Implementing Portals to the Universe
Best Practices for NASA Science Operations Centers
STScI, 25 April 2012

A consensus report submitted to the Astrophysics Division, NASA HQ
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1. Introduction/Context

In 2007, NASA requested that the National Research Council of the National Academies of Sciences carry out a study of NASA astronomy science centers. The study was chartered to conduct a comparative review of current science centers; identify best practices and lessons learned; and assess whether there are optimum sizes or approaches for science centers. The study focused on six science centers: the Chandra X-ray Center, the Michelson Science Center, the Rossi X-ray Timing Explorer mission guest observer facility, the Space Telescope Science Institute, the Spitzer Science Center, and the X-ray Multimirror Mission-Newton guest observer facility.

The results of the study were published as the NRC report "Portals to the Universe: The NASA Astronomy Science Centers". The report executive summary includes three findings and makes three recommendations, as follows:

Findings:

- The Chandra X-ray Center, the Space Telescope Science Institute, the High Energy Astrophysics Science Archive Research Center, and the Infrared Processing and Analysis Center have sufficient scientific and programmatic expertise to manage NASA's current science center responsibilities after the active phases of all current and planned space-based astronomy missions have been completed.
- The ability of the Chandra X-ray Center, the Space Telescope Science Institute, the High Energy Astrophysics Science Archive Research Center, and the Infrared Processing and Analysis Center to provide the appropriate level of support to the scientific community depends critically on the extent to which they can attract, retain, and effectively deploy individuals with the mix of research and engineering skills necessary to maintain continuity of service.
- Embedding GOFs (Guest Observer Facilities) in existing science centers, such as the HEASARC, provides for efficient user support, especially when the scope of a space mission does not require establishing a separate center.

Recommendations:

1. NASA should establish a large new center only when the following criteria are met: (1) the existing centers lack the capacity to support a major new scientific initiative and (2)

there is an imminent need to develop a new infrastructure to support a broad base of users.

2. NASA should adopt a set of best practices as guiding principles to ensure the effectiveness of existing flagship and archival NASA astronomy science centers and to select the operational functions of any future centers.
3. NASA should ensure that NASA astronomy science centers cooperate among themselves and with other agencies to develop strategies and plans for
    - Developing common protocols and formats for proposal entry;
    - Developing a universal infrastructure for data formats and metadata, archiving, and retrieval and analysis tools; and
    - Providing curriculum materials and professional development programs for K-12 teachers.

2. Workshop purpose and format

The 2012 workshop was commissioned by the SMD Astrophysics Division to assess progress in addressing recommendations made in 2007 "Portals to the Universe" report. In particular, the meeting gave a forum for current missions to highlight areas or tasks that are well supported at their respective science centers, enabling the compilation of a consensus set of best practices for current and future NASA missions. In addition, the meeting provided an opportunity for centers to provide direct feedback to Headquarters on policy issues. The meeting charter is included as Appendix I.

The workshop participants included representatives from missions and science centers that span a range of scale and operational lifetimes. All of the missions run Guest Observer (GO) programs, where observing time is allocated based on peer review of proposals solicited from the astronomical community. HST and Chandra are mature Great Observatories that continue to operate with a full complement of instruments; Spitzer is a Great Observatory that has transitioned from the prime mission to an extended warm mission; SOFIA is a similarly-scaled mission that is currently entering its prime phase, with the additional complexities of scheduling aircraft operations; Kepler is a Discovery-class mission that is currently transitioning from a Principal Investigator-led mission to a community-driven mission; NExScI serves as a Kepler data center and coordinates the peer review process for NASA-allocated observing time on the ground-based Keck and Large Binocular Telescopes; Herschel is an ESA-led mission where NASA is a minority partner but the US-based community has a significant involvement supported by the NASA Herschel Science Center (NHSC) at the Infrared Processing and Analysis Center (IPAC); Swift is an Explorer-class mission focused on detection of high-energy transient events.

The workshop agenda is given in Appendix II. The initial presentations made by each mission summarized the current status and highlighted areas where useful experience has been gained for planning and executing future missions. The latter topics were the focus of the second half of the workshop, with the discussion led by individual mission representatives. Participating in those discussions were representatives from the James Webb Space Telescope and the Fermi Gamma-Ray Space Telescope, in addition to members of the Headquarters Astrophysics Division. The full list of attendees is given in Appendix III. Individual presentations are available and can be downloaded from http://www.stsci.edu/~inr/portals.html . The present report summarizes the main conclusions arising from the workshop.

3. Best Practices for Science Operations Center

Broad consensus was reached in many areas on the best practices that should be adopted by NASA astronomy science centers, as summarized qualitatively in this section. It should be recognized that the level of implementation of individual recommendations must depend on the resources available to a given mission.

3.1 General topics

- **The primary goal of a NASA Science Operations Center is maximizing the scientific return of a mission for the user community.** Maintaining the health and safety of the facility is a crucial part of this goal.

- **An active research staff is an essential component of an astronomy center in all phases of a mission.** Research staff members play a vital role during the development phase, ensuring that instruments and operations are designed to optimize the scientific performance. In the operational phase, the research staff interacts with and represents the user community, and has a vested interest in maximizing the scientific capabilities and overall productivity of the mission. An active research staff is crucial to maintaining scientific vitality as a mission evolves. During closeout, research staff members optimize the data products for archival science. Finally, research time provides an incentive to attract and retain high quality staff to support and maximize the science return from NASA missions.

- **Missions should be thought through from inception to closeout.** Some missions can be expected to undergo transitions in the course of their lifetime, either in their operational capabilities (e.g. the Spitzer transition to a warm mission, with the loss of cryogen) or operational modes (e.g. Kepler's transition from a PI-led to a community-focused mission). Those transitions should be considered carefully as early as possible, so that systems and processes can be designed with the transition in mind, and to ensure that both science center staff and the community at large are aware of the implications. Actively engaging staff is important in preserving mission vitality and maximizing the science return throughout the full course of the mission.

- **Missions should develop a model that illustrates the impact of reduced resources in terms of reduced scientific productivity.** The model should provide clear trades in support versus productivity (e.g. on-sky science time, instrument modes), and define funding levels where

1. the science return from a mission begins to drop sharply with further funding reduction (e.g. a 5% funding reductions results in a 20% drop in scientific productivity);
2. the science productivity drops to a level where the science return per dollar makes the mission no longer viable.

- **Joint planning for international missions should start as early as possible.** Partners should play an integrated role in defining, implementing and supporting all processes from mission definition and support through proposal selection to archival support.

3.2 Proposal Processes

- **All observing time should be allocated through well-defined, verifiable processes. Peer review should be used wherever possible.**

- **NASA astronomy missions should provide proposal submission mechanisms that are simple to use and accessible to the broadest community.** Most current missions use independent standalone tools (e.g. Astronomer's Proposal Tool for HST, SPOT for Spitzer) or web-based tools (e.g. RPS for Chandra, ARK/RPS for Swift). Some missions use a two-phase submission procedure to reduce the initial workload on proposers (Phase I submissions focus on scientific justification).

- **NASA astronomy missions should coordinate their proposal schedules to minimize interference.** Proposers and review panelists for different missions are drawn from the same pool, the astronomical community. As far as possible, current missions collaborate to develop schedules that maintain a minimum of 2 weeks between proposal submission deadlines and between time allocation committee meetings.

- **Time allocation processes should have clear procedures for identifying and dealing with conflicts of interest on the part of members of the review panel, and for maintaining confidentiality of the proposal materials.** In most missions, direct conflicts are usually dealt with by employing multiple panels that cover similar subject areas; proposals that involve participating reviewers can be assessed by an unconflicted panel. Panelists subject to any residual conflicts do not vote on those proposals. All participants sign non-disclosure forms to protect the confidentiality of submitted proposal materials.

- **Time allocation processes should have clear procedures for identifying and dealing with conflicts of interest on the part of the astronomy center staff members who are responsible for conducting the review.** In larger centers, firewalls can be put in place to ensure that staff members who submit proposals are not involved in selection or oversight of panelists that will review those proposals. This is not possible in small centers, where 1-2 staff members are responsible for the time allocation process; those staff members are precluded from proposing for time and therefore cannot be involved in research with the facility that they are supporting. Small centers might consider collaboration with other centers/missions to bring in additional personnel, allowing research staff to compete for time on the mission they support. If that option is not available, an alternative would be to allow center research staff to submit proposals for Director's Discretionary time that can be reviewed through a separate process.

- **Community funding is an important tool in increasing the scientific productivity of a mission.** Mission-related funding allows successful proposers to better exploit the scientific potential of their datasets without introducing the double jeopardy of a separate data-analysis funding proposal process. Grants and fixed-cost, advance funded contracts generally provide a more efficient mechanism than complex cost-reimbursable contracts. Centers that are restricted from issuing contracts should create simplified funding instruments for issuing data analysis funding.

- **Consensus favored funding levels set through a formula, although the potential advantages of budget review by committee were also noted.** A funding formula can be applied simply and rapidly; requires less resources from the science center; but may not support the required analysis effort in all cases. A review committee can tailor the funding to match the analysis effort, allowing for specific costs; provides external validation of the work level; but requires more resources and the process takes longer to complete. A formulaic approach is likely to be appropriate for smaller missions and can also be used successfully for larger missions. In some cases, operating missions have used a hybrid system, applying a base-level formula while allowing scope for requests for supplementary funding. In other cases, one or the other approach has been used for different calls on the same mission, depending on the programmatic context, e.g. Key projects vs. regular Guest Observer programs.

3.3 Operational Processes

- **Science input is crucial at all levels.** Research scientists should be embedded members of all design, development and operational teams. All research staff should be assigned specific functions; all functions should be associated with specific research staff.

- **Mission operation concepts and instruments should be developed together, rather than consecutively or independently.** This enables greater interaction between development and operations team members, and can minimize unnecessary differences in operating modes for missions with multiple instruments.

- **Integrate Science Center and Instrument Team staff at the earliest opportunity.** Science center staff will be responsible for instrument support after launch. Early integration maximizes the probability of a smooth transition from development to operation.

- **Missions should implement an initial core set of observing modes that cover the basic science.** This can lead to reduced cost of instrument development and testing, streamlined pipeline development and enable a well-defined, reliably-executed calibration program. Non-standard observations can be handled in engineering mode, at least initially. Additional observing modes can be offered to observers as the mission evolves and as budget circumstances permit.

- **In developing data processing pipelines, missions should collaborate with each other and with the community to make use of tested products and expertise. However, all missions have unique characteristics and will require at least some unique software tools.**

- **Develop planning tools that allow observers to share the workload in preparing observing programs.** Exposure time calculators and prescribed observing modes allow observers to specify observing sequences that can be built into an optimized schedule by science center staff. Non-standard observations require more collaboration between observers and science center staff.

- **Ensure good communications between science operations and mission operations teams.** Co-location can make this easier, but distributed operations can also be very successful if integrated planning processes are established early and maintained through the mission. Good communication on mission progress and achievements is a key step in ensuring that all personnel are engaged in supporting the overall mission goal.

3.4 Support for observers

- **Science Centers require in-house expertise on all aspects of the mission.** Active research scientists who use the observatory are an effective resource in responding to community questions and concerns.

- **User support systems need to be in place 2-3 years before launch and need to evolve and innovate as the mission evolves.** Maximizing the scientific impact requires a well-educated community that can rapidly take advantage of the capabilities offered by a new mission. Data challenges provide an effective mechanism for training the community to deal with real data. Exposure Time Calculators allow the community to explore the potential capabilities of a mission well before launch, since telescope time on orbit is extremely valuable and irreplaceable. Proposal planning workshops held prior to the first and second proposal calls help the community write better proposals and take full advantages of new facilities.

- **Data reduction software should be ready and fully tested by launch.** Systems should be beta-tested by Science Center and external research scientists.

- **Documentation should be readily available through multiple access points.** Science Centers should provide web access to handbooks, calls for proposals, instrument reports, and other documentation. Web pages/threads can be devoted to specific topics of interest.

- **Science Centers should provide at least Level 1 pipeline processed data products for the community.** Level 1 data are calibrated in physical units and have instrumental signatures removed but, depending on the instrument, may require additional processing to be science ready. Access to enhanced processing tools and higher level science products, such as those provided by Legacy/Treasury programs, is also desirable. Experience has shown that higher level science products (e.g. source lists, image mosaics) generated by large programs or by ancillary data processing tools are most utilized by the community, and contribute significantly to the overall impact of NASA missions.

- **Helpdesks continue to provide an important means of addressing specific individual questions, particularly with regard to proposal preparation and data analysis.** Clear protocols should be in place to route questions to the appropriate (single point) reference source for missions with multiple access paths. Web-based tools, such as links to sites with FAQs (Frequently Asked Questions) or wikis that provide a forum for community members to share information, can supplement traditional helpdesks.

3.5 Community Interactions

- **The infrastructure for supporting community interactions needs to be in place before "first light".** Maximising the scientific impact requires a well-educated community that can rapidly take advantage of the capabilities offered by a new mission.

- **"Hands-on" training workshops, analyzing real data, provide an important mechanism for educating the community. In addition,** webinars and other web-based fora provide important mechanisms for broadening community access to information on tools and techniques for data analysis.

- **Regular meetings with user committees provide a direct link with the community. The committee membership should be selected to give appropriate representation of the external community.** User committees can advise missions on their current performance and serve as a sounding board for potential innovations. More focused groups can be convened, if necessary, to provide community input on specific (technical) issues. High-level advisory committees can also serve in the important role of providing strategic advice early on in the development of missions and during periods of transition.

- **Science conferences remain an important forum for engaging directly with the user community.** Locally-hosted conferences can bring the community into contact with a broad cross section of science center staff, and highlight mission-specific scientific capabilities; science center booths or town halls at national conferences, such as AAS meetings, bring the missions to the broader community.

- **Science Centers need to take advantage of modern media resources.** Web pages can serve as repositories for documentation, mechanisms for community feedback and a means of engaging the public through Citizen Science programs. Social media (e-mail, twitter, facebook, blogs, YouTube) can supplement more traditional newsletters (paper and electronic) in disseminating press releases and news updates from NASA missions.

3.6 Archival Support

- **The data archive should be an integral part of mission planning.** Archives should not be afterthoughts. The interface with the permanent archive (parameters archive, data formats, naming conventions) should be defined before launch. A permanent archive should be used during the mission, rather than placing data in an interim archive.

- **Archives should provide rapid access to verified, science-ready data.** Archives should provide open access to non-proprietary datasets. Archives should incorporate calibration data, metadata and telemetry data that are relevant for scientific programs. Developing tools that make it easier to browse the available data (e.g. footprints, interactive image displays) can greatly increase the scientific utility of archives.

- **Users should be provided with tools for reproducing processed datasets from low-level data.** As the mission evolves, opportunities will arise to reprocess data using new calibration information and to combine datasets collected by different programs and/or different instruments. Archives may provide on-site computer resources for large-scale data processing. Alternatively, the mission should plan on reprocessing all data when calibration, reduction algorithms and artifact mitigation are well understood.

- **High-level data products have the highest impact, and missions should provide support to the community for their production.** Such products include: mosaic image datasets; flux-calibrated multi-instrument spectral datasets; source lists with calibrated astrometric, flux and morphological parameters; and target lists with cross-mission source identification.

- **Data processing techniques generally evolve throughout the course of a mission as science centers acquire greater understanding of detectors and instruments. Planning should explicitly include a final data re-processing**

during closeout to ensure that permanent archives include data products of the highest quality and integrity for long-term use by the community.

3.7 Policy Issues

- **NASA should explore additional options for enabling scientists employed at its centers to participate in reviews, user committees and working groups.** NASA scientists can provide valuable insight on a wide range of issues that affect the scientific utilization of missions and facilities. Greater participation can both strengthen those review processes and provide valuable experience for the scientists.

- **Appropriate resources should be allocated to smaller missions to enable complete data re-processing at the mission's end, and to produce the final archive data products.**

- **Science Centers should set appropriate security constraints on access to software and software products.** NASA software requirements and FISMA interpretation vary from center to center. Security concerns need to be taken seriously, but undue restrictions can result in serious obstacles to public data dissemination and significant reduction in mission scientific productivity.

4. Summary

NASA missions and astronomy centers have collaborated and shared experiences extensively in past years, primarily in a bilateral fashion. This workshop provided a forum for exchange of information spanning a broad range of operational issues among multiple astronomy centers. The meeting showed that there are many areas where missions have converged on similar methods of addressing specific issues, but also highlighted other areas where missions differ in their approach. As such, it proved a valuable learning opportunity for all attendees. The remaining diversity in approach reflects the complexity of some issues, and the richness of potential solution space. The ability to experiment with different approaches is itself a valuable learning opportunity.

Maintaining good communications between the various astronomy centers is extremely important and continues at many levels, from individuals contacting their counterparts at other centers to tap experience in key areas to more formal site visits by one or more personnel to learn about particular aspects of mission operations and user support. Astronomy center staff members also serve on Users' Panels, review panels and other forms of oversight or advisory committees for other missions. Future multi-mission workshops, perhaps at ~2 year intervals, can supplement those ongoing activities and provide further opportunities for broad information exchange and cross-fertilization among NASA's active missions.

Appendix I

Implementing Portals of the Universe

Charter: 4/12/2012

In 2007, the National Research Council completed a thorough comparative review of NASA astronomy centers, assessing the roles and services that they provide to the community. The conclusions from that review are summarized in the NRC publication "Portals of the Universe". These include recommendations that NASA should adopt a set of best practices as guiding principles to ensure the effectiveness of existing astronomy science centers, and that NASA should ensure that science centers should cooperate among themselves and with other agencies to develop strategies and plans. The purpose of this workshop is to provide a forum to understand the current processes used by various astrophysics science centers and identify the current best practices candidates in a report to the Astrophysics Division.

The participants in this workshop will include representatives from the Chandra X-ray Center, the Spitzer Science Center, the Infrared Processing and Analysis Center, the NASA Exoplanet Science Institute, Space Telescope Science Institute, Goddard Space Flight Center (SWIFT mission), NASA-Ames (Kepler), and the SOFIA Science Center. Each center will be asked to report on their process for each of the following areas and what they consider works well or not and why:

- Proposal process
    - Schedules and coordination with other observatories (ground and space)
    - Submission tools and proposal format
    - Evaluation processes
    - Grant administration and budget processes
- Community interaction
    - User committee
    - Newsletters and Technical Reports
- User support
    - Documentation needs prior to proposal submission
    - User query support/helpdesk
    - Direct support during observations
    - Post-observation support for data reduction and analysis
    - User committee
- Operational processes
    - Observation planning and scheduling
    - Instrument calibration
- Archival support
    - Data Storage
    - Long-term data curation

In additional, each participant will be asked to identify issues they may have with Astrophysics science policy issues and suggestions for improvements. In particular,

- Duplication policies
- Data Access restrictions
- Complaint processes

The workshop will be held at the Space Telescope Science Institute, Baltimore, in Spring 2012. It will last 1 day. It is anticipated that 2-4 representatives from each science center will attend the workshop in person, and the meeting will be webcast in a manner to allow interactive participation by scientists at remote locations. Remote attendees will be asked to register in advance of the workshop.

The meeting format will comprise a series of 30-45 minute presentations by a representative from each science center, followed by a 30 minutes period for further discussion. A final session will be scheduled for developing the final products of the workshop:

1. A document giving feedback on NASA policies that are constraining operation and may require modification. 3 topics were mentioned: proprietary time; processes for awarding DD time (which probably falls under the proposal process discussion); and guaranteed time for science centers.
2. A best practices document, to be used as a guide for establishing future science operation centers. The NRC Portal report gives high level guidance; this document will focus more on implementation. Contrasts between large and small missions should be drawn, where appropriate. There may also be differences stemming from operational modes: surveys vs GO-dominated missions; collaborative missions with other agencies vs NASA-only missions; multi-user vs PI-led missions.

At the end of the workshop, an oral briefing will be presented to the Astrophysics Division and a written presentation provided to the Astrophysics Division within one month after the workshop.

The presentations, report to the Astrophysics Division, and the webcast will be archived at STScI and made available to the broader community, with links established at the appropriate NASA SMD web pages.

Appendix II
Implementing Portals of the Universe
STScI, April 25 2012

Agenda

8.45 Welcome	Matt Mountain, STScI
8:50 Introduction and context	Paul Hertz, NASA HQ

Recommended best practices

9.00 Chandra	Belinda Wilkes, Roger Brissenden, CXC
9:20 Herschel	George Helou, IPAC
9:40 Hubble	Brad Whitmore, STScI
10:00 Kepler	Martin Still, NASA Ames
10:20 Break	
10:40 NExScI	Chas Beichman, NExSci
11:00 SOFIA	Erick Young, Sofia Science Center
11:20 Spitzer	Lisa Storrie-Lombardi, Spitzer Science Center
11:40 SWIFT	Frank Marshall, GSFC
12:00 Discussion	
12:30 Lunch	

Discussion topics

13:30 Proposal Processes	led by Brad Whitmore
14:00 Community Interaction	Martin Still
14:30 User Support	Belinda Wilkes
15:00 Break	
15:15 Operational Processes	Lisa Storrie-Lombardi
15:45 Archival Support	Frank Marshall
16:15 Policy Issues	Chas Beichman
16:45 Discussion	
17:15 An initial summary	Neill Reid, STScI

Appendix III

Workshop Participants

In person attendance:

Missions & Science Centers

Chandra X-ray Center: Roger Brissenden, Belinda Wilkes
Fermi Gamma-Ray Space Telescope, GSFC: Elizabeth Hays, Chris Schrader
Hubble Space Telescope, STScI: Ken Sembach, Brad Whitmore
HST Project, GSFC: Patricia Boyd, Kevin Hartnett
James Webb Space Telescope, STScI: Massimo Stiavelli, Jason Kalirai
Kepler mission, NASA-Ames: Martin Still
NASA Exoplanets Science Institute: Rachel Akeson, Charles Beichmann, Dawn Gelino
SOFIA Science Center, NASA-Ames: Erick Young, B.-G. Andersson, Pam Marcum, Hans Zinnecker
Space Telescope Science Institute: Matt Mountain, Neill Reid
Spitzer Science Center: Lisa Storrie-Lombardi, Mike Werner (JPL)
Swift, GSFC: Frank Marshall

NASA Headquarters

Paul Hertz, Director, Astrophysics Division
Michael Moore, Deputy Director (Acting), Astrophysics Division
Lia La Piana,
Jaya Bajpayee, Christopher Davis, John Gagosian, Richard Griffiths, Hashima Hasan, Mario Perez, Wilt Sanders, Glenn Wahlgren, Eddie Zavala

Remote attendance:

Missions & Science Centers

HST Project, GSFC: Jennifer Wiseman

NASA Headquarters

Ilana Harrus, Lisa Wainio