The National Academies of
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SPACE STUDIES BOARD

Assessment of the National Science Foundation's 2015 Geospace Portfolio Review

Charge to the Portfolio Review Committee

1. Recommend the critical capabilities needed over the period from 2016 to 2025 that would enable progress on the science program articulated in Chapter 1 of the 2013 Decadal Survey for Solar and Space Physics. The recommendations should encompass not only observational capabilities, but also theoretical, computational, and laboratory capabilities, as well as capabilities in research support, workforce, and education.

2. Recommend the balance of investments in the new and in existing facilities, grants programs, and other activities that would optimally implement the Survey recommendations and achieve the goals of the Geospace Section ... These recommendations may include closure or divestment of some facilities, as well as termination of programs and other activities, and/or new investments enabled as a result. The overall portfolio must fit within the budgetary constraints provided to the Committee.

Subject to the Following Boundary Conditions

- All of the GS-funded activities should be considered together with the Decadal Survey recommendations: Core Programs of Aeronomy, Magnetospheric Physics, and Solar Terrestrial Research, focused programs CEDAR, GEM, and SHINE, elements of the new Space Weather Research & Instrumentation Program (CubeSat, space weather modeling, and other multiuser, space weather-related activities), components of the Geospace Facilities Program, such as the Incoherent Scatter Radar, Lidar Consortium, SuperDARN HF radars, and those activities specifically designed to enhance educational opportunities, diversity, and international participation.

Boundary Conditions (cont)

- The review should be forward looking focusing on the potential of all funded facilities, programs, and activities for delivering the desired science outcomes and capabilities (while taking into account past performances) and considering the value of funded a activities in terms of both intellectual merit and broader impacts.
- The review should assume budget scenarios (to be provided by GS) to encompass the period from 2016 through 2025, and consider the costs of (i) continuing the existing observing capabilities and science-funded programs, as well as of (ii) new facilities and programs, including those recommended in the Survey and others the Review committee may wish to introduce.
- The committee's deliberations should take into consideration the national and international Geospace Sciences landscape and consequences of its recommendations for domestic and international partnerships.

Assessment of the ICCGS

- The PRC's report, *Investments in Critical Capabilities for Geospace Science 2016 to 2025* (ICCGS), was accepted by the Advisory Committee for Geoscience in April 2016.
- The NSF ask the Space Studies Board of the National Academies to provide an independent assessment of the ICCGS. The Assessment Committee performed its task during the remainder of 2016, its report being released in prepublication form in January 2017.
- Additional developments during the course of the NSF/GS portfolio review and its subsequent assessment:
  - The release of the *National Space Weather Strategy* and the *National Space Weather Action Plan* in October 2015 by the National Science and Technology Council of the Office of Science and Technology Policy
  - The release of the National Academies assessment *Achieving Science with CubeSats: Thinking Inside the Box*

Committee

TIMOTHY S. BASTIAN, National Radio Astronomy Observatory, *Chair*
SUSAN K. AVERY, Woods Hole Oceanographic Institution, *Vice Chair*
MARCEL AGÜEROS, Columbia University
PETER M. BANKS, Visual Communications, Inc., and Liberty Plugins, Inc.
GEORGE GLOECKLER, University of Maryland
J. TODD HOEKSEMA, Stanford University
JUSTIN KASPER, University of Michigan
KRISTINA A. LYNCH, Dartmouth College
TERRANCE G. ONSAGER, National Oceanic and Atmospheric Administration
AARON RIDLEY, University of Michigan
NATHAN A. SCHWADRON, University of New Hampshire
MARIA SPASOJEVIC, Stanford University

Statement of Task

Assess: how well the PRC report's findings, conclusions, & recommendations:

1. Align with the science issues and priorities highlighted for NSF-GS and the Geospace scientific community in the NRC's Decadal Survey: Solar and Space Physics: A Science for a Technological Society (hereafter called the Survey);

2. Adequately take into account issues such as:
    a. actions already taken by the NSF-GS in response to the Survey priorities;
    b. the current challenging outlook for the U.S. Federal budget—in particular the expected evolution of the NSF-GS budget;
    c. interdisciplinary aspects and the overall scientific balance of all NSF-GS-funded activities;
    d. the alignment of the capabilities of the Geospace Facilities Program with the current science needs of the community—in particular how well the Facilities Program is specifically designed to enhance educational opportunities, diversity, and international participation;
    e. the integration of technology development with the NSF-GS science program,

Statement of Task

f. the balance of investments between the new and existing facilities, grants programs, and other activities.

3. Provide—considering the value of funded activities in terms of both intellectual merit and broader impacts—a forward-looking focus on the potential of all NSF-GS funded facilities, programs, and activities for delivering the desired science outcomes and capabilities; and

4. Provide a clear set of recommendations on how the NSF-GS should implement the Survey's priorities within the context of the NSF/Geosciences strategic planning process.

The committee's report will also discuss the general readability and clarity of the PRC's report and in particular its recommendations, as well as offering commentary on other issues relevant to the assessment of the PRC report, as determined by the committee. Any recommendations the committee may make will be focused on options and considerations for NSF's implementation of the PRC recommendations.

Approach of the Assessment Committee

- "The assessment is not meant to second guess the recommendations of the [ICCGS] report, or to suggest alternative recommendations, but to assess the process used to establish and prioritize its recommendations and to place them in a broader context." (Preface)
- The assessment committee therefore chose not address each of the many specific findings and recommendations of the ICCGS. Rather, the committee assessed the ICCGS within the broader context of the S&SP Decadal Survey, GS portfolio balance, and future needs of the scientific community while being mindful of the constraints within which the PRC addressed its charge and the role of NSF GS within the larger solar and space physics enterprise.

Bottom line:

Conclusion: The PRC fulfilled its charge within the imposed constraints. The portfolio review process and the resulting report represent a conscientious, thorough, and good-faith effort to review the NSF GS portfolio and make recommendations for portfolio evolution and renewal. (Chapter 4)

"To conclude this assessment, the PRC met its charge in the face of challenging constraints. … The responsibility now passes to NSF AGS and GEO to implement the GS portfolio recommended in the ICCGS and to engage with the community in developing a strategic vision and plan that identifies and builds on the strengths of AGS and GS within the broader solar and space physics enterprise, identifies partnerships within the NSF and external to NSF, and leverages opportunities from the NSWS5 and SWAP6 initiatives." (Chapter 6)

Organization of the Assessment

1. Introduction – PRC charge, assessment SoT
2. Boundary Conditions
   - Scope of the GS section Portfolio Review
   - Budget guidance
3. The Geospace Science Portfolio in Context
   - Strategic planning
   - Interfaces to Solar and Space Physics – other programs
   - National Space Weather Strategy

2.1 Scope of the GS Section Portfolio Review

Finding: The PRC was charged to consider the NSF GS portfolio largely in isolation, without review of relevant facilities, programs, and activities within the wider AGS portfolio. (Chapter 2)

2.2 Budget Guidance

Finding: The PRC's ICCGS report estimates that an augmentation of $11 million, or 25 percent, is needed to fully address decadal survey priorities. However, the PRC was asked to respond to its charge under one budget scenario: a flat budget from 2016-2025 with adjustments for inflation. (Chapter 2)

3.1 Strategic Planning

Finding: GS and AGS do not currently have a clear strategic plan or a visible process for developing one. The portfolio review would have benefitted from a clear strategic vision for an integrated geospace, solar, and space physics program within NSF. (Chapter 3)

3.2 Interfaces

Finding: Geospace sciences include interfaces to facilities, programs, and activities across NSF, other federal agencies, and foreign agencies. These interfaces evolve over time. They present a challenge because of the need to periodically update the GS portfolio balance as considered within this broader context. They also represent opportunities for partnerships in areas of mutual interest, such as MRI, midscale, and MREFC projects as well as through the CCMC, space weather modeling, and Grand Challenge Projects. (Chapter 3)

3.3 National Space Weather Strategy

Finding: NSF has an important role in supporting national space weather policy that may pose additional challenges to GS in a fiscally constrained environment, but may also present new opportunities for fundamental systems science. (Chapter 3)

3.4 The Need for a Strategic Vision

Recommendation: The lack of a strategic plan for the Division of Atmospheric and Geospace Sciences (AGS) and the Geospace Section hinders the ability of the Geospace Section to act fully upon the recommendations given in *Investments in Critical Capabilities for Geospace Science 2016 to 2025.* AGS should develop a strategic vision and a strategic plan that recognizes all components within its portfolio relevant to geospace and interfaces with other programs across other National Science Foundation (NSF) divisions and directorates and across the agency. The plan should be aligned with the 2013 solar and space physics decadal survey, demonstrate awareness of the evolving capabilities outside NSF, and should be regularly updated with close community involvement in response to emerging discoveries, evolving budgets, new imperatives, and developing partnerships. (Chapter 3)

Organization of the Assessment

1. Introduction – PRC charge, assessment SoT
2. Boundary Conditions – budget, scope
3. The Geospace Science Portfolio in Context
4. Assessment of the Portfolio Review Process

- Information gathered by the PRC
- The Portfolio Review alignment with Survey priorities
- Conclusions regarding the Portfolio Review process

4.1 Information Gathered by the PRC

Finding: The PRC collected substantial amounts of information and data about each GS facility in order to perform its comparative assessment. Little of this information and data were presented in the ICCGS report. (Chapter 4)

Conclusion: GS has not had a standard set of performance metrics by which it uniformly evaluates facilities. The assessment committee endorses the ICCGS's recommendation to GS to develop a common set of annual metrics from each facility. (Chapter 4)

4.2 Alignment with Survey Priorities

Finding: The ICCGS report does not explain how the recommended investments in particular programs and facilities satisfy the required capabilities to address the decadal survey science goals. The process used for establishing the relative priorities between facilities and for program elements is not defined in the report. (Chapter 4)

4.3 Conclusions

Conclusion: The PRC fulfilled its charge within the imposed constraints. The portfolio review process and the resulting report represent a conscientious, thorough, and good-faith effort to review the NSF GS portfolio and make recommendations for portfolio evolution and renewal. (Chapter 4)

However, given that ICCGS recommendations will have significant impacts on the scientific community, it must understand the basis for the ICCGS recommendations and have confidence in the process that led to them.

Recommendation: The National Science Foundation Geospace Section should reach out to the geospace sciences community to explain the program recommended by *Investments in Critical Capabilities for Geospace Science 2016 to 2025* and its basis, and to keep the community informed regarding plans to implement the recommended program (Chapter 4)

Organization of the Assessment

1. Introduction – PRC charge, assessment SoT
2. Boundary Conditions – budget, scope
3. The Geospace Science Portfolio in Context
4. Assessment of the Portfolio Review Process
5. Portfolio Recommended by ICCGS
   - Current facilities: recommended actions
   - Facilities evolution
   - Grants
   - Workforce development & diversity
   - Partnerships and opportunities

5.1 Recommended Actions: Class 1 Facilities

Conclusion: Details concerning the actual costs of supporting geospace sciences at Arecibo Observatory and Sondrestrom, including the ISRs and ancillary instrumentation, are not provided in the ICCGS. It is therefore difficult for the assessment committee to understand the nature and extent of capabilities that would remain at the Arecibo and Sondrestrom sites and to evaluate the degree to which the capabilities align with current community science needs. (Chapter 5)

5.1 Recommended Actions: Class 1 Facilities

Conclusion: The two most significant sources of funds for new facilities and programs within GS result from reducing funding to Arecibo Observatory from $4.1 million to $1.1 million and terminating funding for the Sondrestrom ISR. The ICCGS recommends that these funding changes be complete by 2020. However, management and operations at both sites are inherently complex, introducing a degree of uncertainty regarding the full extent of savings realized by the recommended cuts and of the time required before these funds are available for reallocation. (Chapter 5)

5.1 Recommended Actions: Class 2 Facilities

Conclusion: The ICCGS recommendation concerning the CRRL, while freeing up resources for the Integrative Geospace Science grant program, may increase the proposal burden on other core and targeted grants programs. Once evaluation criteria have been defined for DASI-type sensors or networks, programs such as the CRRL and LISN could transition to a Class 2 facility by seeking support from the DASI Facilities Program. (Chapter 5)

5.2 Facilities Evolution: Midscale Projects

Conclusion: Funding a program for midscale projects currently lies outside the means and ability of the NSF Geospace Section alone. (Chapter 5)

Recommendation: The Division of Atmospheric and Geospace Sciences should work with the Directorate for Geosciences and the National Science Foundation to implement the 2013 solar and space physics decadal survey recommendation for a Midscale Projects Program to address midscale priorities. (Chapter 5)

It is encouraging to see NSF Important Notice No. 138: Revision of the Major Research Equipment and Facilities Construction (MREFC) Eligibility Threshold and the draft Large Facilities Manual released in Dec 2016.

5.2 Facilities Evolution: EISCAT

Conclusion: The ICCGS has identified an evolution of the ISR program that maintains most of the important capabilities of the existing program and frees up resources for the near-term renewal of existing facilities and for innovation and development of new instrumentation and observations in the next decade. (Chapter 5)

Conclusion: The EISCAT and EISCAT-3D represent an attractive investment that would ensure United States access to state-of-the-art ISR instrumentation at lower cost than is currently the case. However, the time it will take to enter the EISCAT partnership may be longer than assumed by the ICCGS. The U.S. contribution to current and future operations and management costs will be an important consideration when entering the partnership. (Chapter 5)

5.2 Facilities Evolution: Innovations & Vitality Program

- Major repairs & renovation of existing facilities
- Hardware or software development that would enhance the performance of existing facilities
- Development of new instrumentation to an operational capability
- Development of numerical algorithms & methodologies to improve computational models
- Development of real-time capabilities at facilities

Conclusion: The scope of the Facilities I&V Program, the balance of its constituent elements, and its relationship to the strategic grants program require better definition and focus. (Chapter 5)

5.2 Facilities Evolution: DASI Facilities Program

Conclusion: The assessment committee endorses the intent of the collective ICCGS recommendations regarding DASIs and DASI-related issues, in moving GS toward a guiding role in scientifically directing community thought and efforts toward system-level studies of the geospace region. (Chapter 5)

Recommendation: To begin implementation of the *Investments in Critical Capabilities for Geospace Science 2016 to 2025* recommendations to create distributed arrays of small instruments (DASIs) with the goal of starting new Class-2 facilities, National Science Foundation should support community efforts to establish requirements for future DASI-type sensors and projects, by organizing targeted community workshops, for example, within a wider Geospace Section strategic framework. (Chapter 5)

5.2 Facilities Evolution: Data System Program

Finding: The scope of the proposed data system is not well understood at this point, and the resources required are consequently not known. (Chapter 5)

Conclusion: It is not clear that the proposed budget line is appropriate for the task of supporting a potential Geospace System Observatory. (Chapter 5)

5.2 Facilities Evolution: Research within Facilities

Finding: Facility scientists that are active scientific researchers are critical to ensuring data acquired by instruments are of high quality for science usage. (Chapter 5)

Recommendation: Recommendation 7.29 of *Investments in Critical Capabilities for Geospace Science 2016 to 2025* states that an upper limit of 10 percent be placed on facility personnel budgets allocated for scientific research. National Science Foundation's Geospace Section should evaluate the support for science operations as a factor in judging how well a given facility enables and supports scientific investigations for its users, not fix the fraction of staff time used for science operations a priori. (Chapter 5)

5.3 Grants Programs

Finding: Evolution of the strategic and targeted grants programs emphasizes the continuing transition of geospace sciences from distinct strategic areas to an integrative approach to address more optimally geospace science as a complex dynamical system. (Chapter 5)

Conclusion: Increased pressures on core and targeted grants may result from competing the operation of ancillary instruments on the Sondrestrom and Arecibo Observatory sites, and the Consortium of Resonance and Rayleigh Lidars. (Chapter 5)

5.3 Grants Programs: CubeSats

Conclusion: The ICCGS and ASC* findings regarding GS's CubeSat program are broadly consistent. The assessment committee is concerned, however, that the one-third decrease in budget for the CubeSat program recommended in the ICCGS report will have an unduly negative effect on the scientific and educational results highlighted by ASC if funding from outside GS cannot be found (Chapter 5)

* NASEM 2016 *Achieving Science with CubeSats: Thinking Inside the Box*

5.3 Grants Programs: CubeSats

Recommendation: The assessment committee endorses the *Investments in Critical Capabilities for Geospace Science 2016 to 2025* recommendation to seek partnerships for CubeSats outside of the National Science Foundation (NSF) Geospace Division. However, mindful of the growing potential of CubeSats to be platforms for science and of the 2013 solar and space physics decadal survey recommendation to augment support for CubeSats, the committee recommends that NSF Geospace carefully consider the impact associated with decreasing funding for the CubeSat program before additional resources through intra-divisional partnerships can be obtained. (Chapter 5)

5.4 Workforce Development & Diversity

ICCGS Rec. 4.6: The GS and GS community should be in the vanguard of NSF initiatives to promote engagement of women and under-served populations in all aspects of geospace science from school to research proposal writing to leadership in GS Activities.

Recommendation: The assessment committee recommends that to realize Recommendation 4.6 of *Investments in Critical Capabilities for Geospace Science 2016 to 2025* fully, the lack of diversity and representation in solar and space physics should be attacked aggressively. The National Science Foundation Geospace Section should identify best practices and provide guidance for new approaches to diversifying geospace. (Chapter 5)

5.5 Partnerships and Opportunities

Finding: ICCGS recommendations regarding facilities strongly affect two facilities, one international (Sondrestrom) and one domestic (Arecibo). Since Arecibo is funded by a partnership, the recommended action regarding Arecibo may have wider scientific and budgetary impacts. (Chapter 5)

More broadly,

Conclusion: A number of international partnership opportunities exist that could be broadly utilized, particularly as the geospace science focus evolves to having a larger emphasis on system science and the development of predictive capabilities. (Chapter 5)

5.5 Partnerships and Opportunities

Recommendation: Assessing all possible international partnerships was beyond the charge given to the Portfolio Review Committee. However, when considering the implementation of the portfolio recommended by *Investments in Critical Capabilities for Geospace Science 2016 to 2025*, the National Science Foundation (NSF) Geospace Section should continue to maintain an awareness of and explore opportunities to leverage measurements available from international programs. The potential value of these observations for fundamental research, for the development of system and data assimilative models, and for the improvement of predictive capabilities should be considered as an integral component of the broader NSF observing program.

Organization of the Assessment

1. Introduction – PRC charge, assessment SoT
2. Boundary Conditions – budget, scope
3. The Geospace Science Portfolio in Context
4. Assessment of the Portfolio Review Process
5. Portfolio Recommended by ICCGS
6. Implementation Planning

- Clarity and completeness of ICCGS Recommendations
- Portfolio evolution and renewal
  - Senior Reviews
  - Mgmt processes

6.2 Portfolio Evolution & Renewal: Senior Reviews

Conclusion: The assessment committee endorses ICCGS Recommendations 9.8 and 9.15 to conduct periodic senior reviews of the NSF Geospace Section's grants programs and facilities. (Chapter 6)

However:

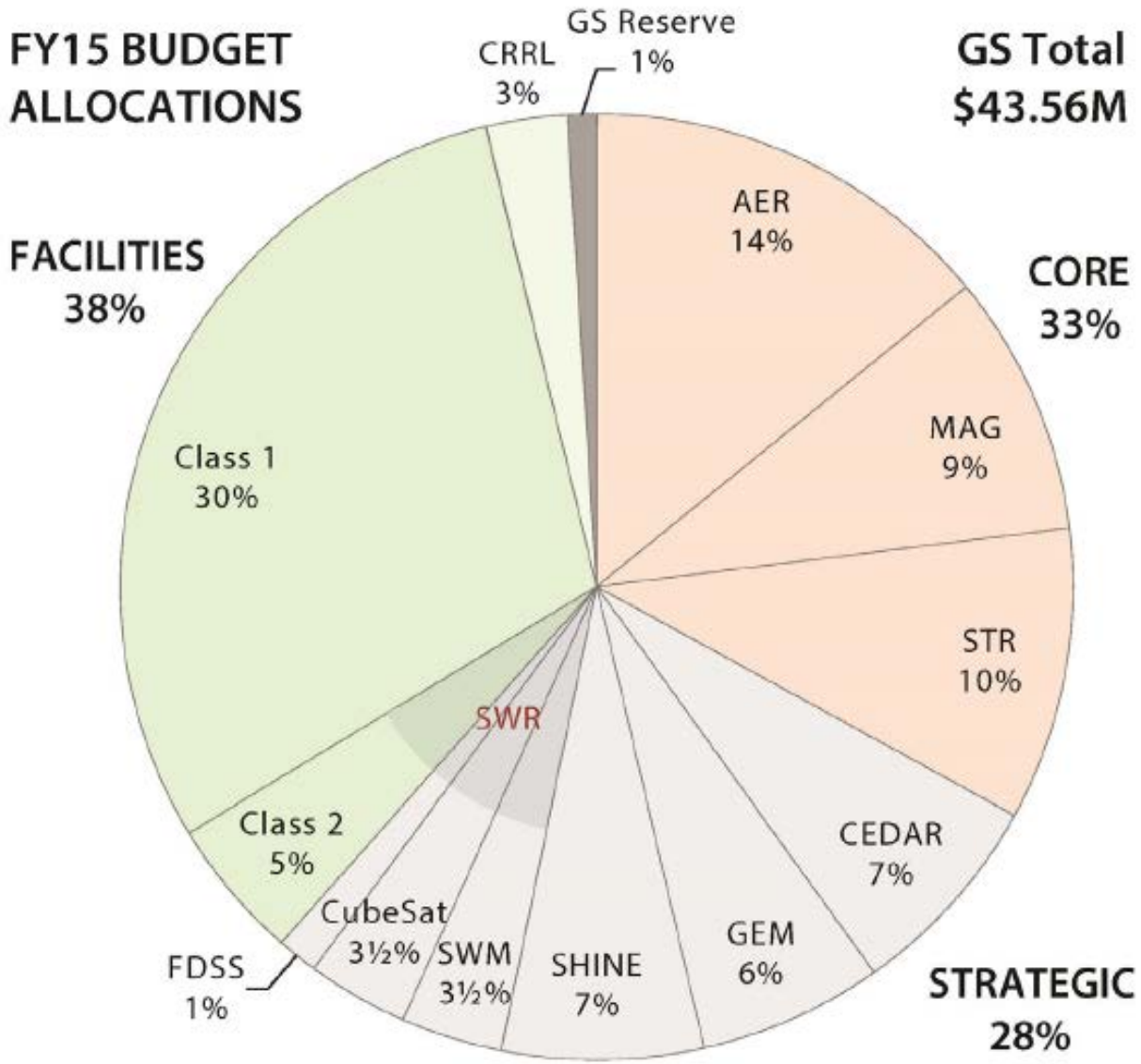
Conclusion: The assessment committee questions the need for two separate senior reviews, one for the Core and Strategic Programs and another for GS facilities. The committee is also concerned about the burden placed upon GS administration by two separate semi-decadal reviews and concluded that a single unified review is preferable. (Chapter 6)

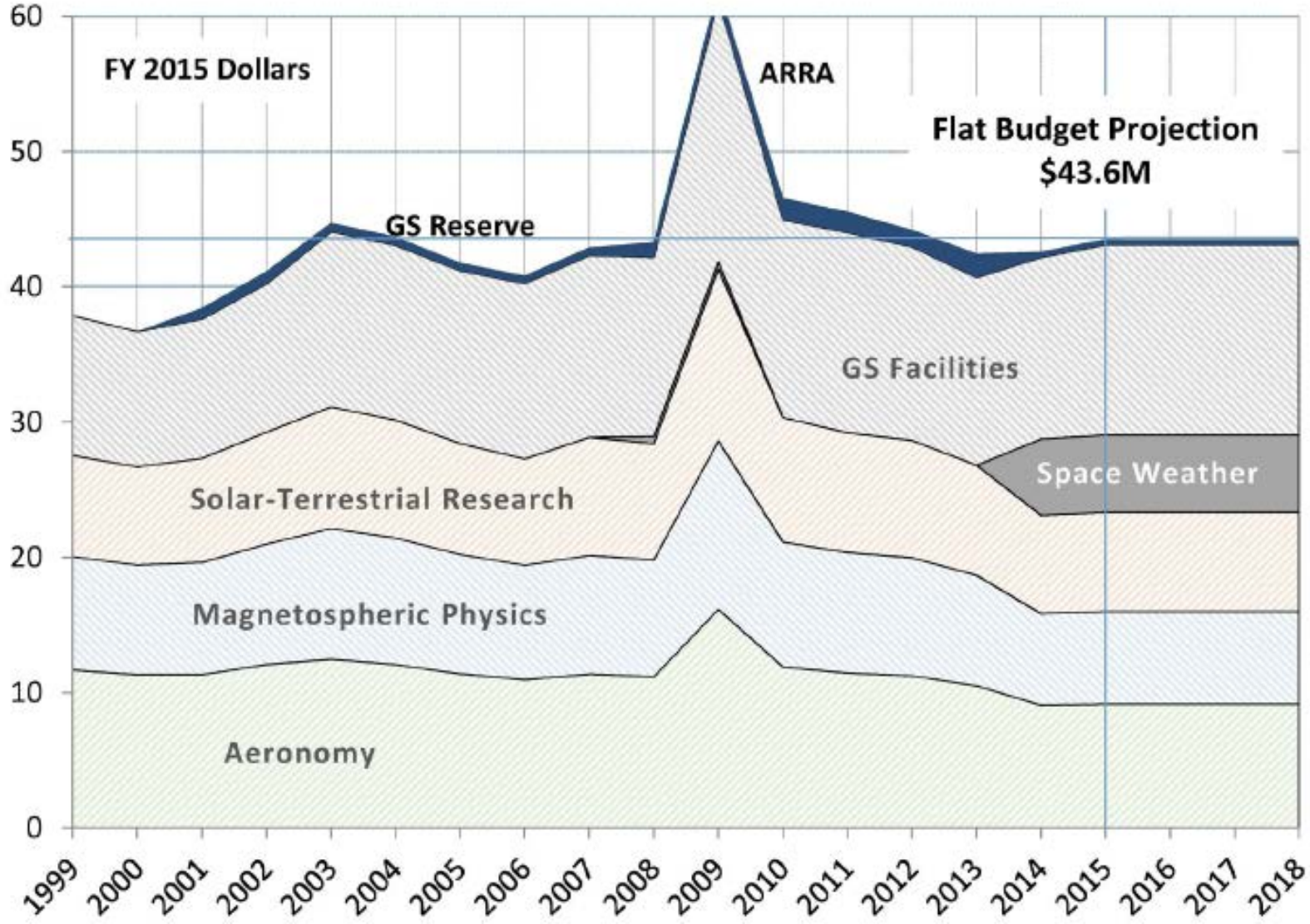
6 Implementation Planning

6.2 Portfolio Evolution & Renewal: Management Processes

Conclusion: The suggestions to NSF GS regarding management processes are excellent and will underpin future senior reviews and allow greater transparency into the decision-making process.

"To conclude this assessment, the PRC met its charge in the face of challenging constraints. … The responsibility now passes to NSF AGS and GEO to implement the GS portfolio recommended in the ICCGS and to engage with the community in developing a strategic vision and plan that identifies and builds on the strengths of AGS and GS within the broader solar and space physics enterprise, identifies partnerships within the NSF and external to NSF, and leverages opportunities from the NSWS and SWAP initiatives." (Chapter 6)


FY15 BUDGET ALLOCATIONS
GS Total $43.56M
GS Reserve 1%
CRRL 3%
AER 14%
CORE 33%
MAG 9%
STR 10%
CEDAR 7%
GEM 6%
SHINE 7%
SWM 3½%
CubeSat 3½%
FDSS 1%
SWR
Class 2 5%
Class 1 30%
FACILITIES 38%
STRATEGIC 28%


FY 2015 Dollars
ARRA
Flat Budget Projection
$43.6M
GS Reserve
GS Facilities
Space Weather
Solar-Terrestrial Research
Magnetospheric Physics
Aeronomy
60
50
40
30
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1999
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Core Grants Program (Priority 1)		2015	2020	2025	%
AER (1)	Core[†]	6.14	14.4	14.4	Core
MAG (1)		3.88			
STR (1)		4.36			
Core Grant Total		**14.38**	**14.4**	**14.4**	**33%**

Strategic Grants Program (Priorities 1, 2, 3)			Change from 2015 to 2020		
CEDAR (1)	Targeted[†]	3.09	8.7	6.7	Strategic
GEM (1)		2.63			
SHINE (1)		2.98			
Space Weather (1)	IGS	1.50	1.5	5.0	
Grand Challenge (2)			1.5		
CubeSat (3)		1.50	1.0	1.0	
FDSS (3)		0.60	0.6	0.6	
Strategic Grants Total		**12.30**	**13.3**	**13.3**	**30%**

Class 1/2 Facilities (All priority 1)		2015[a]	2020	2025[b,c]	
Arecibo [d]	Class 1[‡]	4.10	1.1	8.4	Facilities
PFISR [e]		1.50	1.5		
RISR-N [e]		1.50	1.5		
Sondrestrom		2.50	0.0		
Millstone Hill [f]		2.10	1.9		
Jicamarca		1.35	1.4		
SuperDARN	Class 2[‡]	0.96	1.0	4.8	
AMPERE		1.02	1.0		
SuperMag		0.15	0.2		
CCMC		0.50	0.5		
CRRL[g]	not a facility	1.20	0.0		
Class 1/2 Facilities Subtotal		***16.88***	***10.1***	***13.2***	

New Facilities Programs (Priorities 1, 2)					
EISCAT (1)	Class 1[‡]		1.0	b	
Data Systems (1)	Class 2[‡]		0.5	c	
DASI (1)			1.6		
Innovation & Vitality (2)	Upgrades: Instruments, Facilities		2.4	2.7	
	Upgrades: Community Models		0.3		
New Facilities Programs Subtotal			5.8	2.7	
Facilities Total		***16.88***	***15.9***	***15.9***	**36%**
Midscale Projects Line [h]		out of budget		$1-6M/year	
GS Reserve		**0.43**	**0.4**	**0.4**	**1%**
Grand Total *		**43.99**	**44.0**	**44.0**	**100%**