass that spans more than seven orders of magnitude in mass, and the multifrequency blazar observations have demonstrated relationships between the X-ray emission and the radio and TeV gamma ray emission. Studies of anomalous X-ray pulsars have revealed bursts, demonstrating that AXPs and soft gamma-ray repeaters are all variants of magnetars.

Relevancy strengths:

This mission directly addresses many of SEU’s research themes.

Data accessibility:

Data are easily accessible in user-friendly formats through the HEASARC

Proposal weakness(es):

RXTE is in its ninth year of operation. For a mission at this level of maturity, one expects that there should be major savings in costs that could be realized by accepting greater levels of risk in operation. The Panel is concerned that the budget is not transparent and is therefore unable easily to assess the impact of budget reductions. The requested budget for the instrument teams (at GSFC, MIT and UCSD) makes this very expensive for a nine year-old mission. The Panel was also concerned by the relatively narrowly defined science program, at least as advocated in the oral presentation. The funding level of the Guest Investigator Program is small, especially in relation to the proposed cost of the mission.

Overall assessment and recommendations:

Overall the Panel feels that RXTE still has scientific merit, but not at the proposed level of cost. A mission of this age should be willing to take on more risk in order to reduce operating costs. The large level of support to the instrument teams as well as the operations costs at GSFC are areas that may be fruitfully investigated for expanded risk and reduced cost. Conversely, the GI program needs to be enhanced. With this proviso, we recommend the extension of the mission through FY06, at reduced cost.

CHIPS

CHIPS is a successful University-Class Explorer (UNEX) mission. This very low cost mission is carrying low resolution spectroscopic observations of the diffuse local EUV background between 90 – 260Å. Diffuse EUV emission is expected for hot (10^6 K) plasma in the LISM “bubble”. A cluster of FeVIII – Fe XII emission lines located near 170Å provide temperature and density diagnostics of the local ISM.

Spacecraft/instrument health & status:

CHIPS has operated well during its first year of operation. CHIPS has had some minor technical problems with communications “drop outs” with one of the satellite reaction

wheels but this problem has been overcome. The operation of instrument detectors has been tested by securing a lunar spectrum, and the instrument and detector performance appear to be nominal.

Science strengths:

CHIPS has detected only the lowest energy Fe emission line (Fe IX at 171A). These initial results are both puzzling and interesting. Additional observations may help solve this problem.

EUV observations of the comets LINEAR T 7 and NEAT are planned with CHIPS during May/June 2004. These observations could provide some interesting and important results. If these comets are detected in the EUV by CHIPS, it would be a major boast to CHIPS' participation in the upcoming (2005) Deep Impact comet experiment.

CHIPS can also make some contributions to studying the Earth's plasmasphere with HeII Lyman-Beta (256A) Emission

Relevancy strengths:

CHIPS makes some important contributions to NASA's Origins & SEU themes. CHIPS demonstrates that very small missions can be successfully done by university groups within the UNEX program.

E&PO record:

The Education and Public Outreach Programs of CHIPS have been appropriate for the limited scope of the mission. The team has developed some informative educational products such as "Exploring the Interstellar Medium" that has been produced and disseminated to schools. They plan to develop new material such as a "Cosmic Recycling Website and a video. Also, they have established good links with local schools.

Data accessibility:

The CHIPS data sets are not very extensive and there are plans to deposit the data to MAST. This will make the CHIPS data available to the astronomy community.

Proposal weakness(es):

CHIPS has relatively low sensitivity and is difficult to calibrate (e.g., it is not very sensitive to even very strong EUV point sources). Observations of the Moon, with uncertainties in its EUV albedo, are used. It is unclear what impact the absence of the Fe-lines will have on our understanding of the local ISM. It is possible that no new science may result with an extension of this mission, but the costs are small. Since this is a UNEX mission, it may be valuable for training purposes to include graduate students and undergraduates in the program.

Overall assessment and recommendations:

The Panel recommends operating CHIPS for an additional 18 months. This small amount of funding permits the completion of the diffuse local ISM program as well as carrying out the interesting (but uncertain) EUV observations of two bright comets and

participation in the upcoming Deep Impact Mission with 9P/Tempel 1 during mid-2005. The Panel recommends that some undergraduate and graduate students be included in the operational and data reduction aspects of the program.

INTEGRAL

INTEGRAL is an Observatory class gamma-ray mission launched by ESA in 2002. US investigators had limited roles in its two major instruments (SPI and IBIS), and NASA supplies the DSN for partial telemetry coverage from its high orbit. US participation in the most recent (AO2) program is 24% PI and 37% overall (i.e. including Co-Is) of accepted proposals.

Spacecraft/instrument health & status:

The overall status of the INTEGRAL mission is good, but with two instrument health issues: one of the 19 Ge detectors on the SPI spectrometer failed, resulting in a ~5% loss of sensitivity; and a loss of some microstrips on the JEM-X X-ray monitor was mitigated in part by reducing the detector high voltage. An initial problem of limited data throughput due to telemetry saturation has been fixed by onboard data compression and increased TM bandwidth. The proposal did not include results from the high energy (~100 keV - 10 MeV) back-plane PICsIT array of the imager, or from the optical monitor (OMC), although both are operative.

Science strengths:

Both of the primary instruments, the spectrometer SPI and the imager IBIS, produced interesting results in the first year of operation. SPI has imaged the extended source of 511 keV annihilation line radiation from the galactic bulge and measured its spatial extent to be ~8 degrees (FWHM), which is possibly larger than previously measured with OSSE on CGRO). The 511 keV line and continuum spectrum is largely dominated by positronium. SPI has also detected the 1809 keV diffuse emission from ²⁶Al in the galactic plane, and should be able to better image its spatial distribution in the next several years of the mission.

A population of hard X-ray sources, heavily obscured ($\log N_H \sim 23$) in the galactic bulge/plane, has been discovered with IBIS. A follow-up observation with Chandra found one to be periodic (~1.6h period), suggesting it may be similar to the very hard, and periodic, sources discovered with Chandra near the galactic nucleus. Early results suggest that a significant fraction of the Galactic Ridge emission at energies above 20 keV must come from point sources, rather than diffuse emission as suspected at lower energies. The possible IBIS detection of SgrA*, if confirmed, is a major result since it is at least 10X as luminous as the extrapolated spectrum of the Chandra point source.

Relevancy strengths:

The SPI provides the first high spectral resolution ($R \sim 200$) imaging (coded aperture) coverage of the soft gamma-ray band (~100keV - 2 MeV). It thus provides science relevant to the Life Cycles of Matter goals of the SEU Roadmap. IBIS contributes to the

SEU theme, which includes study of black holes.

Data accessibility:

INTEGRAL data are accessible from the GOF and HEASARC, but analysis software is relatively difficult to use even for groups with prior experience with analysis of gamma-ray data. Additional software tools are needed, and further development of the offline analysis system (OSA) is encouraged. It is particularly important that the INTEGRAL data be ingested into the HEASARC archive.

Proposal weakness(es):

The science case presented in the proposal was not as compelling as it could be and does not adequately reflect the potential of INTEGRAL in future years. The science return thus far from INTEGRAL has been primarily limited to early results on sources previously known (e.g. 511 keV and 1809 keV diffuse emission) or probably already detected with Chandra (e.g. the highly absorbed hard sources in the galactic bulge). The Panel recognizes that INTEGRAL observation times will typically be long to achieve the sensitivities needed for new discoveries. Detection of the galactic nucleus (SgrA*), if confirmed, would be an exciting example.

Overall assessment and recommendations:

The Panel was concerned by the relatively small number (~25) of US PI programs in the AO1 and AO2 programs and encourages the GOF to improve software and analysis tools to make INTEGRAL data more readily accessible. The small over-subscription factor in proposals vs. in time requested suggests that the user community is (still) limited.

The Panel recommends funding at the in guide level for FY05 and FY06 but does not support the request for a theory or archival program. The Panel challenges the GOF to further improve data analysis software and ease of access to archival data. Continued GI funding beyond FY06 vs. support only for ingesting data into the HEASARC should be dependent on this.

HETE

HETE (High Energy Transient Explorer) is the first wide-field coded aperture gamma-ray burst (GRB) mission and thus a forerunner to Swift. It is now producing high quality science.

Spacecraft/instrument health & status:

HETE (formally, HETE-2) has overcome its early difficulties and has been operating as advertised, producing ~25 well localized bursts/year. This burst rate will most likely continue during the remainder of the mission.

Science strengths:

The promptness of the burst notifications to the scientific community has allowed for follow-ups that have elucidated the burst phenomenology and provided for detailed

information across the electromagnetic spectrum. The detection and subsequent follow-up of burst 030329 has been the highlight of the scientific mission and has gone a long way to establishing the link between GRBs and SNe Ib/Ic.

In an extended mission overlapping with Swift, the broad bandpass of the HETE instruments ($\sim 2 - 500$ keV) would allow better study of a particularly interesting class of bursts such as XRFs at the low energy end and possibly high-z bursts at the high energy end.

Relevancy strengths:

HETE is producing data and knowledge that is very relevant to NASA's SEU theme. The team has been very successful at running the program for a modest cost.

Data accessibility:

The notifications of bursts to the community are prompt allowing rapid follow-up. Lightcurves are made available through a web interface and we encourage the inclusion of the data products within HEASARC

Proposal weakness(es):

HETE was conceived as a bridge between the Beppo-SAX era and the era of Swift but is now being "sold" as complementary and synergistic with Swift. The justification is largely based on "doubling" the special cases of bright, nearby bursts and possibly rare high-z bursts. The utility of observing ~ 4 bright bursts per year versus ~ 2 per year was not well justified and, in fact, "...even a handful more may change the whole picture..." was stated as the ultimate justification. In addition, it is highly uncertain that the number of high-z bursts will be doubled during the extended HETE mission (e.g. they may be faint, and inaccessible to HETE).

A 4 year extension of HETE during the entire Swift mission would most likely yield only a marginal benefit for the cost of the extended HETE mission.

Overall assessment and recommendations:

The Panel recommends that HETE be granted an extension through FY 2005 which should allow a 1 year overlap with the Swift mission. The Panel believes that the assumed 1 year overlap will demonstrate the science return of HETE combined with Swift and that any further extension should be considered only in light of these results.

DATA ARCHIVES AND SERVICES ASSESSMENTS (in rank order)

ADS

The NASA Astrophysics Data System (ADS) provides bibliographic information on astronomy, instrumentation, physics, and astronomy preprints to the great majority of

U.S. astronomers (> 95%). It is the astronomical search engine for finding publications on any astronomical subject with links to abstracts and articles (pdf and bitmap). It also provides a number of additional services such as citations, reference lists in any desired format, full text searching on scanned journals, and a new service, myADS, which provides weekly notices on articles satisfying a set of individually programmed criteria.

Relevancy:

ADS is used extensively by the entire professional astronomy community, providing an efficiency savings estimated in the proposal to be ~ 3000 FTE research-years per year (defined as savings in time spent otherwise obtaining the same information from libraries). As such, it is a powerful tool in addressing NASA strategic goals of both the SEU and Origins themes.

Science strengths:

The ADS is designed for the expert user, one who desires speed and simplicity. The result is an extremely efficient, low-cost system. By working with the major scientific publishing houses, ADS obtains tables of contents, abstracts, references, and links to articles (for those with subscriptions), and eventually pdf images of publications directly from the publishers. ADS also receives reference links from NED and SIMBAD (which act as name resolvers). This material is ingested weekly.

Since the 2000 Senior Review the ADS has made satisfactory arrangements with all the major publishing houses with the exception of Science and Nature. We encourage the ADS to continue pursuing arrangements with these two hold-out periodicals.

E&PO record:

The review of ADS E&PO efforts raises questions whether the projects efforts to extend to use of ADS to high school teachers and students are successful. Given the ADS philosophy of serving the expert user (e.g. active research astronomers), we recommend that ADS discontinue its E&PO efforts in future years.

Proposal weakness(es):

For some astronomers, the simplicity and vast reach of ADS make separating the wheat from the chaff a chore. However, because the great majority of all queries involve either author names or portions of the publication title, the ADS wishes to keep its search strategies simple (and fast).

Some of ADS's capabilities, such as the ability to refine searches on the extensive lists mentioned above, or to return results in custom formatting, are not well known by the typical ADS user. The SR recommends that the ADS provide a more obvious link to a small set of examples for making searches, setting up myADS, etc.

Overall assessment and recommendations:

The Panel applauds the ADS team for providing an outstanding service to the astronomical community, for extending the ADS service to many international mirror sites, and for reaching out to other scientific communities such as the Division of

Planetary Sciences. While not a primary data center, the ADS will be an essential part of the Virtual Observatory. The Panel recommends that NASA continue to fund the ADS at the requested-optimal budget level to enable the scanning of older periodicals and observatory reports.

MAST

The Multi-mission Archive at Space Telescope Science Institute (MAST) is NASA's UV/Optical space astrophysics data archive center.

Science strengths:

MAST provides public access (via the internet) currently to data sets from 12 missions. At this time data from four active missions (HST, FUSE, GALEX and CHIPS) are being deposited and archived. In the future the data from KEPLER will also be archived at MAST. MAST goes far beyond being a repository for these data sets and has developed powerful tools for interoperability protocols, web services, and information technologies for ease of use and for carrying out science programs with these data.

MAST provides a crucial service to a large fraction of the Astronomical community and is commended for operating a first class science archiving and analysis facility. Both usage statistics and science output clearly demonstrate the great utility of MAST. The bulk of the planned activities are well motivated and important.

Relevancy strengths:

MAST is very important to NASA's Origins and SEU programs.

Data accessibility:

The interface to the data is simple, and tools for discovering and analyzing data are extensive and powerful. The data are updated regularly, and their availability is clearly noted.

Reviewers were concerned that the data delivery from MAST following a request is still relatively slow. Also, it was noted that the user interface design appears somewhat dated, and multiple jumps to secure the data are often required. The expert interfaces are limited, and the interfaces for the different components seem to have been developed independently, without a common model. The GALEX archive interface appears to represent the state of the art, and should serve as a model for MAST's presentation and delivery of data from its other holdings (including HST).

Proposal weakness(es):

The reviewers did not see a compelling case made for supporting the proposed Post-Doc Archival Position. Likewise, while in principle an interesting notion, the proposal for a theory archive center was not sufficiently developed and justified. Also, it seems unlikely that a CHIPS web interface will be necessary given the nature of the science results they are obtaining.

Overall assessment and recommendations:

MAST provides vital services to the Astronomical community, and the Panel recommends continued support for this important facility over and above the in-guide budget, to allow for many of the planned enhancements to be accomplished. These enhancements are well motivated by the needs for ever more rapid search and retrieval of large data sets, and take good advantage of co-location with the HST-specific archive development and operations. The reviewers specifically support the development of an IDL On the Network (ION) workspace-management function to allow remote analysis, as an effective way of managing the increasing requirements for data distribution.

The Panel commends MAST for the clarity and detail of their budget proposal, which could serve as a model for other mission and archive groups.

HEASARC

HEASARC (High Energy Astrophysics Science Archive Research Center) is the original (1990) multi-mission science data archive for NASA missions and provider of data analysis tools.

Science strengths:

HEASARC's usage statistics clearly demonstrate that it is an indispensable tool to the high energy astrophysics community and beyond. It offers excellent and easy access to a very large number of data sets, as well as very useful tools for viewing and analyzing them. Specifically, the common format of the data sets and the fact that the analysis tools can be used on nearly all of them is a great strength. This uniformity of access to current and past data sets is very important given the transient nature of many high energy sources.

The 25% research time given to staff, as well as the input from the User Group, helps to assure that the HEASARC is serving the community well.

Relevancy strengths:

HEASARC is relevant to NASA's goals, as it archives and manages NASA mission data as well as other data that are scientifically relevant to the analysis and interpretation of NASA mission data.

Data accessibility:

The data are very accessible, and the interfaces to the data are clear and well documented.

E&PO record:

This is a particular strength of the HEASARC. It is to be highly commended for the superb job it is doing in public outreach.

Proposal weakness(es):

The Panel found no major weaknesses with this proposal.

The proposal could have better demonstrated that the 25% of time reserved for staff research is being maintained and is in fact resulting in their ability to accomplish good science.

As noted in an external assessment, the tools for catalog searches could be better, and overlaying sources on images would be useful.

XMM Optical Monitor data could be made more directly accessible through the HEASARC.

Overall assessment and recommendations:

The committee's overall findings are that the HEASARC is an excellent service, whose proposal had many strengths and few weaknesses. We recommend funding at the requested level, which is consistent with the in-guide budget.

NED

The NASA Extragalactic Database (NED) is a powerful tool to "organize and provide access to both the known contents and cumulative knowledge about our Universe".

Science strengths:

NED has become an indispensable tool in the contemporary practice of extragalactic astronomy, taking important conceptual steps toward one vision of the Virtual Observatory. It is indeed difficult to imagine doing galaxy research today without this service.

Relevancy strengths:

NED supports research using the full suite of NASA facilities (and more), thereby underlying both Origins and SEU themes.

Data accessibility:

Excellent.

Proposal weakness(es):

Despite the considerable value added to date by the NED staff in vetting the catalog matching of entries and filtering out the kinds of data blunders that can be damaging when propagated through further research results, the size of the new data sets dictate increasingly automated ingestion. We echo the previous Senior Review's concerns that the time has come for NED to move towards greater automation of data ingestion and object matching. Since even larger surveys are coming beyond SDSS and GALEX, NED can no longer avoid this issue.

Overall assessment and recommendations:

The Panel recognizes the great importance of NED to the astronomical community, and

considers its continued support essential. However, the upcoming “wall” of large survey results will not be a one-time problem, and handling these data in the way NED has traditionally done will be too labor-intensive. It is perhaps inevitable that individual users will need to assume an increasing burden in interpreting results derived from NED.

Our recommendation is to support hardware improvements in addition to the In-Guidelines program. As with the previous Senior Review, we encourage NED to invest more of its resources into automated methods of ingesting new survey data.

IRSA

The Infrared Science Archive (IRSA) is the NASA repository for IR and sub-mm data sets obtained by NASA's IR missions.

Science strengths:

IRSA provides access to 2MASS data, as well as IRAS, MSX, IRTS, and SWAS. Ultimately, the Spitzer data will be archived at IRSA.

Relevancy strengths:

IRSA's archiving efforts are enabling a large community of researchers to address the objectives of the Structure and Evolution of the Universe (SEU) theme and the Origins theme.

Data accessibility:

IRSA provides an extensive range of catalogs and images from IR surveys (IRAS, 2MASS, Spitzer). Data are updated regularly. IRSA provides excellent tools for visualizing the data (e.g. OASIS).

Proposal weakness(es):

External assessments of IRSA find very little interoperability with other data centers or even between different data sets housed at IRSA. This concern was previously raised in the 2000 Senior Review. Searches of current IRSA databases are slow.

The LAMBDA data center is chartered to serve CMB data to the US community, yet the IRSA proposal includes effort directed at serving the future Planck mission. Moreover, IRAS and SWAS data are being served from both data centers (IRSA & LAMBDA) with apparently little coordination concerning responsibilities.

Overall assessment and recommendations:

IRSA should sharpen its focus on relevant data archiving and improving interoperability. Accordingly, we find that the in-guide scenario should be supported, along with effort mentioned in the Baseline Scenario related to data tags and interoperability with other archives.

As a secondary but important priority, the astronomical community will be well served by an interoperable interface to all-sky maps that include the IRAS + MSX maps and the existing CMB maps. The data centers should coordinate their activities concerning the task of providing comprehensive access to archives related to diffuse emission, as well as archives related to discrete sources.

IRSA data may be very useful for Herschel and Planck planning. The costs for supporting these two missions should be covered from the mission budgets.

LAMBDA

The Legacy Archive for Microwave Background Data Analysis was established in 2002 in order to archive, serve and support data from NASA's Cosmic Microwave Background Radiation survey missions, together with the IRAS and SWAS data then held in the NSSDC Active Archive. Recognizing the particular importance of CMB data being served by people with knowledge of the instrument that took it, LAMBDA was co-located with COBE and particularly WMAP specialists at the Goddard Space Flight Center. Additional charges to LAMBDA were to provide a home for suborbital CMB data, relevant ancillary data, and tools to facilitate data manipulation. It is significant to note that at the time of LAMBDA's founding WMAP was a 2-year mission; the subsequent extension of the WMAP mission to 4 (and now potentially 8) years will clearly have a profound impact on LAMBDA.

Science strengths:

Despite the very short time between its founding and the release of the first year of WMAP data in February 2003, the LAMBDA archive opened on time with a website which enabled the rapid dissemination of this dataset, together with the critical associated tools and ancillary data products. The immediacy, efficacy, and scope of the WMAP data release was unprecedented in the CMB field, leading to the first paper with results derived from this dataset appearing within 36 hours.

As anticipated, the intimate relationship between LAMBDA and WMAP has enabled it to provide an effective distribution of, and informed responses to queries about, this dataset.

Relevancy strengths:

LAMBDA supports and enables science fundamental to both the SEU and Origins themes.

Data accessibility:

LAMBDA has fulfilled its mandate of making the CMB datasets and the tools to analyze them accessible to the community.

Proposal weakness(es):

Despite repeated recommendations from NASA's Science Archive Working Group, LAMBDA still has no Users Group. It is clear that the formation of such a group is, and

always has been, the intent of the Director, and that he faces extraordinary pressure of time as both an Archive Director and a key member of the WMAP team. However the continued absence 2 years on of a community-based advisory group, exacerbated by the archive's science staff all splitting their time between it and the same single CMB experiment, has deprived LAMBDA of a certain breadth in its perspective and priorities, which in turn has restricted its potential effectiveness as a general CMB archive.

The IRAS and SWAS data are currently being served (at least in part) by both LAMBDA and IRSA with minimal communication or coordination between them.

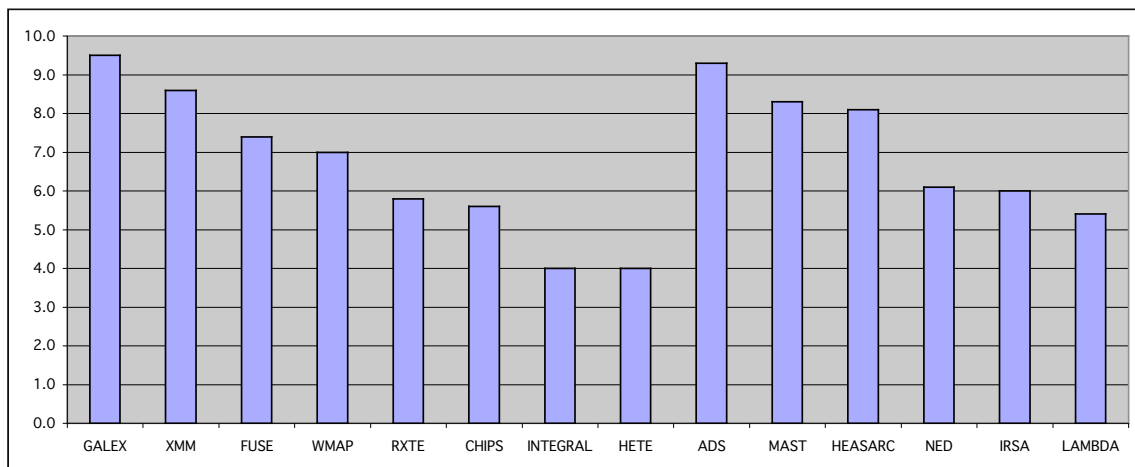
Overall assessment and recommendations:

We strongly recommend that LAMBDA establish a community-wide User Group as an immediate priority, to focus the archive's efforts to best serve the CMB community.

We recommend that LAMBDA continue to be funded at its current level, but that its staff FTEs in FY05 and beyond be more broadly assigned in consultation with this User Group.

We recommend that the dual archiving of IRAS and SWAS data be discontinued, with sole responsibility being passed to whichever of the two centers (LAMBDA and IRSA) is considered more appropriate in each case.

Senior Review 2004: Grades for Missions and Science/Data Services



Appendix A
Education and Public Outreach (E&PO) Assessments

GALEX

Strengths: Significant accomplishments to date and a number of specific items cited for FY05-FY06. Budget appears reasonable for the effort proposed – indicated to be around 2% of the annual budget. Strong partnership with SpacePlace. Has connection to underserved/underrepresented communities, with materials produced in both English and Spanish.

Weaknesses: SpacePlace targets lower grade levels, yet the mission science and multi-wavelength comparisons are better suited to middle and high school audiences. Lack of detailed budget information for individual E/PO elements. Participation of science team in the E/PO effort is unclear

Overall Comments: The program is encouraged to develop broader awareness of other Astronomy & Physics mission products and programs – look for synergy, connections, and cooperative possibilities. The SEU Forum may be able to provide assistance.

XMM-Newton

Strengths: The E/PO program is a quality one with a realistic scope. Effort appears to be appropriate to the level of the mission. There is a capable team in place at Sonoma State. The program appears to be developing effective partnerships with Learning Technologies and SpacePlace, allowing the program to reach large audiences.

Weaknesses: The budget request is summarized, but the details of the allocation (as well as the overall E/PO budget) do not appear to be provided in the proposal. Cannot determine the fraction of the total requested budget allocated to E/PO.

Overall Comments: There is a concern that the effort is becoming an insular, stand-alone program. There appears to be a lack of connectivity to the larger community of X-ray astronomers, X-ray E/PO efforts, and the science of other missions. The proposal does not provide evidence of a link to the SEU Education Forum or to other major X-ray mission efforts, e.g. Chandra. Enhanced connections and partnerships could provide enhanced mechanisms for dissemination, aside from conferences.

FUSE

Strengths: FUSE has been an active contributor to OSS E/PO efforts and requests support to continue a variety of E/PO efforts/ The overall suite of existing and proposed activities

encompass the full range of formal and informal education opportunities, including a formal education kit “Exploring the Universe: From the Classroom to Outer Space,” to involving a wider community of planetaria and museums through duplication of the MSC displays. FUSE scientists will partner with the Maryland Science Center to develop an Astronomy/Space Exhibit, provide ongoing support for a hands-on “SpaceLink” kiosk, and staff a booth for the MSC Space Day event and various other career day activities. Formal education kits were developed in partnership with education interns and have been tested in local (MD) schools. A large number of Web materials are in Spanish.

Weaknesses: A breakdown of the budgetary allocation for the FUSE E/PO coordinator and the various proposed activities was not provided. Information regarding the expertise and background of the E/PO coordinator were also not provided. The proposed enhanced cooperation with GI E/PO efforts should more fully and deliberately exploit the opportunity to more broadly disseminate FUSE E/PO resources on a national scale well beyond the inclusion of resources on a Web site.

Overall Comments: The FUSE E/PO effort presents a well thought out and logical program and implementation strategy that is well aligned with mission science and clearly demonstrates solid alignment with the Origins Forum. The weaknesses noted are relatively minor and primarily reflect the fact that the FUSE E/PO program commenced at an early stage in OSS E/PO evolution.

WMAP

Strengths: The E/PO efforts are tied in to the science of the mission. The team appears capable of carrying out the proposed program, based on their past experience. WMAP science results have been widely publicized in the media and the team has worked with the media and the informal education community to present their science to the lay public.

Weaknesses: There is not much detail in the proposed E/PO plan. For example, which education conferences do they plan to attend, and why? The media stories do not appear to be a part of a larger overall E/PO plan – in order to make the media stories accessible to educators, the E/PO team could make supporting materials available that could be used in classrooms. No evaluation efforts are discussed; evaluation is critical to measure the effectiveness of the programs. Popularity of a Web site does not necessarily indicate the ease of usability for formal or informal education audiences. If the team proposes to use the Web site as a major dissemination tool, they should have it evaluated professionally to determine its efficacy.

Overall Comments: There is an apparent disconnect between the WMAP and LAMBDA E/PO efforts.

RXTE

Strengths: This is overall a good quality program that primarily and appropriately targets middle school and higher audiences. The proposed activities are well aligned with the mission science and partnership with the HEASARC E/PO mission will leverage existing efforts and expand the program's reach. Details of the budget allocation and specific tasks are well described. The educators guide, movies, and other educational materials will be independently evaluated for classroom applicability by the DePaul University Broker/Facilitator teacher network (this is commendable). Materials will be adapted in accordance with recommendations and be incorporated into a workshop targeting a national educator audience in 2005 and 2006.

Weaknesses: While the student population of the Washington, DC metro area is identified as the targeted under-served community, specific strategies for addressing their unique educational needs are not presented. Dissemination of the movie, teacher guide and CD-ROM appears to be limited to teachers participating in the workshops. Have provisions been made for additional requests for materials beyond the immediate workshop participants?

Overall Comments: Overall the proposed E/PO effort presents a well rounded suite of formal products and programs as well as specifically identified informal events including an RXTE 10th Birthday Celebration. The E/PO is commended for targeting the unique needs and interests of students in the Washington, DC metro area.

CHIPS

Strengths: The prior efforts are well-connected to the scope of the mission, as are future efforts such as the development of an educational Web site and video. The E/PO team has demonstrated the ability to carry out the program and has good partnerships in place. The team is working with a professional evaluator to design and implement their evaluation plan.

Weaknesses: A small, focused educational Web site such as "Cosmic Recycling" is likely not the most effective way to disseminate CHIPS science. Providing a component to a more general site or the Forum site should be investigated as an alternative.

Overall Comments: The items listed under the proposal's Informal Education section are not informal education.

INTEGRAL

No plan or budget was presented for future E/PO, though INTEGRAL has contributed to the E/PO effort of the HEASARC in the past.

HETE

Strengths: The HETE team has had an active E/PO program during the lifetime of the mission comprising teacher workshops, development of materials for college-level introductory astronomy courses and involvement with the informal education community. The proposed professional development institutes for teachers to introduce them to the material and themes of the SEU program are appropriate activities. Prior experience with and evaluation of these programs should allow the HETE E/PO team to continually improve upon their workshops.

Weaknesses: It is not clear whether the E/PO products (videos, posters, postcards) were developed as educational materials (in response to a needs assessment) and with educator involvement, or if they were developed as marketing tools (which would not be considered an E/PO activity). Specific standard that can utilize this material are not discussed. There is also not much connection to the SEU Forum and their activities.

Overall Comments: The HETE E/PO team proposes to continue their ongoing efforts with additional teacher professional development workshops and ties with the amateur astronomy community. They have taken the time to develop their curriculum materials in advance and test them before running the first workshop, which is commendable. However, it would have been useful to present the syllabus with the proposal. Overall the program appears to be reasonable.

ADS

Due to the nature of the service, E/PO opportunities for ADS are limited, being mainly directed towards demonstrating the ADS at conferences, and attracting amateur astronomers. Non-scientists do not easily use the ADS, as the majority of the journals require a subscription and are at an advanced reading level. Before investing additional resources in advertising the ADS to amateurs and to teachers, it would be wise to consider a needs assessment. A small evaluation effort would provide input needed to understand the potential impact of the ADS with E/PO audiences and provide input needed to develop a small, focused, and appropriate E/PO program.

MAST

Strengths: MAST proposes to partner with the Office of Public Outreach at STScI to develop an E/PO program based on the science contained in the archival datasets. They plan to use MAST data to create new material for the Amazing Space modules usable in formal education settings. They also plan to develop tools and interfaces to allow use of the data in informal education settings such as museums. The presented budget is adequately detailed in portraying how the money will be allocated, and the MAST team

will work with the formal education team at OPO to develop their materials in accordance with the NSES.

Weaknesses: There is insufficient detail provided about the workshops to determine whether the budget is reasonable for what is being proposed. It is not clear if the proposers have obtained commitments from the OPO team.

Overall Comments: The proposed E/PO program is not presented with adequate details, which makes it difficult to do a thorough evaluation of the proposal. It is also not clear what the specific duties of the FTEs assigned to this project will be. Although there is some concern about the lack of details, it is likely that a good program will be developed and implemented given the expertise of the partner (the OPO at STScI).

HEASARC

Strengths: The HEASARC E/PO program provides SEU-themed curriculum support materials and training for K-14 educators. In this funding period, the HEASARC E/PO program will expand on its work, both with the Beyond Einstein initiative and the LHEA missions. This includes integrating content from these programs into the Imagine program. Student Hera brings HEASARC data to students, and will be completed and field-tested. Efforts to address underserved audiences are included. The program is a major commitment, with 15% of the budget dedicated to E/PO. This level of commitment recognizes the need for a critical mass and level of infrastructure to carry out effective and high-quality E/PO. It involves an appropriate mix of LHEA scientists, Goddard educators, and E/PO professionals,

Weaknesses: In developing workshops and materials on the electromagnetic spectrum, the program might wish to clarify their relationship to and explore the synergies with the wide range of existing materials and programs on the EM spectrum that are available through many OSS missions and Forums

Overall Comments: The infrastructure provided by HEASARC contributes to the success of many small mission E/PO efforts at Goddard. The 15% budget allocation is well beyond what is typically supported on a single-project E/PO budget, but this is needed to provide context and continuity for the large number of small missions and mission scientists operating out of LHEA. As such, this provides an important component of the overall SEU program. The program has been effective.

NED

The proposal appears to request ongoing funding to maintain the Web site. Web site maintenance does not constitute E/PO and therefore is not appropriate. Although the proposal acknowledges the high interest and potentially educationally valuable nature of NED, there is no evidence to support the involvement of a team member or partner with

sufficient expertise in the area of E/PO. The reviewers recommend that the team bring in an individual to assist with the creation of an educationally effective web product(s), or contact the OSS SEU Education Forum to identify opportunities to partner with other scientifically relevant missions for the creation of useful educational resources.

IRSA

Although IRSA has not requested support for an E/PO effort, it does provide content to support the E/PO activities of the IPAC and Spitzer E/PO programs. The proposers plan to contribute data and supporting images to create a new educational product entitled “Infrared Constellations,” an interactive IR sky map to be included as a component of the “Cool Cosmos” IRSA archives. However, no support for this was explicitly requested in the budget.

LAMBDA

The Director and staff are to be commended for their personal commitment to E/PO. However, no explicit request or plan for LAMBDA E/PO was presented. The LAMBDA E/PO program appears to consist primarily of linkages to COBE and WMAP. It is unclear that many other than knowledgeable professionals ever find the LAMBDA Web site, and hence the links to education are likely ineffective in communicating to the OSS E/PO target audiences.