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Assessment of NASA's Space Science Research and Analysis Programs

Foreword

The research and analysis (R&A) portion of NASA's space science program consists of ~40 discipline programs for instrumentation, suborbital flights, theory, simulation, data analysis and laboratory research addressing Sun-Earth Connection, Solar System Exploration, Astronomical Search for Origins, and Structure and Evolution of the Universe.

In 1997, the formal advisory committee for NASA's Office of Space Science (OSS), the "Space Science Advisory Committee", formed a Task Group to address structural aspects of the OSS R&A programs. Among its recommendations (July 1998; http://spacescience.nasa.gov/adv/minutes.htm) was a call for an independent outside assessment of the performance of the R&A programs. In 1998, the National Research Council's Space Studies Board published a set of recommendations for "Supporting Research and Data Analysis (R&DA) in NASA's Science Programs" (http://www.nas.edu/ssb/rapmenu.htm). This report, which addressed NASA's Space, Earth and Life and Microgravity Sciences, recommended that NASA should "…regularly evaluate the impact of R&DA on progress toward the goals of the strategic plans…", and "…regularly evaluate the balance among various sub-elements of the R&DA program." All of these recommendations point to the need for an assessment of both the merits of the Space Science R&A programs and their relevance to the goals of the OSS Strategic Plan (http://spacescience.nasa.gov/strategy/2000/index.html).

Since mid-1999 it has been my responsibility to establish an R&A Senior Review process by working with the Discipline Scientists in the Research Division, others in OSS, the formal advisory committees, the outside working groups and science writing teams which supported the Discipline Scientists, and finally the R&A Senior Review panel. As part of the preparations for this independent outside assessment, the ~40 research sub-disciplines were grouped into 11 research "clusters". The contents and budget plan for these R&A clusters for Fiscal Year 2002 are:

Space Science Research Clusters	FY02 Budget
1A and 1B: Cross-Theme Theory and Data Analysis Programs (Mellott; Golombek)	
Space Physics Theory	$ 4 M
ATP-Astrophysics Theory Program	$ 7 M
2: Solar and Heliospheric Sciences (Wagner, Guhathakurta, Jones and Ling)	$ 11 M
Heliospheric Physics SR&T	
Solar Physics SR&T and suborbital programs	
Solar Rocket	
3: Geospace (Ionosphere, Thermosphere, Mesosphere, Magnetosphere (Mellott and Sharber)	$ 12 M
Magnetospheric Physics	

ITM
Plasma Rocket – suborbital program

4: Origin and Evolution of Solar System Bodies (Boyce and Grant)	$ 38 M
Cosmochemistry (from Astrogeochemistry perspective)	
PG&G - Planetary Geology&Geophysics	
Origins of Solar Systems (incl. Cosmochemistry, Observations and Theory)	
MDAP - Mars Data Analysis Program	
5: Planetary Systems Science (Bergstralh, Beebe and Morgan)	$ 19 M
Planetary Astronomy	
Planetary Atmospheres	
Planetary Suborbital Program	
6A and 6B: Exobiology and Planetary Instrumentation (Meyer and Betts)	
Exobiology	$ 9 M
PIDDP; PIUP	$ 7 M
7: Space Astrophysics/ASO (Hasan, Crane, and Stringfellow)	$ 16 M
IR/Radio Astronomy incl. Instrumentation, laboratory and suborbital	
UV, Visible and Gravitational Astrophysics incl. Instrumentation, lab and suborbital	
8: High Energy Astrophysics (Kaluziensky, Kniffen, and Jones)	$ 16 M
High Energy R&A incl. Instrumentation, laboratory and suborbital	
Cosmic Ray Balloon	
Low Cost Balloon	
Cosmic Ray Physics Experimental SR&T	
9: Information Systems	$ 10 M
Applied Information System Research	

This assessment report contains the conclusions of the R&A Senior Review committee from its meeting in Washington, DC on June 12-14, 2001.

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Assessment of NASA's Space Science Research and Analysis Programs

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Introduction

The R & A Senior Review Committee received a report from each of the 11 program clusters in May 2001. The charge to the Committee consisted of 4 questions:

- **Merit and Relevance:** What is the science quality and productivity of each science cluster, and to what degree does each cluster support or enable the strategic goals and objectives of the Space Science Enterprise?
- **Budget Distribution:** Judging by the priorities in the SSE strategic plan, is the current funding distribution across the nine science clusters the optimum, or would the Panel recommend changes?
- **R&A Program Structure:** Is the current science cluster structure optimal for attaining the long-term strategic goals of the Office of Space Science?
- **New Initiatives or Augmentations:** What are the highest-priority new initiatives or augmentations in space science R&A?

Overall Recommendations

Merit and Relevance

- The Committee is impressed with the uniformly high quality of the R & A reports.
- The Committee finds that the OSS R & A program is essential to realizing the full potential of flight missions and to defining the imperatives for new flight programs. The R & A programs provide the universal context for the flight program.

Augmentations to the R&A Program

- The individual R & A cluster programs are oversubscribed by substantial factors; investigator turnover is good but individual grants have decreased in size or the total focus of each program has narrowed. During the last decade, the OSS program content has increased but the R&A program has been flat funded.
- The R & A program should be augmented to provide the proper level of science support for utilizing the results of missions and preparing for future missions. An additional or special augmentation should be targeted towards science areas where mission activity has increased.

Structure of R&A Program

- The Committee notes that the current reorganization of OSS provides an opportunity to streamline the organization of the R & A clusters and to make them consistent across the science divisions.
- The Committee recommends that the clusters be restructured such that the program content is uniform amongst them. The current “clustering” is very non-uniform, some including DA and some not, some including instrument development and some not, and some including theory and some not.
- The Committee endorses the concept in the recent Astronomy & Astrophysics Decadal report of including directly-related theory with data analysis in mission line MO & DA. Consideration should be given to including directly related laboratory work, fieldwork, and ground-based observations.

Structure of Reviews

- We recommend that all R & A elements should be included (e.g. Astrobiology and LWS R & A programs) in the next review cycle.
- Future R&A reviews require a better description of the DA programs.

Recommendations for Augmentations and New Initiatives

Recommendations on Changes in the Budget Distribution

One of the questions to the review Committee was "Judging by the priorities in the SSE strategic plan, is the current funding distribution across the nine science clusters the optimum, or would the Committee recommend changes?" In order to respond to this question, the Committee developed the following categories:

Category I: Most deserving of additional resources in a general R & A program augmentation.

Category II: Deserving of continuing support and some increase in a general R & A program

Augmentation, (as appropriate).

Category III: Requires improvement in performance. Candidate programs for reduction of support.

Category IV: Candidate for a major decrease in support or termination.

Using these categories, the Committee reached the following recommendations for changes in the budget distribution between the 11 research clusters:

- Category I: Theory Program for Sun-Earth Connection, Theory Program for Astrophysics, Solar and Heliospheric Sciences, Origin and Evolution of Solar System Bodies, Planetary Systems Science, Space Astrophysics Research and Analysis, and High Energy Astrophysics.
- Category II: Geospace Sciences, Exobiology, and Planetary Instrument Design and Development.
- Category III: Information Systems.
- Category IV: None.

Recommendation for Special Augmentation: High Priority Initiatives

Three clusters are recommended for special augmentation:

- Cluster 1b (theory Program for Astrophysics) would benefit from an increase of 50 per cent ($3M/year) to increase theoretical efforts to both motivate and help to define new missions. This augmentation is consistent with the recommendation of the Astronomy & Astrophysics Decadal Survey.
- Cluster 3 (Geospace Sciences) proposed to establish an Instrument Definition and Development program to facilitate instrument development to the "proposal ready" level. We recommend an SEC-wide augmentation of $2.25M/yr for this important new initiative for instruments in the Sun-Earth Connection Strategic mission flight program.
- Cluster 4 (Origin and Evolution of Solar system Bodies) strongly merits an augmentation ramping up to $5M/year after 3 years to expand the search for extra-solar planets using ground-based techniques.

This amounts to a doubling of the Cluster 4 budget in this area. It is particularly important to establish teams to provide the continuity of observation necessary to detect extra-solar planets with orbital periods of many years, to upgrade instrumentation, to capitalize on the investment that NASA has made in the Keck telescopes and the SIM interferometer, and to prepare properly for TPF.

Assessments and Recommendations for Space Science R&A Clusters

Research Cluster 1a: Sun-Earth Connection Theory Program

Science Strengths

- Addresses key SEC science areas.
- Focuses on both interpreting and predicting observables, enables the integrated interpretation of diverse SEC data sets.
- Includes models important to all three elements of SEC Theme.
- Pushes state-of-the-art, realistic, physics-based modeling of the complex SEC system.
- Leverages on other related theory and modeling programs, inside and outside of NASA.
- Provides critical mass funding (~300K/yr) for a three-year period; enables substantial projects, reasonable program turnaround.

Science Concerns

- Needs distinction from, or coordination with, other related theory/modeling programs both inside (e.g. regular SR & T program, LWS) and outside NASA.

Relevance Strengths

- Inspires designs of instruments and missions.
- Provides tools for sophisticated data interpretation.
- Enables modeling efforts too ambitious for a single SR&T investigation.
- Provides prospects for physical understanding of the coupled SEC system not otherwise possible.
- Allows informative and exciting visualizations of the largely invisible space between the Sun and the Earth.
- Helps connect SEC science to applications in NASA, other agencies (particularly NOAA and DoD), and industry (telecommunications, power).

Relevance Concerns

- SECTP cannot do all SEC theory - smaller efforts are necessary within regular SR & T program.
- The connection to LWS theory and modeling, in particular their unique roles and distinctions, as well as supporting relationships, needs to be defined.

- A more proactive role in mission definition, particularly in the course of Science Definition Team efforts, could be directed/solicited.

Overall Assessment and Recommendations

The selections represented in the SECTP proposal suggest this program is on-target in addressing some of the most important major questions of the SEC theme, and in pushing the state-of-the-art in applying large-scale and/or large-scope numerical simulations across the breadth of SECTP. A notable fact and great advantage of SEC theoretical and modeling work is that SEC theories and models are imminently testable (and some even involve observational data assimilation). Conversely, the models can tie together the diverse observations of space physics, which generally involve combinations of remote-sensing and in-situ plasma diagnostics at the site of a spacecraft or rocket. We would be hard-pressed to understand these, and many planned mission data sets (e.g. STEREO, MMS), without the guidance from increasingly realistic models and simulations with 3D geometries and accurate boundary conditions.

In the SECTP solicitation and selection process, it is important to recognize the advantage of supporting similar modeling in critical areas if funding and merit permit. Competing models spur faster, better progress, sanity checking of results, etc. There should be a natural evolution of SECTP group participants into other programs requiring their skills and products, like LWS (Living With a Star). It is moreover important to recognize the essential role of data validation as a key component of the best modeling investigations, and of producing visualizations that will communicate the physics to the larger SEC community, and SEC concepts to the larger science and non-science communities.

It will be necessary to distinguish SECTP from the LWS Theory and Modeling Program in the event that this other, related program funds groups and consortia of comparable size and scope. Consider what should be the distinguishing factors that separate the two, and whether there should be coordination in the selection process. Continue the practice of explicitly requiring discussion from proposers on overlapping/complementary work under NSF, DoD, as well as other NASA programs including SR&T, LWS, and HPCC. (Some proposers already offer this.) The aim is to both track and make the most of joint agency and program-funded projects, allowing reviewers, panels, and program managers to weigh the true investment in the subject of the investigation against its overall importance. Relationships to other work, including one's own, should be recognized as potentially leveraging and/or enhancing the value of a proposed effort.

The above is particularly important in light of the requested program enhancement for a new initiative involving cross-scale coupling and sub-grid scale phenomena. As many modelers are already moving to adaptive mesh/grid approaches in their finite-difference codes, any augmentation should be directed towards increasing the size of individual grants.

Research Cluster 1b: Astrophysics Theory Program

Science Strengths:

The Astrophysical Theory Program (ATP) supports basic research on the physical foundations of cosmology and astrophysics by providing a paradigm against which observed cosmological parameters, large scale structure, galaxy morphology and composition, star formation and the late stages of stellar evolution, can be compared. Some of the recent accomplishments of research supported by ATP include:

- Predicted the peaks in the power spectrum of the cosmic microwave background (CMB) that determine the fundamental cosmological parameters, recently observed by BOOMERANG and MAXIMA.

- Determined the evolution of the universe from simulations that combined gas and dark matter.
- Predicted the observational signature of the gravitational wave background in polarization observations of the CMB.
- Developed the theory for angular momentum transport in accretion disks.
- Predicted the optical afterglows of gamma-ray bursts, which were subsequently observed.

Science Concerns:

None.

Relevancy Strengths:

The theoretical programs described in this proposal are relevant to the goals of the Space Science Enterprise especially those concerning the structure and evolution of the universe and how galaxies and stars form, interact and evolve.

Relevancy Concerns:

None.

Overall Assessment and Recommendations:

The proposal requested:

- Doubling of Astrophysical Theory Program budget over next 5 years.
- Creating a prestige postdoctoral Fellow program in theoretical astrophysics (broad-based rather than mission directed, modeled on HF program, 10/year (three year terms).

The panel concludes that a 50% increase in support for the Astrophysics Theory Program is justified, given the high oversubscription.

We also recommend that the Astrophysics Theory Program should encourage large/group grants as in the SEC program, as well as the individual grants.

We applaud the fact that theorists are members of missions to study the cosmic microwave background such as MAP and Planck. This involvement with the missions and General Observer programs should be encouraged as a means to increase the funding for theory; although this should not be the only means by which theorists can obtain support in NASA's program. We also note that the HST Program has just announced a theory program under archival research as part of its Cycle 11 call for proposals.

Research Cluster 2: Solar and Heliospheric Physics

Science Strengths:

- The highlights captured the exciting and relevant science of this cluster. The identification of "sigmoid" X-ray structures in coronal active regions as precursors of potentially Earth-threatening coronal mass ejections (CMEs) highlights the importance of magnetic helicity and contributes to the formation of the Living With a Star program.
- The work on nanoflares suggests that the corona is heated by these mini-explosions. Magnetic reconnection releases energy as direct heat, or as waves that subsequently dissipate. The discovery of these small features has provided the impetus for the high-resolution X-ray images now obtained by TRACE.

- The work supported on particle acceleration and transport has led to mechanisms responsible for the acceleration of solar energetic particles. It has also generated controversy on the mechanism for the very effective transport of particles across the average magnetic field. This work highlights the need for a Particle Acceleration Solar Orbiter (PASO) to explore particle acceleration close to the sun.
- Helioseismology remains the only effective way of probing the solar interior. Work supported by this cluster has used helioseismology techniques to infer the structure of a large sunspot on the backside of the sun.
- Numerical models of the heliosphere including the interaction of the solar wind with the local interstellar medium have revealed the presence of a “hydrogen wall.” The hydrogen wall is inferred by analysis of the absorption in the wings of Lyman-alpha from nearby stars. Other absorption features could be identified as hydrogen walls about the nearby stars. This work highlights the importance and interest in exploring the outer heliosphere and the local interstellar medium.

Science Concerns:

None.

Relevancy Strengths:

The highlights clearly relate to objectives in the Space Science Enterprise Strategic Plan as described. Furthermore, they relate directly to (or even provide the impetus for) future missions. Solar Probe is required to identify the mechanisms of coronal heating and solar wind acceleration. STEREO will view the eruption and transport of CMEs stereoscopically. Studies of particle acceleration at the sun motivate PASO. The science strongly supports the Living With a Star (LWS) program.

Relevancy Concerns:

None.

Overall Assessment and Recommendations:

This cluster successfully focuses on major new flight programs. To that end, and to assure balance and completeness, it allocates funding to 7 areas: theory and modeling, data analysis and interpretation (involving archival or multiple mission data), instrument development, sub-orbital flight opportunities, ground based observations, laboratory studies and education/public outreach. Many of these activities result in the training of students.

A summary of the relative amounts of science done with R & A funding and with mission DA funding should be given in the proposal.

This cluster has an excellent program in solar and heliospheric physics which has made significant contributions to science, supports the objectives of future missions (e.g. STEREO and Solar Probe), is relevant to the SSE Strategic Plan, and links well with the Living With a Star program. We recommend strong support for this R & A program.

Research Cluster 3: Geospace Sciences

Science Strengths:

- The program has advanced our understanding of the space environment of the Earth through study of the coupling of the solar wind to the magnetosphere and of the magnetosphere to the ionosphere and lower regions of the atmosphere using analysis of archival data, modeling, and theory.

- The program has provided new insights into the chemistry and dynamics of the mesosphere and lower thermosphere through a combination of ground and rocket-based measurements, laboratory measurements, and modeling and simulation.
- The program contributes to the understanding of basic plasma processes using near space as a plasma laboratory to study wave phenomena, particle acceleration, and magnetic field reconnection. This understanding is applicable to other astrophysical environments as well as to potential applications such as energy generation.
- The program supports development of innovative instruments and provides suborbital opportunities to test them and carry out scientific studies. This provides a basis for designing spaceflight instruments and trains future investigators.

Science Concerns:

- The program investment in advanced technologies to improve future measurement capabilities is very small.

Relevancy Strengths:

- The program overall addresses NASA objectives “Understand our changing Sun and its effects throughout the solar system”, “Chart our destiny in the solar system” and “Learn how galaxies, stars, and planets form, interact, and evolve”.
- The program has provided both the understanding of basic geophysical processes and the instrumentation basis necessary to enable the Living With a Star initiative, which is aimed at developing the capability to predict space weather and its impacts on satellites, humans in space, and ground-based systems. This addresses directly the NASA Objective to “Chart our destiny in the solar system/Develop the capability to predict space weather”.

Relevancy Concerns:

None.

Overall Assessment and Recommendations:

- The Geospace R&A program is of high quality and is scientifically and technically necessary to enable and guide the spaceflight program in this discipline.
- There is strong apparent overlap of some subject matter with the Solar and Heliospheric cluster, and important major theoretical efforts are supported by the SEC Theory Program. Managers of these programs should coordinate activities to assure that there is coherence and efficiency in the pursuit of SSE objectives.
- The program managers established a proposal selection process in which Discipline Scientists decide which proposals best meet the objectives of the SSE Strategic Plan. We recommend that in the future the relevancy of proposals to the Strategic Plan be a criterion evaluated by the peer review panels.
- The Cluster proposes a new initiative for a Geospace Instrument Definition and Development Program, which would bring instruments from the SRT level (now just concept development) to flight readiness level so they are ready for use in “smaller, faster, cheaper” space flight programs. We recommend that funding be provided to support such a mechanism for the continued health of the program.
- There is currently little investment in technology to meet long-term needs of future missions. We encourage program managers to develop a roadmap to identify such needs and map out a plan for achieving them.

Research Cluster 4: Origin and Evolution of Solar System Bodies

Science Strengths:

The science content within this cluster has four components: Cosmochemistry, Planetary Geology and Geophysics, Origins of the Solar System, and the Mars Data Analysis program. The broad scope of this interdisciplinary research is pertinent to many areas of the OSS strategic plan, and targets fundamental questions in solar system studies. Researchers funded through this cluster engage in a variety of approaches to achieve results, including laboratory analysis, theoretical studies and modeling, data analysis, and ground-based observations. Many of NASA’s solar system exploration missions are supported and motivated by the basic research conducted within the Origin and Evolution of Solar System Bodies cluster. Further, PI’s from this cluster have assumed a leadership role in developing investigations for the Discovery Missions program.

. The science is not only of high quality and merit, but is of a nature that stimulates great public interest. Highlights include:

- History and distribution of water on Mars
- Discovery of extrasolar planets
- Study of interstellar grains in Chondritic meteorites
- Formation and delivery of organic molecules
- Pluto and planetary migration
- Kuiper Belt studies
- Formation of planetary systems
- Understanding the properties of small bodies

The above results enhance our knowledge of the origin and evolution of the solar system, and extends these insights to enable more realistic modeling of the formation of planetary systems.

Science Concerns:

None.

Relevancy Strengths:

The research in this cluster addresses 6 of the 8 science objectives of the strategic plan:

- How planets form, interact, and evolve
- Exploration of life in other planetary systems
- Understanding the formation and evolution of the solar system and the Earth within it
- Probing the origin and evolution of life on Earth
- Understanding the changing Sun and its effects
- Understanding impact processes and their effect on Earth

Relevancy Concerns:

None.

Overall Assessment and Recommendations:

A concern of the committee was the rationale behind the division of science content between this cluster and others. Numerous instances of science overlap with the Planetary System Science cluster were noted, prompting suggestions involving the reorganization of the content of the cluster. Such a restructuring may be beneficial to ensuring continued quality and progress. It would also help guard against important science initiatives falling through the cracks between clusters with related interests.

This cluster's science accomplishments are robust, exciting, and advance fundamental concepts highly relevant to NASA's goals and objectives. We recommend awarding the requested augmentation for a more vigorous and expanded planetary detection program.

Research Cluster 5: Planetary Systems Science Cluster

Content Strengths:

The cluster has a broad and comprehensive program that studies many key areas in solar system studies. The cluster has funded a number of projects that produced very high profile results. These include

- The census of Near-Earth Objects (NEOs).
- The study of Kuiper Belt Objects (KBOs) and the possible detection of the edge of the solar system.

The cluster supported strong research programs that study a wide range of planetary phenomena including

- Winds on Titan.
- Characterization of the dynamics of the Kuiper belt, which may clarify the evolutionary history of the solar system.
- Characterization of the composition of comets.
- Developing a full understanding of the Shoemaker-Levy 9 impact on Jupiter.

Content Concerns:

None.

Relevance Strengths:

- The study of KBOs and the composition of comets provide key insights into primitive solar system material that contribute to "understanding the formation and evolution of the solar system".
- Studies of planetary atmospheres and especially the heat transfer in planetary thermospheres contributes to "learning how the solar system evolves", as do the KBO studies.
- Studies of Titan's atmosphere contribute to "probing the origin and evolution of life on earth" and charting the distribution of "life-sustaining environments within our solar system."
- Studies of NEOs contribute to "charting our destiny within the solar system".
- Studies of Auroral emission on the outer planets and X-ray emission from comets contribute to understanding solar "effects throughout the solar system".

Relevance Concerns:

None.

Overall Assessment and Recommendations:

The scope of the Planetary Systems Science Cluster is the study of the solar system. The Cluster is composed of Planetary Astronomy, Planetary Atmospheres, Planetary Suborbital and the Near Earth Objects programs.

The report contains an exemplary model of the interaction of theory, modeling, data analysis, mission definition, laboratory measurements and the actual flight missions. It displays outstanding examples of results from work that it sponsors, and provides very clear connections between its activities and the OSS Strategic Plan. The areas under the cluster: Planetary Astronomy, Planetary Atmospheres, Planetary Suborbital and Near Earth Objects all are excellent programs that have clear relevance to the OSS strategic plan.

The orbit determinations of Kuiper Belt Objects are sufficiently inaccurate that some will be hard to recover and study in the future. This is due to insufficient investment of effort in recovery and orbit determination. We concur that this represents a missed opportunity for further research in future years. We encourage clusters 4 and 5 to give this a higher priority

Adequate NASA-funded Keck telescope time should be made available for KBO searches. KBO objects are primitive solar system bodies whose distribution constrains the history of planet migration. Because KBO studies are central to the Origins Theme, KBO proposals for telescope time should compete on an equal footing with Origins proposals, and should not be arbitrarily discriminated against.

We are concerned that the present budget does not permit a more extensive program for physical characterization of NEOs. This represents a significant missed opportunity to better characterize this constituent of the solar system.

Research Cluster 6a: Exobiology

Science Strengths

- Deals with problems of great importance.
- Research area very broad with great public appeal.
- Many interesting and important papers have been produced. Few are highly speculative.
- In many of the credited papers, exobiology provides only partial support, leveraging on other programs.

Science Concerns

None.

Relevancy Strengths

- Hits many key areas in the Strategic Plan.
- Work focused on supporting Mars rover missions.

Relevancy Concerns

None

Overall Assessment and Recommendations:

The report was informative, clear and well written. The asterisked reference list was very convenient.

In the future, Exobiology and the R&A part of the Astrobiology program should be funded and peer reviewed together.

The wide breadth of the program makes a comprehensive peer review very difficult. On the peer review panels, some cross-membership with Cosmochemistry and perhaps Planetary Astronomy Review Panelists should be considered.

Future R&A Senior Reviews should cover the science and funding of the Astrobiology Institute.

Leveraging the efforts of prominent scientists to work in this field means that the exobiology program will act as “supplemental science” support that may well facilitate new advances, but may prevent a concerted long-term focus. The actual value of this leveraging to NASA goals should be periodically evaluated.

Making significant progress on questions of extraterrestrial life is a challenge. A policy of reduced expectations on the part of senior management and the public is probably best for the long-term health of this program and for science in general.

The review committee recommends that NASA’s OSS make an assessment of its goals in Astrobiology/Exobiology to define its unique role in studies of microorganisms relative to those of other agencies (NIH, NSF, DOE). This assessment should be accomplished soon, given rapid change in this field and in other agencies’ programs.

Research Cluster 6b: Planetary Instrument Definition and Development Program

Content Strengths:

- Addresses key approved mission measurement areas
- Focuses on small scale and low-resource concepts
- Includes a variety of instrumentation, including orbiter, lander rover aerobot, balloon and penetrator instrument concepts
- Pushes state-of-the-art planetary mission technology
- Leverages on commercial technology development programs

Content Concerns:

- Requires stopping development at breadboard stage, not allowing brass-boarding or environmental simulation testing

Relevancy Strengths:

- Essential program for many groups to get to the competitive stage for mission flight opportunities
- Demonstrated strong impact on mission hardware selections (promotes reduced risk where heritage is lacking)

Relevancy Concerns:

- Does not include the full range of measurement types needed in payloads for all planetary missions, including those in the Discovery program

Overall Assessment and Recommendations:

Unlike its other OSS counterparts, the Solar System Exploration theme has chosen to, or succeeded in, creating a separate instrument development program, PIDDP. PIDDP focuses on the development of techniques, components, and instruments up to the stage where engineering, and ultimately flight hardware models could be built. Ideally, PIDDP takes concepts to the point where they can successfully compete in the mission opportunity selection process. Though this proposal makes the strong point that PIDDP does not take concepts far enough, to where they have been validated in an environment simulating their destination, it is shown that many PIDDP-funded concepts do indeed make it to flight.

The recently created ASTID and MIDP for exobiology and Mars rover/lander instruments previously fell under PIDDP's wing. In general, PIDDP enables development of instruments which address key measurements set out by the science definition teams for NASA's approved missions especially fostering concepts that might have multiple mission use and are geared toward the smaller mission philosophy.

It is a highly oversubscribed program, attesting to the level of demand for hardware development resources, and the number of ideas for instrumentation, in the community.

The list of instruments deriving past support from PIDDP has as its major theme planetary surface and atmosphere diagnostics, with a relatively small contribution from aeronomy (upper atmosphere/ionosphere) and space plasma and magnetic field concepts. It is not clear whether this reflects the spectrum of submitted proposals, the approved mission strawman payloads, or the perception that such instruments are sufficiently developed. If the latter two are the case, a revision of priorities might take into account the fact that some planetary missions require particles and fields instrumentation. Example included Pluto mission concepts selected for study, and two of the Discovery finalists. The new PIDDP funded list from the most recent selection emphasizes technology for Mars exploration, much of which may move into the ASTID and MIDP arenas – relieving PIDDP for other investments. The relationships between ASTID, MIDP and PIDDP need to be defined.

One matter not discussed in the proposal, and of possible importance to PIDDP, is any overlap in remote sensing instrumentation technology with the Earth Science Enterprise. Much effort has gone into environmental monitoring and resources prospecting technologies for NASA, commercial and defense applications. The extent to which there are heritage/leverage prospects is unclear, and may represent an opportunity for NASA inter-office collaboration it is does not exists.

The proposal discusses the distribution of efforts among institutions, showing that JPL remains the single most-supported institutional recipient of PIDDP funds. Though JPL is the designated Center for managing and supporting NASA's planetary missions, the advantages of open competition and external peer review should be kept in mind.

The proposal requests augmentation to allow for the funding of PIDDP "Phase II" proposals, which take instrument concepts from breadboard to brassboard. With the relief to the existing program provided by ASTID and MIDP, resources for this extension of PIDDP, as well as for the broadening of the instrument types included, should be available.

Research Cluster 7: Space Astrophysics Research and Analysis (SARA)

Science Strengths:

- Detector Development:
  - Development of microchannel plate (MCP) detectors and readouts enabled the science of EUVE, HST-STIS, and FUSE
  - Development of feedhorn-coupled micromesh bolometers enabled BOOMERANG and MAXIMA to demonstrate that the universe is flat from observations of the CMB.

- Suborbital payloads: Supported BOOMERANG and MAXIMA
- Laboratory astrophysics: Supported experimental work on dielectronic recombination, the dominant process by which electrons recombine with ions in many astrophysical plasmas, and many other atomic processes.
- Gravity and General Relativity: Supported many basic solar system tests of general relativity based on time of flight signals between solar system objects, precision radar ranging of Mercury, and lunar laser ranging

Science Concerns:

None.

Relevancy Strengths:

- Detector development: Development of detectors for future instruments such as MCPs for HST-COS, Ge:Ga photoconductor arrays for SIRTF, feedhorn-coupled micromesh bolometres for Planck and FIRST (now Herschel), and SIS mixers for submillimeter observations with SOFIA and Herschel
- Suborbital program: Effective program for training the next generation of experimental space scientists and for testing new detectors
- Supporting technology: Providing some support for energy-sensing detectors (STJ and TES) needed for future major optical – UV mission
- Laboratory astrophysics: Supported Atomic Spectra Database which provides basic atomic data for interpretation of spectral data from spacecraft
- Gravity and General Relativity: Support for theoretical and experimental studies for LISA, which have led to substantial improvements in the predicted performance.
- Ground-based astronomy: Very limited support for ground-based observations has supported space-based observations and tested detectors for future space missions

Relevancy Concerns:

- Laboratory astrophysics: The program recognizes the need for additional cross-section and transition coefficient data at X-ray wavelengths, from experience with Chandra, makes it clear that, when SIRTF is launched, the same will become necessary for IR and FIR data.
- New Detector Development: It will be important to ensure that energy-sensing detectors be vigorously pursued in order to be prepared for the next-generation missions.

Overall Assessment and Recommendations:

SARA is doing an outstanding job in supporting the detector development, technology development, and suborbital program in the submillimeter, IR, optical, and UV astrophysics.   It plays a major role in supporting research on gravitation and general relativity, and it is preparing the way for the important LISA mission to measure gravity waves from astronomical sources. It provides a valuable service in supporting most of the laboratory astrophysics in the Astrophysics programs.

Increased support for advanced detector development is important if this cluster is to meet the needs for instruments in NASA's Strategic Plan and recommended by the Decade Survey. This has become more important in view of disappearance of Explorer technology program.

We recommend that consideration be given to combining all the laboratory astrophysics programs in OSS within a single program. Such a program would have to enable grants large enough to support entire groups.

Research Cluster 8: High Energy Astrophysics

Science Strengths:

The balloon campaign results in cosmic rays are excellent in a field where space flight opportunities are few. They provide important measurements of cosmic ray composition at high energies to investigate the extent of cosmic ray acceleration at supernovae. They also provide fundamental measurements of the contribution of primordial antimatter (antiprotons) to the antiproton intensity, which is dominated by secondary production in interstellar space. The proton/antiproton measurements are also of interest in studies of cosmic ray modulation in the heliosphere, a subject of interest in the SEC theme.

The studies in gamma-ray astrophysics are also excellent: the discovery of the optical flash by ROTSE (Rapid Optical Transient Source Experiment) following a long-duration gamma-ray-burst is evidence of a reverse shock formed in the explosion of a massive star to form a black hole, and supports this interpretation of this class of gamma-ray bursts. The observations by HIREGS and GRIS in the MeV gamma-ray band provide important information on nucleosynthesis throughout the galaxy.

In X-ray studies, the laboratory spectroscopy measurements involving highly ionized ion species are of high importance in interpreting CHANDRA measurements of plasmas, which are rarely in local thermodynamic equilibrium. The sounding rocket measurements of the diffuse soft X-ray background using microcalorimeters are also at the forefront of both scientific observations and technology development.

In addition the report provides an impressive list of technology developments in support of the near and mid-term missions Constellation-X, GLAST, ACCESS and EXIST: particle tracking technology, CdZnTe detectors, and grazing incidence optics for the hard X-rays.

Science Concerns:

None.

Relevancy Strengths:

The activities of this cluster prepare for Cosmic Journeys, which is relevant to several objectives in the SSE Strategic Plan. The technology development and suborbital science provide the underpinnings for upcoming missions. The focus on processes in extreme energetic environments may very well lead to discoveries of new physics.

Relevancy Concerns:

The technology development for long-range missions is limited by funding constraints. An important example is the development of an X-ray interferometer capable of imaging matter near the event horizon surrounding a black hole.

Overall Assessment and Recommendations:

This cluster supports SEU programs in X-ray, Gamma-ray and cosmic ray astrophysics. It relates to studies of energetic phenomena: supernovae, black holes, neutron states, and the very highest energetic particles. It supports the SEU theme by preparing for the new initiative, Cosmic Journeys, aimed at breakthroughs in fundamental physics and astronomy. The cluster includes science data acquisition from balloons, rockets, laboratory studies and ground observations (50% of funding), new instruments and technology development for near and mid-term missions (41%), and innovative technical approaches for vision missions (9%). The technologies and instruments needed in this field of research are not developed for the most part in industry or elsewhere; they are only developed in R & A.

There is synergism in this cluster between technical advances and their utilization for excellent suborbital science.

Long-term technology development is underfunded, a weakness recognized in the proposal augmentation in this cluster for a high-energy-astrophysics-technology-concepts program.

We recommend that any increased support for this cluster be invested in the new initiative, HEATC.

Research Cluster 9: Information Systems

Content Strengths:

- Develops tools (SPICE, NEAT, SAO.tng, etc) useful for data management, mining and visualization for space science research areas.
- Establishes connections between computer scientists, technologists and space scientists.
- Initiates EPO projects with new information system tools and products

Content Concerns:

- Recent program has not succeeded in selecting projects with high risk and high innovation.
- Only a very limited number of algorithms or products could be identified in general or even specialized use in the community.

Relevancy Strengths:

- Advanced information science technology is needed throughout space science.

Relevancy Concerns:

- There is insufficient evidence that products meet widespread needs, and have widespread utilization.

Overall Assessment and Recommendations:

The committee recommends that all funding, including funding currently awarded to JPL, should be subject to normal competition and external peer review.

A system should be developed to demonstrate the value and general utility of the program products. In particular,

1. The cluster should make a greater effort to ensure that info systems products are actually produced as proposed. All products should be made available "open-source".
2. A more visible process is needed to disseminate products so benefits can be widespread, with greater awareness of the program accomplishments by the space science community. The discipline scientist has made a commendable start on this process by hosting annual meetings of his PI's at which they share their work and results, including computer demonstrations. Additional efforts should be made to assure dissemination to the broader community.
3. The cluster should achieve a higher level of accountability with regard to the usefulness of projects it funds. It should be able to identify major projects or major components of the community that use techniques or products developed through its support. The committee recommends establishment of a more complete tracking system for usage by the broader community.

Appendix: List of Acronyms

A&A	Astronomy and Astrophysics
ACCESS	Advanced Cosmic-ray Composition Experiment on Space Station
ASTID	Astrobiology Science and Technology Instrument Development Program
ATP	Astrophysics Theory Program
BOOMERANG	Balloon Observations of Millimetric Extragalactic Radiation and Geomagnetics
CHANDRA	Chandra X-ray Observatory (CXO)
CMB	Cosmic Microwave Background
CMEs	Coronal Mass Ejections
DA	Data Analysis
DoD	Department of Defense
DOE	Department of Energy
EPO	Education and Public Outreach
EUVE	Extreme Ultraviolet Explorer
EXIST	Energetic X-Ray Imaging Survey Telescope
FIR	Far Infrared
FIRST	Herschel (formerly Far Infrared and Submillimeter Telescope, FIRST)
FUSE	Far Ultraviolet Spectroscopic Explorer
GLAST	Gamma-Ray Large Area Space Telescope
GRIS	Gamma-Ray Imaging Spectrometer
HEATC	High Energy Astrophysics Technology Center
HF	High Frequency
HIREGS	High Resolution Gamma-ray Spectrometer
HPCC	High Performance Computing and Communication
HST	Hubble Space Telescope
HST-COS	Hubble Space Telescope – Cosmic Origins Spectrograph
HST-STIS	Hubble Space Telescope – Space Telescope Imaging Spectrograph
IR	Infrared
JPL	Jet Propulsion Laboratory
KBOs	Kuiper Belt Objects
LISA	Laser Interferometer Space Antenna
LWS	Living With a Star
MAP	Microwave Anisotropy Probe
MAXIMA	Millimeter Anisotropy Experiment Imaging Array
MCP	Microchannel Plate
MIDP	Mars Instrument Definition Program
MMS	Magnetospheric Multiscale
MO&DA	Mission Operations And Data Analysis
NASA	National Aeronautics and Space Administration
NEAT	Near Earth Asteriod Tracking
NEOs	Near Earth Objects
NIH	National Institute of Health
NOAA	National Oceanic and Atmospheric Adminstration
NSF	National Science Foundation
OSS	Office of Space Science
PIDDP	Planetary Instrument Definition and Development Program
PASO	Particle Acceleration Solar Orbiter
R&A	Research and Analysis

R&DA	Supporting Research and Data Analysis
ROTSE	Rapid Optical Transient Source Experiment
SAO	Smithsonian Astrophysical Observatory
SARA	Space Astrophysics Research and Analysis
SEC	Sun-Earth Connection
SECTP	Sun-Earth Connection Theory Program
SEU	Structure and Evolution of the Universe
SIM	Space Interferometry Mission
SIRTF	Space Infrared Telescope Facility
SIS	Superconductor-insulator-superconductor
SPICE	Spacecraft, Planet, Instrument, Camera matrix, Events
SR&T	Supporting Research and Technology
SSE	Solar System Exploration
STEREO	Solar Terrestrial Probe Mission
STJ	Superconducting tunnel junction
TES	Transition edge sensor
TPF	Terrestrial Planet Finder
TRACE	Transition Region and Coronal Explorer
UV	Ultraviolet