2014 NASA Astrophysics Senior Review

March 31-April 3, 2014
Washington, D. C.

Panel:

Chair: Ben R. Oppenheimer (American Museum of Natural History)

Joel Bregman (University of Michigan)

Edward Guinan (Villanova University)

Martin Harwit (Cornell University)

Sebastian Heinz (University of Wisconsin—Madison)

Kenneth Johnston (U.S. Naval Observatory)

David Kieda (University of Utah)

H. Richard Miller (Georgia State University)

Richard Rothschild (University of California—San Diego)

David Sanders (University of Hawaii)

Final report delivered to
Program Officers: Jeffrey Hayes, Debra Wallace
Director, Astrophysics Division: Paul Hertz

Table of Contents

Introduction

Every two years NASA's Astrophysics Division is required by the NASA Authorization Act of 2005 to conduct a "Senior Review" to evaluate operating missions that have completed their prime operations through Phase E and are seeking to continue operations for augmentation of science returns on the initial investment. This is the highest-level peer-review process in the Astrophysics Division. Many spacecraft can continue to operate beyond the originally proposed mission duration and remain extremely valuable assets for fundamental science. Many such science goals will be impossible to achieve without extending missions, primarily because the spacecraft provide unique measurement capabilities, which are not planned to be conducted in future missions. The Senior Review Panel (hereafter SRP) is tasked with ranking the missions and recommending distribution of available funds from the Missions Operations and Data Analysis (MO&DA) budget line, primarily based on the expected value of the science returns for each mission. This year the SRP was asked to make recommendations on the fiscal years 2015 through 2018, with the last two years to be revisited by the 2016 SRP. The 2014 SRP was conducted somewhat differently from previous review panels. First, the flagship missions Hubble and Chandra were reviewed by separate committees, primarily because of their size and complexity and influences outside of the NASA Science Mission Directorate (SMD). Second, the mission teams were directed to set specific Prioritized Mission Objectives (PMOs) for the next two years, partly for review of progress by the 2016 SRP. Education and Public Outreach programs were not reviewed by the SRP, although they have been in previous SRPs.

Charge to the 2014 SRP:

1. In the context of the research objectives and focus areas described in the SMD Science Plan, rank the projects, reviewed during the period (FY15 through FY16) and the extended period (FY17 and FY18), on the scientific merit and expected scientific returns on the basis of NASA's "return on investment" for the requested funding in an era of limited resources.
2. Assess the cost efficiency, any ongoing technology development, data collection, archiving, distribution, mission and data usability, and the vitality of the mission's science team as secondary evaluation criteria.
3. Assess the current costs of the various missions under review.
4. Consider the scientific tradeoffs and opportunity costs involved in extending existing projects versus reducing or terminating them and using that funding for future flight opportunities, most especially in light of new Astrophysics missions expected to be launched.
5. Provide an overall assessment of the strength and ability of the MO&DA portfolio, including new missions expected to be launched, to meet the expectations of the Astrophysics Division priorities from FY15 through FY18, as represented in the 2010 SMD Science Plan and in the context of the recent 2010 Astrophysics Decadal Survey.
6. Based on the above criteria, provide findings to assist with an implementation strategy for Astrophysics Division MO&DA for FY15 through FY18, including an appropriate mix of:
    a. continuation of projects as currently baselined;
    b. continuation of projects with either enhancements or reductions to the current baseline;

c. for missions that have just completed Phase E: mission extension beyond the prime mission phase, subject to the "Mission Extension Paradigm" which typically involves in a funding level of roughly 2/3 of prime mission funding; and/or,
d. termination of projects.

The SRP was carefully formulated so that none of the people had any direct involvement with proposed missions that might constitute a conflict of interest. As such, all panel members reviewed all of the missions proposed and participated in all discussions and the writing of this report.

The missions reviewed by the 2014 SRP are:
Fermi, Kepler/K2, MaxWise, NuSTAR, Planck, Spitzer, Suzaku, Swift and XMM-Newton (in alphabetical order). Detailed descriptions of the science goals of the proposed extended missions are included in the consensus mission assessments, which constitute the latter part of this report.

Ranking Methodology

In the interests of fulfilling the part of our charge to rank the missions primarily on science and secondarily on cost, the SRP devised a procedure. For each mission, we evaluated the following:

Science Program
A. Uniqueness and overall strength of the science case
B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities
C. Synergy with other missions
D. Quality of archiving plans

Cost Elements
A. Cost efficiency in terms of meeting proposed goals
B. Adequacy of Science Support Program(s), including GO/GI elements or others

Responsiveness to NASA Senior Review Process
A. Assessment of meeting goals set or recommended in the 2012 Senior Review
B. Quality of PMO description and goals for the 2016 Senior Review

A summary of our findings for each mission is included in the individual Mission Assessments in the latter half of this report. All ten panelists were then instructed to complete a matrix (shown in Fig. 1) whereby each of these categories was given a rating from 1 to 10, with 10 the best rating. A weighted mean of each panelist's ratings for each mission was then calculated using the weighting factors shown in the yellow line at the bottom of Fig. 1. The weightings were unanimously agreed upon and were meant to reflect the priorities given in our charge along with a sense of the SRP that certain elements should be more important that others (such as Science A).

Mission	SciA	SciB	SciC	SciD	CostA	CostB	ResponseA	ResponseB	Wtd Mean
Swift									0.0
Spitzer									0.0
NuStar							na/		0.0
Fermi									0.0
XMM									0.0
Suzaku									0.0
Kepler/K2							n/a		0.0
Planck									0.0
MaxWISE							n/a		0.0
Weights	1.00	0.20	0.30	0.30	0.50	0.50	0.25	0.25	3.30

Fig. 1 Individual panelist's rating matrix. Each row corresponds to a mission and each column corresponds to one of the ranking criteria. In a few cases Response A was not relevant and the corresponding weighted mean was computed with a total weight of 3.05 instead of 3.30, to normalize the results to span the range of 1 to 10 for all missions.

After all panelists completed their rankings, they were sent to the two program managers who completed a calculation of the median and standard deviation of all ten weighted means for each mission. This method allowed for anonymity among the panelists in their ratings.

It is extremely important to note, at this point, that none of the proposals were considered substandard and frankly all had excellent science cases, with only a few minor exceptions in sub-projects proposed. In an ideal world the SRP would certainly recommend funding all of them based on the science cases presented, especially in light of the dearth of planned mid-scale and small missions on the near term horizon. Many of the reviewed missions were quite novel and exploited aspects of the spacecraft that allowed for truly new types of science. However, we were charged with ranking the proposed missions.

Ranking Results

The result of this initial ranking is shown in Fig. 2.

Mission	Median	Std
Swift	9.2	1.9
NuStar	8.8	1.2
XMM	8.4	2.4
Fermi	8.3	2.8
Kepler/K2	8.2	0.8
Spitzer	7.8	2.2
Suzaku	7.6	1.7
Planck	7.0	1.6
MaxWISE	6.8	2.1

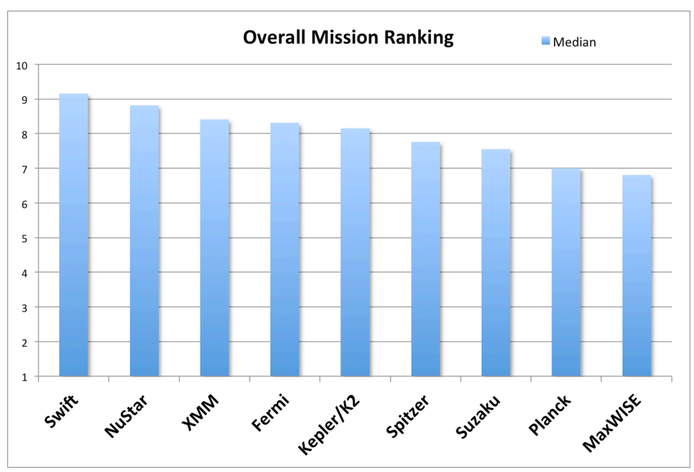

Fig. 2 Ranking Results

Discussion

The rankings provided in Fig. 2 are heavily weighted toward the scientific goals of proposed missions and, further, considered the costs on a mission-by-mission basis, without general regard for the overall budget of MO&DA. In addition due to a severely constrained budget, this SRP's recommendations are not strictly tied to the rankings above, because the SRP was charged also with maintaining a reasonable balance among the scientific goals that addresses as many of the Astro2010 science questions as possible. The SRP recognizes that this deviation from strictly applying the ranking metric above is slightly different from the conclusions of previous SRPs, but the reasoning has to be placed in the context of the actual funding climate at this point.

As currently understood by the SRP, the requests from operating missions decline roughly 10% per year over the next four fiscal years (partly due to efficiencies and partly due to some anticipated mission closings in FY17 and beyond). Indeed, by FY17 four missions are slated to end. However, the total budget available falls 23% in FY16 and another 43% from FY16 to FY17, resulting in nearly a 60% reduction from the FY15 levels. The SRP feels that operating missions already in flight is so important that unless substantial funding is located to fill these gaps, significant and lasting damage will be done to the US standing in astrophysics.

The SRP, thus, unanimously agreed that cost became a critical consideration in attempting to maintain a broad range of science in the Astrophysics portfolio of operating missions. In addition total requests for funding were more than $16 and $24M above what is notionally allocated in FY15 and 16. This necessitated extensive discussion of each mission's proposed costs and in nearly all cases significant reductions from the proposed "over-guide"[1] budgets for FY15 through 18. Furthermore, even after consensus on the various recommended cost distributions (presented in detail in the next section below), a considerable deficit exists, more than $6M in FY15 and more than $18M in FY16, rising to a $32M deficit in the MO&DA budget in FY17, but decreasing to $14M in FY18 (largely due to planned mission terminations). **The operation of the nation's space borne observatories is so severely impacted by the current funding climate in Washington that the SRP feels that American pre-eminence in the study of the Universe from space is threatened to the point of irreparable damage if additional funds cannot be found to fill the projected funding gaps.**

The SRP was also asked to recommend a path forward should no additional funds be found. Reluctantly the Panel did so.

Thus, our recommendations are given in two parts. One set assumes some funds could be located from elsewhere, but SRP's recommended allocations were made to make the total required budget as low as possible with minimal damage to the scientific programs. A second set of recommendations achieves a $0 deficit, in FY15 and 16, by making further cuts and recommending the end of a major mission. This recommendation, however, still results in a $17M deficit in FY17, when four of the reviewed mission will have been terminated, and a further deficit of about $1.5M in FY18.

Balancing the budget for FY15 and 16 was achieved not by strictly following the rankings. **The panel is unanimous in its sense that simply cutting missions from the bottom of**

[1] n.b. "over-guide" refers to budgets that exceed the nominal allocations budgeted previously, the "in-guide." This should not be interpreted as excessive requests by a mission, but rather that capabilities change and new ideas emerge on the time scale of the Senior Reviews, so assumed "in-guide" budgets may not reflect completely reasonable new costs and opportunities.

the ranking going up, purely based on the numbers in Fig. 2, would result in a heavily imbalanced science program and do enormous damage to the science capabilities of the Astrophysics Division.

When reviewing the MO&DA portfolio it was noted that the US investment in these currently flying missions is nearly $3B over the years, with significant additional investment by foreign partners. The fact that the available funding for FY15 and 16 is roughly 2.3% and 1.8% of that investment, seems to indicate, based on standard management practices (~10%), that MO&DA is substantially, even critically, underfunded.

Recommendations

The SRP recommendations in the next two subsections are explained in further detail in the Consensus Mission Assessments that follow this section. These recommendations should not be interpreted without considering the other materials in this report.

Case I: Assuming Additional Funding for MO&DA

Under this assumption no mission would end prematurely, but significant cuts to various missions are recommended in order to accommodate the broader range of science. This recommendation leads to a need to locate additional funds for MO&DA of roughly $6M, $18M, $32M and $14M in the fiscal years FY15, 16, 17, and 18, respectively, under current Notional Operating Allocations (NOAs). These recommendations also essentially follow the ranking established above.

Swift: As one of the highest rated missions, the SRP recommends implementation of the full over-guide request.

NuSTAR: In this case, the SRP recommends a significant reduction of the administrative costs of the Guest Observing (GO) program. In the proposal the GO program grants roughly 50% of the funds, with the rest going to administration. It is understood that there are initial costs in setting up a GO program, but the SRP felt these costs were too high. The size of the GO program (i.e. the grants made) should not be reduced.

XMM: XMM requested an expanded GO program. Given the success of this, the SRP feels that this augmentation is an excellent use of resources, but due to budget constraints, recommends a reduction from the full over-guide.

Fermi: Fermi continues to be one of the most expensive missions in the portfolio, but it is also extremely productive. The SRP recommends continuation of the Fermi extended mission through FY18, but at a modestly reduced funding level. We recommend that this funding reduction be accommodated through additional efficiency gains in Science Operations and Data Analysis, including strategic reduction in FTEs which preserves core LAT science. As discussed in the 2012 Senior review report, a reduction in FTEs is a natural result of a mission in extended phase. We expect some additional reductions beyond FY16 with the completion of the Pass 8 analysis and the release of the 5 year LAT source catalog. Additional cost savings can be achieved through a reduction in the average size of the GI award funding.

Kepler 2: Kepler 2 is recommended for full over-guide funding, for the closeout of the Kepler mission and the execution of the Kepler 2 mission.

Spitzer: Spitzer, formerly a Great Observatory, is operating at significant current cost and, given its proposed level of funding, it would be the most expensive of the missions reviewed, despite the fact that Spitzer's observational capabilities are significantly reduced since its prime mission. Given the budget situation, SRP could not recommend full over-guide funding. If the mission cannot operate with the recommended allocations, the Spitzer team should consult with Headquarters for a smooth termination of the mission.

Suzaku: This mission is an important connection to the soon to be launched joint JAXA/NASA mission Astro-H. While the SRP could not justify full over-guide funding, the mission is recommended for a significant, but low-cost, increase to accommodate a broader range of GO projects.

Planck: Planck requested additional funds to ensure that all final calibrations are carried out before this legacy mission ends, noting that the complexity of those calibrations was not fully appreciated until recently. The SRP recommends the current in-guide budget plus ~25% as well as new funds in FY16 to complete the work, however, this is a reduction from the requested over-guide.

MaxWISE: The SRP was concerned that the proposed transient detection program would yield little science considering how much it cost, but recommends full over-guide funding without the transient program (roughly half of the requested amount).

Case II: Assuming No Additional Funding for MO&DA

The SRP was unanimous in affirming the statement that this possible outcome represents serious damage to the astronomical community. However, in the interests of mitigating that damage, should this alternative be the only possibility, the SRP felt that ending one large mission was preferable to cutting every mission to the point where operations and science analysis would be crippled. These Case II recommendations result in complete compliance with the currently allocated funding (no deficit), except in FY17 and 18, which will be reviewed again in two years.

Swift: The SRP recommends current in-guide budgets for FY15 and 16, with a flat continuation adjusted for inflation in FY17 and 18.

NuSTAR: Same recommendation as Case I.

XMM: Same recommendation as Case I.

Fermi: SRP recommends an additional cut from the Case I recommendations of about 7%.

Kepler 2: Kepler 2 is recommended for an additional cut from the Case I recommendations of about 5% in FY15 and 16.

Spitzer: The SRP recommends current in-guide funding for mission termination in FY15.

Suzaku: Due to the low cost of this effort, SRP issues the same recommendation as Case I.

Planck: The SRP recommends the current in-guide budget as well as the same new funds in FY16 as in Case I.

MaxWISE: Same recommendation as Case I.

Consensus Mission Assessment: Swift

Summary of Science Program

Swift is the premier facility for multi-wavelength time domain astronomy in the world. Swift is the only mission capable of gamma ray burst detection and localization to arcsecond accuracies, and the tracking of afterglows in the optical to X-ray bands. From early BeppoSAX results on long bursts, and more recently from Swift, we have learned that long gamma ray bursts originate in supernovae of massive stars with jets interacting with the surrounding media, that these bursts occur in star forming regions, and thus high-z events probe early universe star formation. Short gamma bursts, on the other hand, are a current topic of interest with respect to possible NS-NS mergers. Follow-up observations of Swift-detected bursts have yielded extensive information on these stellar explosions, including indications of r-process material expelled into the interstellar medium.

Not all hard X-ray transients are gamma ray bursts, and Swift regularly discovers and monitors outbursts from a wide range of astrophysical objects, including known and newly discovered magnetars, black hole binary state changes, accreting X-ray binary system flares, and nova outbursts. Swift has also made and enabled major discoveries in other fields of astrophysics as diverse as millisecond pulsars, blazars, and tidal disruption events.

One of the great strengths of the Swift team is that they are constantly striving to improve mission performance with new operational and science initiatives and to interact with a wide variety of astrophysical science endeavors. Another strength is the manner in which the Swift team accepts almost all ToO requests, again demonstrating their support for all manner of science topics. No other mission approaches this broad-based synergy. The broad reach of Swift observations into a wide variety of astrophysical topics is very impressive, and will continue to be so.

A. Uniqueness and overall strength of the science case

As stated above, Swift is unique among all space missions in its capability to contribute to a vast array of time domain astronomy and spectral energy distribution topics. The satellite's rapid response, flexible scheduling, and ultraviolet to hard X-ray coverage is the reason so many other missions and investigations request Swift support. Past, current, and potential future Swift science investigations, exhibit exceptional breadth and importance. These include discovery of an anti-glitch in a magnetar which may indicate differential rotation within the neutron star, discovery of a new magnetar within 3" of Sgr A*, leading to a precise measurement of the integrated magnetic field, prompt observation of the brightest gamma ray burst in decades, which yielded multi-wavelength coverage that challenged current models of shocks in the jet for the afterglow emission, and a hard X-ray sky map containing over 150,000 sources, nearly 2.5 times the number detected by XMM-Newton. Continuing the Swift history of expanding its science capabilities, the Swift team has provided prioritized mission objectives that are challenging and at the forefront of astrophysical research.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

Swift addresses key priorities of the New Worlds, New Horizons Decadal Survey. Swift science is deeply involved in research pertaining to the first Scientific Objective in the main report, "Searching for the First Stars, Galaxies, and Black Holes", and the major scientific theme "Time Domain Astronomy". Swift directly addresses 2 of the 3 astrophysics imperatives in the 2010 SMD Science Plan: Discover How the Universe Works (gamma ray burst afterglows yield information about the supernova explosion leading to black hole formation), and Explore How the Universe Began and Developed into its Present Form (high redshift gamma ray bursts reveal star formation rates, UVOT observations of Type Ia SNe). Swift has begun a program to observe exoplanet transits in the ultraviolet, which relates to the third theme, Search for Earthlike Planets. Swift science also relates to the Enduring Quests, Daring Visions Roadmap in several areas. Stellar Life Cycles and Evolution of the Elements is addressed through studies of compact objects and their explosive origins at the end of stellar life, and enabling near-infrared observation of possible r-process products in short gamma ray burst afterglows. Archaeology of the Milky Way and its neighbors is addressed in the ongoing survey of the 400 nearest galaxies with UV and X-rays to characterize star formation and dust extinction, as well as generating a rich sample of X-ray binaries and ultra-luminous X-ray sources. Studies of compact objects and gamma ray bursts are part of "Revealing the Extremes of Nature".

C. Synergy with other missions

Synergy with other missions is possibly Swift's greatest strength. With its rapid repositioning, optical to hard X-ray coverage, and flexibility in scheduling, Swift accommodates the schedules of ground and space based observatories for simultaneous multi-wavelength observing. No other mission has this flexibility. Presently, all NuSTAR observations have enhanced scientific return due to a Swift kilosecond snapshot with each observation. Joint Swift-Chandra and Swift-XMM-Newton programs have become the norm. The prioritized mission objective #4 is to work with the new wide-field optical and radio transient surveys, thus demonstrating Swift's determination to work with all manner of other missions.

D. Quality of archive plans

The Swift and HEASARC teams have created and maintained an archive of the highest quality. The Swift data archive at the HEASARC has a long history of providing quality data products to the science community. In addition, suites of analysis tools are maintained and calibration databases updated in the archive. All data are public immediately and are included in the archive within about one week of the observations. Quick-look data for most observations are available on the Science Data Center website within hours and are removed when the full dataset is placed in the archive. Catalogs of sources seen in the three instruments are planned, and the BAT 70 month catalogs are available. A major reprocessing is underway and will be delivered to the HEASARC archive and comprise a catalog, maps and light curves and/or spectrum for individual sources. A catalog of 36,000 sources (excluding GRBs) found in over 35,000 XRT fields from the first 7 years of Swift operations (the 1SWXRT catalog) and a catalog of 151,524 sources detected in the first 8 years of operation (the 1SXPS catalog) have been generated.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

The Swift mission operates with about \$5M/year including \$1.2M going to guest investigators. With 21.2 FTE, that translates to \$200K/FTE, which is very reasonable. The Swift request assumes that Swift continues in "extended mission" mode through 2016, plans for continuing in a similar manner through 2018, and has no close-out costs assumed. The level of FTEs is the minimum needed to operate the mission with its flexible scheduling and addition of 2-3 ToO requests per day, and to rapidly pipeline the data into the archive. This is a very cost conscious operation. The overguide requests of $200K/yr 2015-2016 for rapid response and risk reduction programming, $200K/yr continuously for guest investigator support of new key project initiatives, and $40K/yr 2015-2016 to support reprocessing of BAT data to provide 12 energy channels instead of 8 (^{44}Ti searches would be enabled) are highly desirable.

B. Adequacy of Science Support Program(s), including GO/GI elements or others
The level of guest investigator support has been shown over the last few years to be adequate to provide the science analyses for many of the prime Swift science investigations. It will also be sufficient to address the new initiatives the project has identified.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review
The 2012 Senior Review reported only strengths and had no recommendations for Swift. In response, the Swift team chose goals for 2013-2014 to 1) develop automated tiling of 1 deg^2 areas to search for counterparts of Fermi LAT GRBs, MAXI triggers, IceCube neutrino candidates, and other missions' transients with similar localizations (Now routinely implemented); 2) reprocess the 70 month BAT survey data to generate a new BAT Hard X-ray Survey Catalog (published in APJS); 3) augment the BAT on-board catalog (added 350 nearby galaxies); 4) search for sub-threshold BAT triggers (typical lag time 1-8 hours); and 5) implement long-lived fluence BAT triggers (soon select appropriate trigger threshold and implement searches). They have been successful in meeting these self-imposed goals. The Swift team is to be commended for continuing to maximize the science from Swift with these efforts.

B. Quality of PMO description and goals for the 2016 Senior Review
The Swift team has condensed their science initiatives to emphasize the highest impact science Swift will conduct over the next 2 years utilizing the operational initiatives proposed. These four objectives are at the forefront of astrophysical research.

1. **Towards a "Smoking Gun" Short Gamma Ray Burst Progenitor**: Afterglows, redshifts and host galaxies of short gamma ray bursts will be derived from deep NIR observations of short gamma ray bursts. Some of these events may prove to be kilonovae with neutron rich ejecta left over from the NS-NS merger undergoing r-process nucleosynthesis. This would be strong direct evidence of the NS-NS merger scenario, and would be the type of event Advanced LIGO/VIRGO are designed to detect. Several operational initiatives are designed to support this.
2. **Probing the Epoch of Re-ionization:**
   Prompt NIR spectrograph observations of a Swift z>7 gamma ray burst would provide an unbiased view of star formation in the early universe, probing the galaxy luminosity function well below any competing technique with current instrumentation.
3. **Supernovae: Progenitors and Cosmological Utility:**
   Working with current and planned transient surveys, Swift will construct a sample of extensively monitored SNIae in the Hubble flow for current and future high-z Type Ia SNe surveys. The Swift result of two classes of SNe Ia based on UV colors will aid in

refining their use in cosmological studies.

4. **Serendipitous Time Domain Discoveries:**
   Unexpected discoveries can be the most exciting. Swift observations in conjunction with wide field transient surveys in the optical and radio may provide them. Again, some of the operational initiatives to be undertaken over the next 2 years will be made to support this objective.

Overall Assessment

Swift continues to provide unique and exciting science both as stand-alone results and as part of multi-wavelength campaigns. The multitude of science produced with Swift addresses many of the themes and objectives of NASA and Decadal Surveys. The spacecraft and instruments' performance has not degraded. The mission should be renewed for another 2 years, and extended into FY 17 and 18. Funding of the guest investigator program needs to remain at $1.2M per year. The in-guide funding is essential and if funding is available, the operational initiatives, key projects, and BAT reprocessing are strongly recommended for 2015 and 2016. The panel further recommends that Swift funding remain flat (taking inflation into account), minus the over-guide requests, in 2017 and 2018.

Consensus Mission Assessment: NuSTAR

Summary of Science Program

NuSTAR is the first imaging hard-X-ray telescope, covering the bandpass 3-79 keV. As such, it represents a unique asset in the NASA portfolio, slotting between Chandra and Fermi in energy. Launched in June 2012 as a SMEX mission, NuSTAR is on track to achieve all of its level 1 mission objectives. NuSTAR has enabled a wide range of new science not possible before, that aligns closely with the prioritization of compact objects and fundamental physics formulated in the Astro2010 "New Worlds, New Horizons" Decadal survey and NASA PCOS priorities.

The increasing rate of high-impact NuSTAR results during the second year of operations suggest that NuSTAR has barely scratched the surface of the science possible with a sensitive 10-80 keV imager. The large oversubscription of the NuSTAR time made available through joint XMM/NuSTAR observations in the most recent XMM call for proposals underscores the case for operating NuSTAR beyond its initial two year mission horizon and illustrates the need for a GO program.

The spacecraft is healthy and anticipated to be operational well beyond 2016. The ongoing operational difficulties of the primary Malindi ground station present a moderate risk for future cost overruns or reduced science return, should the use of secondary ground stations become necessary. This risk is within the acceptable margins for an extended mission.

Beyond a two-year horizon, the launch of the Hard X-ray Imager on Astro-H should provide performance that approaches the angular resolution capabilities of NuStar, albeit over a smaller field of view. The continuation of NuSTAR beyond 2016 should therefore be evaluated in light of the post-launch performance of Astro-H.

A. Uniqueness and overall strength of the science case

The science case for a two-year extension of the NuSTAR mission with a GO program is very strong. NuSTAR's ability to image the 3-80keV sky at sub-arcminute resolution has allowed an increase of two orders of magnitude in point sources sensitivity and made possible imaging observations of extended objects like young supernova remnants in a new bandpass previously inaccessible. No other such mission capability currently exists.

NuSTAR addresses fundamental scientific questions in the areas of strong gravity and the growth of structure that have been consistently identified as top priorities in the past three Decadal Surveys. For example, the ability of NuSTAR, in conjunction with XMM, to break degeneracies in black hole spin measurements present a significant step forward towards the goal of probing matter under the extreme conditions of strong gravity. NuSTAR's hard X-ray imaging capability has allowed measurement of the spatial distribution of radioactive ^{44}Ti in the Cas A supernova remnant, providing strong evidence for asymmetric collapse of the nuclear core. The complementarity between the NuSTAR energy range and Suzaku has recently allowed breaking of the degeneracy between low-energy x-ray absorption versus intensity of continuum emission in AGN through measurements of the Compton hump.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

NuSTAR, in combination with Chandra, Swift, XMM, and Fermi, directly addresses a number of core objectives identified in Astro2010 and NASA Astrophysics priorities.

NuSTAR's primary science objective, the study of high energy emission from compact objects and supernovae addresses directly the priorities of "Searching for the First Stars, Galaxies, and Black Holes" and "Physics of the Universe: Understanding Scientific Principles" of Astro2010, as well as core themes of NASA's PCOS program and 2010 SMD Science Plan: "Discover How the Universe Works" and "Explore How the Universe Began and Developed into its Present Form":

- Determining the cosmic growth history of black holes through observations of AGN
- Testing models of stellar collapse through supernova observations
- Testing strong gravity by precision measurements of black hole spin
- Constraining the internal structure and magnetic properties of neutron stars and finding new high energy transient sources
- Understanding the role of black holes in the formation of cosmic structure

C. Synergy with other missions

NuSTAR is synergistic with the other NASA X-ray missions currently operating. Its high-energy capabilities are best matched to the larger effective area of Chandra and especially XMM at energies below 6 keV. Currently, all NuSTAR observations are joint observations with SWIFT, and many NuSTAR observations are joint observations with XMM and Suzaku. NuSTAR has also been used for coordinated multi-wavelength campaigns of AGN using the Fermi Gamma-ray telescope in combination with ground-based optical, radio and TeV gamma-ray observatories (VERITAS, MAGIC, HESS, HAWC).

D. Quality of archive plans

All NuSTAR data will become public. Integration of the NuSTAR data and calibrations into HEASARC will make them widely available and allow seamless access by the community through the standard interface and secure maintenance of the database beyond the mission's lifetime. Integration of data analysis software into FTOOLS will assure continued maintenance and access to reduction tools, as has been the case for the entire suite of X-ray mission software currently integrated into FTOOLS over the past decades.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

NuSTAR is delivering high-impact science at a rapid rate. A two year extension represents are high return on investment, given the modest footprint of operations costs.

With a robust GI program, scientific productivity can be expected to increase further. While the GI program will constitute a substantial fraction of the overall budget, the programmatic gain from a competitive call for observing proposals and the increase in science productivity of a well funded community of guest investigators would be far preferable to keeping target selection and data analysis confined to the current science team.

Given the lean phase E operations budget of $6.2M/yr of the original NuSTAR mission, the proposed reduction by 26% to the operations level of $4.6M is unlikely to leave much room for significant further cost savings.

The requested 107% administrative overhead for the NuSTAR GO program is disappointingly high. Reductions in the overall funding of the NuSTAR GO program relative to the requested levels should come out of the administrative part of the budget, rather than the funding for guest investigators.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

Scientific research will be supported through GO grants. Additional funds will be available through synergistic observations with other NASA observatories with guest-investigator funding (Chandra, Fermi), as well as ADAP. The proposed level of $50k per investigator would be sufficient to support analysis and publication.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

N/A

B. Quality of PMO description and goals for the 2016 Senior Review

The proposal team did not specify a set of scientific PMOs against which a two-year extension could be measured. The prioritized mission objectives listed in the proposal are operational and can be paraphrased as:

- Image the so far largely un-explored sky from 10-80keV through continued operation of the spacecraft
- Develop a guest observer program
- Support analysis and science through guest observer funding

A reasonable set of three science priorities may be formulated based on the well-defined original mission objectives, given that only two years of observations have been completed and that further improvements and discoveries in these areas would represent significant advances:

- Probing the cosmic growth of black holes by resolving 50% of the 10-80 keV cosmic X-ray background and by observing a sample of obscured AGN
- Probing the nature of strong gravity and matter under extreme conditions by measuring black hole spin and observing neutron stars and high energy transient sources like blazars and X-ray binaries
- Probing supernova physics by measuring the intensity and distribution of ^{44}Ti in a sample of young supernova remnants

Overall Assessment

As the first imaging hard X-ray telescope, NuSTAR is a new and unique asset in the NASA portfolio, bringing a two order of magnitude increase in sensitivity to the 10-80 keV band. Its science objectives are aligned with top priorities identified by NASA and the Decadal survey. The mission should be continued beyond its initial two-year primary mission and should implement a funded guest observer program, but with a significant reduction of the administrative cost of the GO program.

Consensus Mission Assessment: XMM

Summary of Science Program

XMM has a robust science program providing cutting-edge science. XMM observes in the 0.2–12 keV and optical/UV bands. The observatory has three coaligned, high throughput, 7.5 m focal length X-ray telescopes with 6″ full width at half maximum (FWHM) angular resolution (15″ HPD). Three European Photon Imaging Camera (EPIC) charge-coupled device (CCD) detectors (PN, MOS1, and MOS2) provide X-ray imaging over a 30′ FOV with moderate energy resolution. XMM's imaging is complementary to Chandra's, having larger effective area, broader bandpass, and larger FOV but with lower angular resolution. Compared to Suzaku, XMM has larger effective area, larger field of view, and better angular resolution, but somewhat poorer energy resolution and higher background. The sixth instrument, the Optical Monitor (OM), is a co-aligned 30 cm optical/UV telescope sensitive in the 1600–6500A band with a 16′ FOV and a wide variety of operational modes and filters. This simultaneous optical/UV imaging and spectroscopy is a capability shared only by Swift. All of XMM's scientific instruments operate simultaneously, providing exceptionally rich data sets. All instruments can be run in a variety of modes, enabling them to be tuned for the scientific needs of specific investigations. There is no current mission, or any mission planned for launch in at least 15 years, which has XMM's combination of simultaneous high throughput X-ray imaging and spectroscopy, broad-band (X-ray, optical, and UV) capabilities, and ability to make long observations. It supports an annual peer reviewed Guest Investigator program that is heavily over subscribed. NASA only provides funding for the Guest Observer program. Mission operations support is provided by ESA. Typically U.S. GOs successfully compete for and receive ~30% of the observing time available on XMM. This is exceptionally good value for NASA's investment in this program.

A. Uniqueness and overall strength of the science case

XMM provides a wide-ranging science program. The results include (1) the solution of the cooling flow problem in clusters, (2) the detection of X-ray emission from brown dwarfs, (3) the detection of the first LMXB/MSP transition object, (4) the discovery of new types of novae and supernovae, (5) the study of relativistic Fe lines in NS, (6) the detection of first QPO in AGN, and (7) detection of the WHIM between two clusters of galaxies.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

XMM addresses the priorities of Astro2010 and the NASA Astrophysics Division priorities with the far-reaching science program summarized above. There is every reason to expect the mission to continue to operate without problems for the next ten years.

C. Synergy with other missions

XMM complements the X-ray capabilities of Suzaku, Chandra, NuSTAR and Swift. In addition, XMM has provided follow up observations of galaxy clusters detected in the Planck data. The Suzaku low-surface brightness studies of nearby clusters of galaxies, probing the distribution of baryons near the outermost boundaries of the virialized regions of clusters of galaxies leverage the constraints on point source contamination that can be obtained by much shorter (but higher spatial resolution) observations by XMM. Thus XMM provides a significant leveraging of the scientific return from a number of other missions.

D. Quality of archive plans

The XMM data center, together with the US GOF, has significantly improved the support for XMM data analysis, although the analysis of extended sources, requiring careful treatment of the background, remain difficult. Standard reprocessing and the addition of basic image and spectral production scripts make basic XMM analysis accessible to a broad range of users.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

ESA provides the operations costs for XMM. US guest observers are awarded ~30% of the time on the mission. The only cost to NASA is the cost of supporting the GOF and the GO program. This provides extraordinary return for the investment that NASA makes in this mission.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

The cost of the proposed GO program is reasonable but budget constraints limit the resources that may be available for this purpose.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

The previous Senior Review recommended requesting additional GO funding for this mission. This was included in their proposed program.

B. Quality of Prioritized Mission Opportunity (PMO) description and goals for the 2016 Senior Review

XMM provided a clear prioritization of its scientific goals, and the resources needed to accomplish those goals.

Overall Assessment

XMM is a highly capable mission in the class of the Great Observatories, offering science opportunities to the US community at low cost. It is an excellent example of a successful international mission and we greatly value the partnership with ESA. The highly competitive GO proposal process ensures that the observatory continues to do excellent science. It is the largest X-Ray telescope that is planned before 2028, and it is a unique capability that is important to preserve. The SRP recommends an extension XMM through 2016, and that NASA continue funding the US Guest Observer program at the proposed levels.

Consensus Mission Assessment:
The Fermi Gamma-ray Space Telescope

Summary of Science Program

The Fermi Gamma-Ray Space Telescope provides unparalleled capability for exploration of high-energy astrophysical phenomena. The Fermi telescope consists of two instruments: the Large Area Telescope (LAT), which employs a wide field-of-view pair conversion telescopes to observe gamma rays with energies between 20 MeV and > 300 GeV, and the Gamma-ray Burst Monitor (GBM), an array of NaI(Tl) and BGO scintillators which cover an energy range between 8 KeV and 40 MeV. The Fermi instrument is capable of performing observations in pointed mode or survey mode; in survey mode the LAT performs an all-sky survey in approximately 3 hours. Fermi was launched in June 2008, and commenced science operations in August 2008. Fermi was planned for a 10-year mission lifetime, and has no operational consumables. Fermi completed its 5-year prime phase in August 2013 and is currently being operated in its extended phase. Fermi is currently operating with no degradation in science performance since launch. Fermi operates a vigorous Guest Investigator program that supports both Fermi and multi-wavelength science investigations in conjunction with Fermi. The 2012 SRP recommended extension of operations through 2016 with a review of operations in 2014.

A. Uniqueness and overall strength of the science case

Fermi provides an exceptional combination of broad high-energy gamma-ray sensitivity, wide field of view, excellent angular resolution, and source monitoring capability on time scales ranging from 10 microseconds to years. This combination of capabilities has opened up a new window on the astrophysical universe in Time Domain Astronomy (TDA), and provided pathfinder capability for rapid follow-up by multi-wavelengths satellite and ground-based observatories.

Fermi's combined all-sky coverage and spectral energy resolution capabilities have enabled searches for indirect electromagnetic signatures of dark matter WIMP annihilation in the Galactic Center, Galactic Halo and in dwarf galaxies, providing the most stringent limits on the existence of GeV mass WIMPs in astrophysical settings. Fermi's all sky capability and imaging capabilities have also enabled detailed studies of particle acceleration over a wide range of length scales ranging from the terrestrial to the cosmological, including terrestrial gamma-ray flares, solar particle acceleration, compact objects and binary systems, supernova remnants, massive stellar clusters, the Fermi bubbles, starburst galaxies and active galactic nuclei, galaxy clusters, and gamma-ray bursts. Key discoveries since the last Senior Review include the observation of the record-breaking GRB of 2013 April 27, discovery of the new, unanticipated gamma-ray source class of emitters (Galactic novae), discovery of a new class of gamma-ray bright, radio quiet millisecond pulsars, including `black widow' pulsars, and discovery of pulsed emission from many pulsars extending beyond 25 GeV, strongly constraining the locations of high energy particle acceleration in pulsars. There has been additional major progress in characterizing the nature of cosmic ray acceleration in supernova remnants, observation of a correlation between gamma-ray luminosity and star-forming activity in starburst galaxies, and in the potential discovery of a spatially extended excess of 1-10 GeV gamma-rays coincident with the Galactic

Center. Investigators funded by the GI program led the majority of these science discoveries.

The science PMOs for the next two years focus on the continued exploration and development of Time Domain Astronomy, the search for electromagnetic signatures of astrophysical dark matter, and the exploration of particle acceleration mechanisms on a wide variation of astrophysical scales. The Fermi LAT team proposes to realize these science PMO through completion of the Pass 8 data analysis, which will provide a factor of 1.2-2x improved acceptance, a 30% improvement in point source sensitivity above 1 GeV, and reduction of the LAT data analysis threshold to 30 MeV. The Fermi LAT team will also release the five-year source catalog, and proposes to continue a new all-sky observation strategy that overexposes the Galactic center region by a factor of two while keeping all-sky survey coverage on a three-hour timescale. The Fermi GBM team proposes to increase the number of short GRBs detected to ~80/year through completion of the CTTE pipeline, and to implement further speed and event localizations in the GRB event reconstruction in order to improve success rate of multi-wavelength follow-up observations.

The science impact of the proposed PMOs is exceptionally strong. The mission extension will provide legacy-level data products (Fermi all-sky catalog, GRB catalog) from the instrument team combined with strong collaborative science contributions enabled by the successful GI program.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

The Fermi Observatory continues to carry out a mission that is strongly aligned with the 2010 Decadal Survey Report *New Worlds, New Horizons in Astronomy and Astrophysics*, as a concrete realization of the science discovery potential of Time Domain Astronomy, as a search for the first stars, galaxies and black holes, and as advancing understanding of the fundamental physics of the Universe. Fermi science investigations also directly address NASA's SMD 2010 Astrophysics Science Plan questions regarding the behavior of matter, energy, space, and time under extreme conditions, and the origin and evolution of the Universe.

C. Synergy with other missions

The Fermi mission is synergistic with the other NASA missions currently operating. Its unique high-energy capabilities have been used for coordinated multi-wavelength studies of compact objects, GRBs and AGN using X-ray telescopes (SWIFT, XMM-Newton, Chandra, Suzaku, and NuSTAR) and in combination with ground-based optical, radio and TeV gamma-ray observatories (VERITAS, MAGIC, HESS, and HAWC). Fermi AGN observations support ground-based radio observation programs and surveys (F-GAMMA, MOJAVE, IVRO and TANAMI). Fermi continuous all-sky map observations also support neutrino observations by ICECUBE, and upcoming GW observations by LIGO/VIRGO.

D. Quality of archive plans

All Fermi gamma-ray data are immediately made available to the public through the Fermi Science Support Center (FSSC) at GSFC, and through their Italian partner mirror site ASI-SDC. The archive plan is well documented through the Fermi Project Data Plan. The HEASARC provides the primary repository for high-level data, whereas NSSDC provides a repository for the Level 0 data. FSSC's database will conform to HEASARC standards both in architecture and format, employing the standard FITS file format with metadata that allows public access through non-proprietary formats (tables available through standard web-interfaces).

All Fermi Level 0 data is preserved both during and after the mission completion; Fermi MOC raw telemetry is preserved only during the operational phase of the mission.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

The Fermi in-guide budget is flat at $18.6M/year for 5 years under the extended mission profile. This level of support is running at approximately 73% of the prime phase budget. This budget reduction has been accomplished through a reduction in the GI program, a reduction in scientific staffing for the LAT diffuse modeling and data verification, and a ~1 year delay in the release of the Pass 8 data and the 5 year LAT source catalog. Additional impacts on the GBM instrument include a delay in the implementation of the sub-inflight threshold short GRB trigger, and a delay of corrections to the gain calibration and timing glitches in the Level 1 CTTE data.

The completion of the data reprocessing associated with the Pass 8 analysis, and the release of the 5-year catalog indicate the mission is entering into a mature operational phase. Personnel costs associated with observation scheduling, data analysis pipeline and data archiving activities are expected to decrease as the mission extends beyond 2015. Consequently, the SR recommends that Fermi develop a strategy to capture an increasing level of cost efficiency in the following fiscal years.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

The average Cycle 6 GI award is approximately $78k/year, which provides sufficient support to fund the full cost of a graduate student. While the SRP was supportive of this strong commitment to the GI program, the SRP is recommending the average GI support be reduced to $40-50k/year. This level of support will allow an increased amount of GI participation in Fermi science under the existing budget constraints, and it is more in line with other extended mission GI programs.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

The 2012 SRP recommended that the Fermi team develop and implement a plan for reduction of FTEs supporting instrument operations as the mission entered the extended phase. The SRP also recommended strong sustained support of the GI program. During the past two years the Fermi team has succeeded at reducing their operational budget by 27% while maintaining a strong GI program, according to Table 1 of the proposal. However, the identical table in the Fermi proposal for the 2012 SR indicated a substantially lower number of FTE during 2012 Fermi Prime phase compared to the same column in the 2014 SR proposal. Compared to the Fermi 2012 SR proposal, the Fermi team has met the expected FTE reduction for MO and for LAT activities, but has not met this goal for the GBM and FSSC.

B. Quality of PMO description and goals for the 2016 Senior Review

The proposal includes an excellent breakdown of both the operational and science PMOs. The operational PMO and goals for the 2016 Senior Review include the following:

- Complete the reprocessing of the entire LAT data set with Pass 8, thereby increasing detector acceptance, angular reconstruction, improving the energy resolution while decreasing the routine LAT analysis energy threshold to 30 MeV.
- Improve the rate of exposure gain at the Galactic Center region by a factor of two while maintaining the 3 hour all-sky survey mode.
- Increase the number of short-duration GRB to 80/year using the new CTTE pipeline.
- Improve the speed and accuracy of transient localizations to improve the success of multi-wavelength follow-up observations.

The science PMO and goals are not as explicit as the operational goals, because they are described as 4-year goals, and the GIs lead many of these science programs. However, progress on the following PMOs would be expected to be among the items to be reassessed by the 2016 Senior Review:

- Providing extended multi-wavelength monitoring of electromagnetic counterparts to initial GW observations by LIGO/VIRGO, and multi-wavelength campaigns on AGN, SNR and pulsars.
- Testing the possibility of high-energy emission by the passage of G2 by the Galactic center
- Resolution of the question regarding the existence of the apparent 130 GeV line signal near the Galactic center
- Resolution of the nature of the diffuse 1-10 GeV excess near the Galactic center.
- Publication of updated dark matter limits from stacked observations on dSph galaxies.
- Exploration of the structure and origin of the observed Fermi bubbles.

Overall Assessment

The Fermi Observatory is the only all-sky NASA GeV gamma-ray instrument in orbit, and consequently is a unique asset to the NASA portfolio. Its ability to survey the entire sky in 90 minutes has provided an important new capability in time domain astronomy, and has also led to new investigations in the particle nature of astrophysical dark matter. The Fermi GI program has been very successful, and has directly led to several important science discoveries. The SRP recommends continuation of the Fermi extended mission through FY18, but at a modestly reduced funding level. We recommend that this funding reduction be accommodated through additional efficiency gains in Science Operations and Data Analysis, including strategic reduction in FTE which preserves core LAT science. As discussed in the 2012 Senior Review report, a reduction in FTE is a natural result of a mission in extended phase. We expect some additional reductions beyond FY16 with the completion of the Pass 8 analysis and the release of the 5 year LAT source catalog. Additional cost savings can be achieved through a reduction in the average size of the GI award funding.

Consensus Mission Assessment: K2, Kepler Extended

Summary of Science Program

With the loss of the second reaction wheel of the Kepler Observatory, an innovative way of operating the observatory pointing along the ecliptic makes possible long-term high precision photometric observations of galactic and extragalactic sources as well as some solar system objects.

Kepler with its two remaining reaction wheels will point towards the ecliptic, sequentially observing a variety of well-characterized (and astrophysically interesting) celestial fields-of-view for intervals of about 68 days, allowing very high precision photometric monitoring across a wide range of galactic latitudes. This set of long time-series observations will use the proven Kepler Mission infrastructure to calibrate, and catalog the data into an archive. Recent demonstrations by the K2 Team have shown that the operational technique using only two reaction wheels for pointing control will result in a photometric precision of ~44 ppm in six hours.

A. Uniqueness and overall strength of the science case

This mission will obtain unique long-term, high-precision, time-series photometric data over a period of ≈75 days of tens of thousands objects in a single field of view of 100 sq. deg. With the planned nine fields along the ecliptic, the precise photometric characteristics over 100,000 objects can be acquired at levels of ~44 ppm permitting the K2 Mission to explore the astrophysics of the entire population of stars versus Kepler's objective of finding exoplanets in the habitable zones of mostly G and K dwarfs. K2 will allow exoplanet surveys of all stellar classes, O-M, giants-dwarfs, and white dwarfs as well as the asteroseismology of late stars, studies of nearby open clusters for the fundamental properties of pre-main sequence (PMS) and zero age main sequence (ZAMS) stars, and explore supernovae and accretion physics in AGNs. These are but a small sample of what can be achieved with the study of precise photometric long term continuous data.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

This mission is fully responsive to the Astro2010, SMD Roadmap and SMD priorities. The SMD roadmap objectives "Identification and Characterization of Nearby Exoplanets," and "Time Domain Astronomy" are addressed. For the three programs in SMD's Astrophysics Division it answers the following: Physics of the Cosmos: How does the universe work? AGN monitoring will indicate how galaxies evolve. Cosmic Origins: star formation and evolution and the formation of proto-planetary disks, Exoplanet Exploration: The characteristics of planetary systems orbiting other stars. In addition the program also contains some solar system objects that may be included in the proposed K2 fields. These could include fast moving objects such as asteroids as well as the 8th mag gaseous planet Neptune. Thus K2 has the promise of addressing all of the priorities of the SMD by its ability to study of order ~100,000 mostly stellar and extragalactic objects.

C. Synergy with other missions

The discovery space with the K2 mission is enormous and will initiate follow-up observations or simultaneous observations in all of the present missions supported by SMD such as HST, Chandra, Spitzer, and others.

D. Quality of archive plans

The K2 mission uses Kepler's mature operating procedures, proven software pipeline, methods, experienced personnel and archiving experience. The archive will contain a target catalog, calibrated focal plane pixels, time series target photometry and additional products such as diagnostics for validating individual events as planet candidates or false positives. The time series data will be delivered to the legacy archive hosted at the Mikulski Archive for Space Telescope (MAST; http://archice.stsci.edu/kepler).

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

The costs appear reasonable when compared with the Phase E cost for Kepler. The cost to cover the operation of the Kepler satellite, maintain the data reduction pipeline, calibrate the data products, foster community involvement, and maintain the source data analysis software, documentation and archive are reasonable.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

The science support program is excellent. This is a new mission in its infancy. The scientific community has been polled to determine the best plan of execution of the mission overall and the execution of the first two FOVs to be studied. A GO/GI program will be developed with the initial funding for the mission in FY15.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

N/A

B. Quality of PMO description and goals for the 2016 Senior Review

The PMO for this mission addresses fully the aspects of conducting the space operations by economizing fuel usage, maximizing the number of targets, collecting and returning calibrated photometric target data, providing community support via documentation. It also includes a GO program and diagnostics for validating archived lists of transit events for validation as planet candidates or false alarms. The science case for this proposal has been well described in the proposal. The mechanisms for its delivery are clearly provided in the PMO.

Overall Assessment

This is an outstanding mission and we look forward to the results from the program. K2 uniquely addresses a range of observational goals and is expected to engage a broad community of scientists. As it appears that there may be only enough fuel for a three year mission, this program should be reviewed at the next Senior Review for likely closeout in FY18.

Consensus Mission Assessment: Spitzer

Summary of Science Program

The post-cryogenic phase of the Spitzer Mission continues to provide unique and important scientific observing capabilities for pointed observations of the entire sky at two near-infrared wavelengths. Spitzer continues to support an extremely diverse and community driven suite of observing programs -- from exoplanets and brown dwarfs, to the highest redshift galaxies ($z > 7$). The availability of over 7000 hr/yr in support of peer reviewed observing programs, and the largest oversubscription (7:1 in C10) of any NASA mission in FY13-14, are testaments to the continued strong demand for Spitzer observations to carry out a suite of multi-wavelength science programs.

A. Uniqueness and overall strength of the science case

Unexpected improvements in photometric stability and sensitivity have driven the need for deep Spitzer NIR observations for studies of the nearby as well as distant universe, covering a very wide range of projects, from exoplanets to the highest redshift galaxies. The overall health of the observatory has also allowed a large and diverse suite of observations to be carried out by the astronomical community. Spitzer will continue to be the premiere observatory for identifying the true counterparts for the large population of far-infrared extragalactic sources being detected by the new sub-millimeter observatories (e.g. ALMA, SMA, ACT, …). Deep Spitzer observations will also be critical for the identification of the large population of heavily blended faint far-infrared sources that are now in the Herschel Archive.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

The Spitzer Mission has demonstrated its commitment to “New Worlds, New Horizons”, by continuing to provide new and unique capabilities in the NIR that are enabling unexpected science to be carried out, such as the composition and temperature of exoplanet and brown dwarf atmospheres, new high precision studies of the P-L relation for RR Lyrae stars, and precision photometry in the rest-frame optical that allows identification of the highest redshift galaxies (at $z > 7$) that can then be followed up immediately with sensitive spectrographs on the world’s largest telescopes.

C. Synergy with other missions

Spitzer continues to provide unparalleled access to the NIR (3.6, 4.5 micron) wavelength bands, and thus has strong synergies with major surveys being carried out with other NASA facilities. Spitzer is critical for the detection of rest-frame optical emission from high-redshift galaxies, and is currently our most sensitive probe of extragalactic sources at redshifts close to the epoch of re-ionization ($z > 7$). Spitzer has also proven to be crucial for identifying the correct counterparts for far-infrared sources detected by Herschel given Herschel’s relatively large beam and severe confusion problems that characterize all deep extragalactic surveys at wavelengths > 100 microns. Spitzer also continues to play a critical role in exoplanet and brown dwarf searches, where stable photometry and minimal viewing constraints are enabling the characterization of exoplanets as well as brown dwarf atmospheres.

D. Quality of archive plans

Accessibility to the current Spitzer archive continues to be excellent, and the quality of the archival data products is one of the strengths of the mission. Every effort should be made to continue past practices of insuring that all Spitzer archival data are of similar high quality.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

This proposal was somewhat unique in the current SR, and presented difficult challenges to the SRP. The cost of the Warm Spitzer Mission continues to be high and it is not clear that an adequate funding line is available in FY15,16 to meet the proposed over-guide funding scenarios. The SR continues to be impressed with the quality of the Spitzer data products and level of user support, but notes that the mission continues to defend the need for a relatively large core FTE team that may not be sustainable in the future due to the prospects of continued declining budgets.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

One of the major strengths of the Spitzer Mission is the quality of its GO/GI program and the impact of this program on enabling key science projects (large, medium and small) to be carried out by astronomers in a wide variety of fields (from exoplanets to high-z galaxies). The GO program produces high quality data products that are immediately usable by astronomers for their research, and provides fast response to solving any technical issues that may be encountered when attempting to achieve maximum sensitivity results from the data.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

Spitzer has continued to improve the performance of the spacecraft, which has allowed new science to be carried out in the post-2014 extended mission phase. The current unparalleled sensitivity in the mid-infrared (100 ηJy, 5σ in 100hrs @ 3.6μm) will not be approached until JWST. The large-scale, ultra-deep NIR survey capability will continue to be unmatched by any currently operating NASA mission, and will provide a critical database of sources for future follow-up studies by JWST.

B. Quality of PMO description and goals for the 2016 Senior Review

Spitzer is in excellent health and all technical requirements through 2016 have been demonstrated on the spacecraft. There appear to be no technical barriers to operating through 2018.

Overall Assessment

The Senior Review was impressed with the new high precision photometry capabilities that have been demonstrated by the project team and the new sensitivity limits that have enabled wide-field surveys of unprecedented depth that will not be approached until JWST. The health of the spacecraft and the quality of the GO/GI program also continue to be core strengths of the mission, and should not be compromised. However, the overall proposed cost of continuing the warm Spitzer mission continues to present difficult challenges to the SRP. The cost is particularly difficult in the context of an observatory with greatly reduced capabilities with respect to its prime mission. The mission also did not present substantial plans to reduce operations costs with such reduced capabilities. Given the budget climate, the SRP cannot recommend funding of Spitzer at the levels requested. Should the mission be unable to operate given the levels of funding recommended through FY18, the mission should plan, in consultation with NASA HQ, for termination.

Consensus Mission Assessment: Suzaku

Summary of Science Program

Suzaku is an X-ray astronomy mission that was built by the Institute of Space and Astronautical Science of Japan Aerospace Exploration Agency (ISAS/JAXA), in collaboration with the US (through GSFC and MIT; funded by NASA) and Japanese institutions. Launched in July 2005, it included an X-ray micro-calorimeter (X-ray Spectrometer; XRS), X-ray cameras with CCD detectors (X-ray Imaging Spectrometer; XIS), and a hard X-ray detector (HXD), which collectively covers the energy range 0.2-600 keV. Shortly after launch, the XRS failed, leaving two working instruments. The XIS originally contained four co-aligned telescopes, three with frontside illuminated CCDs (FI) and one with a backside illuminated CCD (BI), which is more sensitive at the softer energies. One of the frontside illuminated CCDs was damaged by a micrometeorite in 2006 and has not been used since for science operations. The XIS has a field of view of 18' with an angular resolution of 1.8'.

Current Spacecraft Health: Modest degradation has occurred for the CCDs, but they still retain good performance and have the highest spectral resolution of any X-ray camera in space. The hard X-ray detector continues to operate with little change, with significant improvement being realized in the gain calibration and background models in the past six years.

There was a significant loss of power generation in the last half of 2011, causing a battery undervoltage in early 2012. The problem is associated with a decrease in the output from the solar cells, causing a drain on the batteries when the spacecraft is in shadow. This difficulty was solved by turning off unnecessary devices and shifting some heating operations to occur primarily during the sunlit portion of the orbit. The telescope now operates normally and solar cell degradation returned to normal. It is expected that power will not need to be reduced before the end of 2016.

Suzaku is in low Earth orbit and the orbital altitude has decayed only 20 km in 8.5 years, so the orbit lifetime is at least 10 years from now.

A. Uniqueness and overall strength of the science case

In consideration of this issue, we consider the presence of other operating spacecraft in the same energy ranges as well as the upcoming launch of Astro-H.

Unlike *Chandra* and *XMM-Newton*, *Suzaku* is in a low-Earth orbit, which leads to a lower background in the 0.2-10 keV band. It has newer and better CCDs, providing improved spectral resolution and absolute energy calibration. The telescope has less collecting area at the soft energies (< 1 keV) than *XMM* (although comparable to *Chandra*) with 2-10 keV sensitivity between *Chandra* and *XMM*. *Suzaku* has poorer angular resolution (1.8') than *XMM* (15" HPD) or *Chandra* (1"). The HXD covers a very broad energy range (12-600 keV) but in the 10-80 keV range, NuSTAR has a very significant sensitivity advantage.

In late 2015, Astro-H will be launched into low-Earth orbit and it will contain a microcalorimeter, a wide field of view (38') CCD camera for soft X-ray studies, a hard X-ray telescope, and a soft gamma-ray detector. The calorimeter offers an entirely new capability. The soft X-ray imaging system, a single CCD system, has less collecting area than *Suzaku*, while the hard X-ray imagining system has more collecting area (at 30 keV).

There are research areas in which *Suzaku* has a technical advantage relative to other operating observatories, such as in the study of low surface brightness emission, which occurs in the outer parts of galaxy clusters, in the *Fermi* bubbles, or the study of emission from the hot Galactic ISM, to give three examples. The advantage in CCD spectral resolution has led to improved abundance measurements in SNR and the ISM as well as the separation of the Fe band in a variety of compact objects. It is a competitive instrument in many other scientific fields (e.g., AGNs, SMBHs) and has made broad contributions on a wide range of problems.

Suzaku has a very active guest investigator program, with an oversubscription by a factor of 3-4, despite the absence of research funding. By agreement, the US has access to 50% of the observing time during a year, partly through joint programs. There are about 40 observing programs led by US PIs and about 90 publications per year from the mission, with about 60 of them involving or led by US scientists.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

The *Suzaku* science is broad and contributes to a number of NASA Strategic Goals and a number of priorities identified in NWNH; there is strong overlap between the two sets of priorities. With regard to NWNH, *Suzaku* has contributed to the issues: "How do cosmic structures form and evolve?"; "What are the connections between dark and luminous matter?"; "What controls the mass, radius and spin of compact stellar remnants?"; "How do black holes grow, radiate, and influence their surroundings?"; and "What controls the mass-energy-chemical cycles within galaxies?" If *Suzaku* confirms the 3.5 keV line, seen by *XMM-Newton*, and thought to be from dark matter decay/annihilation, it will also make a major contribution to the issue "What is dark matter?".

A NASA Strategic Goal, reiterated in the 2010 NASA Science Plan, is to: "Discover how the universe works, explore how the universe began and developed into its present form, and search for Earth-like planets." The specific question to which *Suzaku* makes considerable contributions is: "How do matter, energy, space, and time behave under the extraordinarily diverse conditions of the cosmos?" and "How did the universe originate and evolve to produce the galaxies, stars, and planets we see today?"

C. Synergy with other missions

Like many space observatories, *Suzaku* cannot point to any location on the sky on demand, so it is limited in its ability to provide rapid follow-up in the time domain for most triggers. However, *Suzaku* provides significant synergy with other missions through improved wavelength coverage. Astrophysical objects that have a nonthermal component, such as AGN, GRBs, XRBs, or SNR, produce emission from a wide range of wavelengths. Such objects need multiple observatories to obtain the relevant data and *Suzaku* observations complement many space-based observatories as well as ground-based observatories. The observatories with the greatest synergies are other high-energy observatories.

D. Quality of archive plans

The data from *Suzaku* observations (and calibration files) are archived in the HEASARC, with a copy in Japan. Most of the data for individual programs have proprietary rights for 12 months, after which they become public. The data can be processed with standard X-ray software tools that are used for many other missions (HEAsoft and CALDB), providing a commonality. The data can be downloaded to local machines or analyzed on computers at the HEASARC using the HERA interface. There are few high-level products and no serendipitous source catalog. Such a catalog was envisioned for this mission but inadequate funding at the GOF has delayed its production to date.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

As a joint program, most of the data acquisition and basic data processing occur in Japan, with some tasks at GSFC, including delivery of the data to the GOs and the HEASARC. The in-guide budget ($0.3M/yr) is not adequate to fund the necessary GOF activities or to produce the XIS serendipitous source catalog. However, an overguide budget, shown during the presentation, funds the GOF activities adequately ($0.7M/yr) and can achieve their programmatic goals. This overguide budget is consistent with the 2012 Senior Review.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

The in-guide budget does not contain funding for science. The 2012 Senior Review recommended that GO funds be made available, and in their overguide budget, funding for guest observers is given at two possible levels. At the higher level ($1.2M/yr), funding is made available for only A category programs (not B or C category) at $50K for an ordinary program and $100K for large programs. At the lower level ($0.5M/yr), either fewer guest observers are supported or they are supported at a level likely to be inadequate.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

The 2012 Senior Review concluded that the *Suzaku* data center and the GO program were underfunded (a similar finding of the 2010 SR) and that the budget for the data center be raised to $0.7M and that GO program funds of about $1.0M be allocated, both annually. Unfortunately, budget pressures prevented this augmentation from being realized, and the data center is funded only at the $0.3M level, with no GO funding.

B. Quality of PMO description and goals for the 2016 Senior Review

The *Suzaku* mission has focused on the science themes that use its strengths relative to other X-ray missions. The themes include: the study of galaxy cluster properties at large radii extending to the virial radius; the use of the broad Fe lines to measure the spin of stellar mass and supermassive black holes; measurements of neutron star radii through the use of the Fe line; studies of the outflows from SMBH, especially regarding the energetics and composition; obtaining spectral energy distributions of AGN, that can reveal which are Compton-thick;

characterizing the X-ray properties of Galactic TeV sources; and studying the emission due to charge exchange from the Solar Wind, which affects all observations and is time-dependent. To facilitate reaching these goals, the mission introduced 10 key projects over the mission lifetime, three of which are currently active (2 US and 1 Japanese program). These large projects were suspended when battery issues arose, but now that those problems are resolved, the key projects were reinstated.

Overall Assessment

The *Suzaku* mission has produced excellent science and is a model of international cooperation in executing a successful mission. The mission continues to execute programs of high scientific value that address NWNH priorities even 10 years after launch by pursuing the areas where the technical advantages of *Suzaku* are fully exploited. NASA funding for the US GOF and the guest observers has been inadequate, which has limited the GOF in software development and the production of high level products, such as a serendipitous source catalog. We recommend augmentations for the GOF and for GO programs.

There is the desire to have *Suzaku* last through the first year of operation of *Astro-H*, for cross-calibration purposes. Although this is not essential for the success of *Astro-H*, it should facilitate calibration as these would be the only two telescopes with soft X-ray telescopes in low Earth orbit, so they share similar background properties. We recommend that *Suzaku* be carried through 2016 (or approximately 1 year after *Astro-H* becomes operational), but after that time, the need to maintain *Suzaku* becomes weaker. This corresponds in time to a degradation of the solar cells that might become problematic for continued spacecraft operation.

Consensus Mission Assessment: Planck

Summary of Science Program

Planck is the first space mission promising to reveal the history of the Universe all the way back to the dawn of time when the age of the Universe was of the order of 10^{-35} seconds. It thus begins to answer age-old questions that generations of humans have been asking over past millennia: Where and how did the Universe begin? What were the forces at work? Where, ultimately, do we come from? The past few months have indicated that Planck may well take us as far back in time as current theory permits. We are unlikely to venture back any further until the nature of quantum gravity is understood. The mission's findings may well become one of the great landmarks in human history.

A. Uniqueness and overall strength of the science case

Although most of the results that Planck is delivering are entirely unique, the South Pole telescope has recently measured the so-called "B polarization patterns" that Planck is now about to unveil over much larger regions of the sky and thus with considerably greater insight and certainty. Differences in the assumptions inherent to the two sets of observations may then be settled and lead to a unified view.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

The recommendations of the 2010 Decadal Review and the astrophysical priorities of NASA could not have predicted that Planck would meet or exceed expectations as significantly as the mission's recent findings now demonstrate.

C. Synergy with other missions

Astrophysics incorporates many sub-disciplines ranging from Solar System studies, to investigations of star and galaxy evolution, the expansion of the Universe, and the origins of some of the largest cosmic structures we observe. Each of these areas of study will be affected in one way or another by Planck's findings. The expansion rate of the Universe is now far more firmly known, as are the motions of clusters of galaxies relative to each other. Aspects of astrophysics involving neutrino species are also being affected by the mission's findings.

D. Quality of archive plans

The data to be archived by Planck are expected to be far more complete than any assembled in the history of astronomy to date. This measure of completeness has come at a cost --- a level of expenditure carefully considered and judged essential because once the Planck mission officially ends, those archives will become the sole repository of all knowledge the mission has revealed. Those who conducted the mission will ultimately disperse, their corporate memory will gradually wane, but the archives they compiled will remain available to all as the final authority on Planck's findings.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

Planck has been a very complex mission, requiring exquisite calibrations. The mission team has worked with laudable dedication and skill. The SRP, however, was unable to determine whether the tasks identified for FY15 and FY16 would to lead to an insignificant or a significant improvement in the data analysis already planned and budgeted for. Given this indeterminacy more resources are recommended to continue working on the data.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

This mission included no GO/GI program. Its complexity required long-term dedication that cannot be guaranteed by a more flexible GO/GI approach.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review

Given a number of changes agreed on by ESA and NASA since the 2012 Senior Review, the Planck mission has been conducted with satisfactory fidelity to the goals set by the review.

B. Quality of PMO description and goals for the 2016 Senior Review

The Planck Mission is expected to have ended by the time the 2016 Review convenes.

Overall Assessment

Planck, more than any other mission assessed by the current Senior Review, requires extreme attention to systematics and detail. The mission promises to yield a definitive new understanding of the early history of the Universe, as well as its subsequent evolution --- topics that will affect all areas of astrophysics in fundamental if subtle ways. The results the mission will yield will not be improved on in the foreseeable future. As the mission approaches its culmination it is essential to provide the critically required funding to enable Planck to assure an orderly completion of its work. Even with current budgetary constraints on NASA's astrophysics program it is important to recognize the unique significance of this mission and to ensure the most accurate final results.

Consensus Mission Assessment: MaxWISE

Summary of Science Program

Science Background: In 2010 during the first six months of operation the Wide-field Infrared Survey Explorer (WISE) carried out an all-sky survey in four band passes from 3.4 - 22 μm. After completing its primary mission and exhausting its coolant another ~6 months of science operations were completed in the two lower band passes. After this in early 2011, WISE was placed into hibernation with major data releases provided in 2012 and 2013. However in October 2013 NASA's Planetary Division reactivated the satellite (now a warm mission with only the 3.4um and 4.6um band passes available) with the goal of discovering and characterizing the expected thousands of Near-Earth Objects (NEOs) over a planned three-year mission. The reactivated mission has been dubbed NEOWISE-Reactivation (NEOWISE-R) and the spacecraft has been operating nominally since that time. This proposal exploits this new opportunity to combine, characterize and release the full datasets from both WISE and NEOWISE-R and apply these data to several very exciting astrophysics problems. This endeavor is dubbed MaxWISE.

The three additional years of the 3.4um and 4.6um IR all-sky survey data will cover the sky six more times and quadruple the existing number of exposures to a minimum of 96 per position over the entire sky. When these data are combined, fainter limiting IR magnitudes are reached opening the window to new discovery space. Multiple visits to the same sky locations also permit the IR variability of the targets to be assessed and characterized. Also, extending the time baseline to six years will permit proper motions and parallaxes of nearby (< 20 pc) very cool red and brown dwarfs to be measured. With these data MaxWISE will address all three of the primary objectives given in the *New Worlds, New Horizons Astro2010 Decadal Survey (NWNH):* Physics of the Cosmos, Origins and Exoplanets.

1. The resulting proper motions and parallax measures for the nearest sources (< 20 pc) will permit the discovery of the stars and brown dwarfs closest to the Sun. This will also result in a greatly improved census of the yet undiscovered, nearby cool brown dwarf and the coolest red dwarf star populations. This aspect (via high proper motions) is also sensitive to discovering many high velocity cool Pop II red dwarf objects.
2. The planned program should discover most of the Main Belt asteroids with sizes of >3 km.
3. Multiple visits to the same sky locations will obtain IR light curves of important classes of variable stars such as RR Lyr, Cepheids and Miras. The observations with MaxWISE will help define the slopes of the Period-Luminosity relations of RR Lyr and Cepheids. The multiyear MaxWISE photometry of these important distance indicator stars could lead to an improvement in the extragalactic distance scale and even the Hubble Constant (H_0). Also these time-series measures should identify many transient IR-light events from optically obscured novae, super-luminous supernovae and outbursts from Young Stellar Objects (YSOs) such as FU Ori variables.
4. A transient detection and alerts program is proposed: Single frame processing will be used, and alerts will be issued to allow rapid follow-up of mid-IR transients that could arise from optically obscured YSOs, Novae, and SNe.

5. The Study of Massive Distant (Early)/Luminous Galaxies: The increased total exposure times (by stacking the additional six exposures) will reach fainter brightness limits that will permit the detection of distant galaxies, AGN and young galaxy clusters out to z~2.0. The identified early luminous massive galaxy clusters will be excellent targets for JWST follow-up studies and to probe the era when major changes in their star formation properties were taking place.

A. Uniqueness and overall strength of the science case

The extension of the program in time will permit the discovery of the expected tens of thousands of nearby cool brown dwarfs and faint low mass stars from their space motions and parallaxes. Most of these objects will be too cool for Gaia parallaxes. The longer time baseline also permits the exploration of the dynamic mid-IR sky and discovery and characterization of cosmically important variable stars such as RR Lyr and Cepeheids that could improve the extragalactic distance scale. The planned science program also yields vital information about AGN, galaxies, and galaxy clusters back to z~2.0. These data are important for JWST and WFIRST.

B. Responsiveness to the Astro2010 and NASA Astrophysics Division priorities

MaxWISE will address all three of the primary objectives given in the Astro2010 Decadal Survey: Physics of the Cosmos, Origins and Exoplanets. The mission fits extremely well with the NASA Astrophysics Division goals and priorities.

C. Synergy with other missions

The proposed extended IR (3.4um and 4.6um) all-sky survey products from MaxWISE provide an excellent imaging and source catalog for JWST as well as interesting targets for Spitzer. MaxWISE will identify nearby brown dwarfs (that could host planets) as well as massive distant galaxies and galaxy clusters. These are astrophysically important targets for follow-up deeper exposures with Spitzer. The identification and characterization of distant luminous galaxy clusters out to z~2 will be valuable to the Euclid and WFIRST missions for investigations of dark energy.

D. Quality of archive plans

The proposers have a great deal of expertise and experience in collecting and archiving large data sets from their prior work on the WISE mission. These prior data sets were released on time and without problems. The same personel are responsible for the planned data archiving and releases for the MaxWISE mission.

Cost Elements

A. Cost efficiency in terms of meeting proposed goals

NASA's Planetary Division funds the reactivation and operations of the MaxWISE mission. This makes the cost to the Astrophysics Division very low for the interesting science proposed. The MaxWise mission is thus leveraged by a major investment from Planetary Science that covers three years of mission operations and single frame processing used in the NEOWISE-R discovery program.

B. Adequacy of Science Support Program(s), including GO/GI elements or others

The support of the science program is very sound. The program has no GO/GI elements, and a large team of experts produces the analysis and publication of the science.

Responsiveness to NASA Senior Review Process

A. Assessment of meeting goals set or recommended in the 2012 Senior Review
N/A. The program was not previously reviewed in the 2012 Senior Review

B. Quality of PMO description and goals for the 2016 Senior Review
The PMOs map to Astrophysics Science Objectives as addressed in the proposal and are very clear and informative. Three PMO options are provided.

PMO-1: Phase 1 data processing with the first data release in March 2016 in which they co-add prior WISE data from 2010 and the first two epochs of NEOWISE Reactivation data. This is for one year and costs $2.4M (1 year).

PMO-2: Phase 2 data processing with the second data release in February 2018. They plan to co-add the two epoch WISE datasets from 2010 and all six epochs of NEOWISE Reactivation data as well as proper motion and parallax fits. MaxWISE includes 8 sky coverages expected to contain ~160 billion source measurements.

PMO-3: Transient Source Detection and Alerting is planned to start in February 2015 and the Transient/Variable Star Database will be released in the second data release.

Overall Assessment

MaxWISE is considered by the SR panel as a scientifically strong and compelling program that should be supported. Due to the synergy with NEOWISE, operated by the Planetary Science Division, the data are being taken anyway, so for a modest input of funds, the data can be combined with existing data for a much deeper science, as well as producing entirely new information − proper motion and parallax of cool nearby bodies. SRP deemed that the production of the proposed data set would lead to valuable science, so the cost was mostly justified. However, the extra cost of supporting the PMO-3 Transient Source Detection and Alerting program is not justified and not supported by the SR panel.