An Evaluation of Atmospheric Research in the Outer Planet Research Program

December 4, 2006

Fran Bagenal, University of Colorado, OPAG Chair
William Bottke, Southwest Research Institute, PSS-MOWG Chair
Timothy E. Dowling, University of Louisville, PSS-MOWG Member
Julianne Moses, Lunar and Planetary Institute, OPAG Participant
Scot Rafkin, Southwest Research Institute, OPAG Participant
Adam Showman, University of Arizona, OPAG Participant
Amy Simon-Miller, Goddard Space Flight Center, OPAG Participant

Executive Summary

Atmospheres represent a critical component of outer-solar-system research and provide important clues to questions involving the origin and evolution of the solar system and the origin of life that were deemed of vital importance in the NAS/NRC decadal survey, NASA Roadmaps, and other strategic-planning documents. The current policy of excluding atmospheric research from the Outer Planet Research Program weakens the program, slows the attainment of NASA's strategic goals, lessens the scientific return from past NASA missions, and risks the loss of critical scientific expertise, particularly junior researchers. Atmospheric research should be reinstated within the NASA Outer Planets Research Program.

Background

The NASA Outer Planets Research (OPR) Program, initiated under ROSS-2004, began by soliciting a broad array of fundamental research or data-analysis proposals dedicated to increasing our understanding of the interiors, surfaces, atmospheres, magnetospheres, rings, dynamics, and evolution of outer solar-system bodies. The goals of the OPR program were in resonance with the recommendations of strategic planning documents like the 2003 National Academy of Sciences/National Research Council decadal survey, "New Frontiers in the Solar System: An Integrated Exploration Strategy", and past and current Solar System Exploration Roadmaps, in recognizing the importance of the outer solar system in providing us with answers to many critical science questions, as well as providing high-priority targets for future exploration. These and other strategic planning documents also emphasize the importance of Research and Analysis (R&A) programs; the initiation of a new R&A program on a topic of fundamental interest in planetary sciences is responsive to the findings of the strategic plans. R&A programs maximize the success of NASA spacecraft missions, provide the resources with which the current generation of researchers can address key science goals and formulate future missions plans, and supply resources critical for the training of the next generation of space scientists. The OPR program, in particular, provides a means to maximize scientific return from data collected from highly successful past missions such as Pioneer, Voyager, and Galileo.

In ROSES 2006, research related to atmospheres and origins of the outer solar system was excluded from the OPR Program. According to OPR Program Manager, Dr. Curt Niebur, the

two main reasons for exclusion of atmospheric research were that (1) the NASA Planetary Atmospheres program already funds a high percentage of outer solar-system work and is, therefore, a *de facto* OPR program for atmospheric research, and (2) the initial intention of the program was not to include funding for atmospheric research in OPR, but atmospheres were included for the initial two years because of certain programmatic problems (now resolved) in PATM.

The exclusion of atmospheric research from the OPR program is detrimental to the achievement of NASA strategic science goals, weakens the quality of science being conducted at NASA, prevents cross-disciplinary approaches to key science questions from being implemented, and may be preferentially harmful to the younger generation of atmospheric researchers. Atmospheres of outer solar-system objects represent the most easily accessible remote-sensing targets in the outer solar system. These atmospheres provide key clues to the origin and evolution of the entire solar system and, as such, have been given high priority for further research in NASA strategic-planning documents. For example, the atmospheres of Titan, Enceladus, and comets may hold clues to the origin of life and volatiles on Earth and to habitability on other planets. The deep atmospheres of the giant planets have retained volatiles from early stages of solar-system formation and can provide important clues as to the conditions operating at this time. Past ground-based and spacecraft observations have revealed intriguing and unusual atmospheres in the outer solar system, including the exotic yet Earth-like atmosphere of Titan, the newly discovered plumes on Enceladus, the heterogeneously variable, volcanic-sublimation atmosphere on Io, and the continually changing atmospheres of the gas and ice giants. Outer solar-system atmospheric research encompasses a broad variety of topics, ranging from laboratory studies of the irradiation of ices, smog formation in Titan-like chambers, and the investigation of fundamental spectroscopic or kinetic parameters of gases; to theoretical studies of aerosol formation on the giant planets and Titan, the generation of a ring atmosphere at Saturn, nonlinear fluid dynamics including vortices, large amplitude waves, and climate-feedback systems, magnetosphere-atmosphere interactions, and cometary-coma dynamics; to analyses of intriguing past ground-based and spacecraft data acquired with NASA funding. Many compelling questions and puzzles remain regarding atmospheres in the outer solar system, and excluding atmospheres from the Outer Planet Research Program limits scientific productivity in this important area and reduces the impact of the OPR program.

Dr. Niebur this year has indicated to a number of relevant forums a willingness to revisit the decision to exclude atmospheric work from OPR. This paper is a response to his invitation to provide factual information about outer planet research in PATM, OPR and across NASA's R&A programs in general.

This paper is organized as follows. First, we provide statistical information and analysis from the period 2004-2006 on the R&A programs relevant to this discussion—OPR, PATM, Origins, Planetary Geology and Geophysics (PG&G), and Planetary Astronomy (PAST). Second, we address the impact that the exclusion of atmospheric research has had on the community, individual researchers, and the overall NASA R&A program. Finally, we present findings and recommendations.

Statistical Comparison and Analysis Across NASA R&A Programs

Overlap in R&A programs is not uncommon. Scientific research is rarely strictly compartmentalized. PATM and PG&G fund a significant amount of Mars work despite the

existence of several Mars-specific science programs; PG&G and PATM prefer instead to let the community dictate which topics are interesting and to let the best-proposed science prevail. Laboratory experiments on ices are funded in PG&G, PATM, OPR, and Origins. Magnetosphere-atmosphere interactions are covered in Geospace Sciences, OPR, and PATM. Extrasolar giant planet research can be proposed to PATM, Origins, and other astronomy programs at NASA. Numerous examples such as these can be cited.

According to PATM program manager Dr. Philippe Crane, the percentage of what he considers to be outer planets research funded in PATM this year (2006) is around 40%. The percentage calculated using data from the NSPIRES and SYSEFUS Web sites for 2004 and 2005 is somewhere between 55% and 70%, depending on the subjective categorization of what constitutes outer-planet-related work. Regardless of the exact number, PATM does fund a considerable percentage of outer-planet atmospheric research, as noted by Dr. Niebur. However, understanding the true meaning and context of these funding percentages requires digging deeper.

Is the number or percentage of outer solar-system research funded in PATM out of line with other programs? If atmospheric research were eliminated from OPR because PATM was a viewed as a *de facto* OPR-atmosphere program, then can the same be said for other programs? The percentage and fractional number of outer-planet research funded outside of the OPR program is shown in Table 1. These data include comets and asteroids and the broadest and most inclusive definition of "outer planet research". In terms of funding percentage, PAST has the most overlap with OPR. PATM comes in second in years 2004 and 2005, and probably third or fourth for 2006, although the numbers are not yet in. However, in terms of *number* of proposals, both PAST and PG&G exceed PATM. Therefore, in terms of shear numbers, PATM, and most certainly Origins by any measure, is no more a *de facto* OPR program than is PAST or PG&G.

Another way to look at this issue is to examine the amount of OPR research that could be funded under other programs (Table 2). Using the "percentage standard" applied to atmospheric research within OPR, it is clear that OPR, based on 2005 numbers, is a *de facto* PG&G program. Furthermore, the percentage of PG&G-fundable research in 2006 OPR is likely to skyrocket due to the exclusion of atmospheric research. Therefore, more than ever, OPR, both in terms of percentage and number, is a *de facto* PG&G program. Should PAST, PATM, PG&G and Origins exclude other outer-solar-system research since there *is* an existing Outer Planets Program? Following the current overlap principle applied in OPR, the answer might be "yes". We do not believe this course of action is proper, but such a decision would be consistent with the current OPR program policy.

Table 1. Percentage and Fractional Number of Outer Planet Research Funded Under R&A Programs.

Program	2006	2005	2004
PATM	40% (8/20)*	70% (19/27)	75% (33/44)
PAST	?	91% (21/23)	86% (25/29)
PG&G	?	45% (26/58)	42% (31/73)
Origins	?	31% (10/32)	38% (15/39)

*PATM numbers from 2006 obtained from Program Manager.

Now consider proposal pressure and acceptance rates in the relevant programs (Table 3). The impact of the 15% cut in R&A for 2006 is evident in most programs. The bottom line is that PATM is certainly no better off, and in several cases, is worse off than other programs that overlap with OPR in terms of the acceptance rate of proposals.

Table 2. Percentage and Fractional Number of 2005 OPR Research Fundable Under Other Programs

Program	
PG&G	59% (17/29)
PATM	28% (8/29)
Other	13% (4/29)

Table 3. Proposal acceptance rate in terms of percentage and fractional number (when available)

Program	2004	2005	2006
OPRP	39% (55/142)*	38% (30/80)*	20% (10/51)*
PATM	~40% (45/112)*	35% (29/84)*	31% (20/64)*
PAST	72%*	69%*	<30%*
PG&G	~50%	49% (58/119)*	~50%
Origins	≥ 39%*	33% (32/98)$^{+}$	25-30% (*est.)

*Numbers obtained from Program Managers. $^{+}$Based on rejection letter.

Impact of Atmospheric Research Exclusion from OPR

Proposal pressure and exclusion of atmospheric research from OPR has hit outer-planet atmosphere researchers particularly hard. In many cases, there are no other programs other than PATM to which these researchers can propose. The PATM program rarely funds 100% of a researcher's salary, and the difficulties in obtaining outer solar-system atmospheric funding are especially hard on young, promising scientists trying to remain viable in the field. Although there is no overt bias against younger researchers in the PATM program, older scientists are more likely to understand how to write a good research proposal and are more likely to be given the benefit of doubt if they have written a less-than-excellent-ranked proposal. Even senior researchers have difficulty maintaining a healthy program (often employing students, post-docs and other junior scientists) relying on the PATM program alone. In contrast, those doing outer-solar-system geologic or geophysical research can apply to PG&G, where the acceptance is relatively high as well as to OPR, which is currently dominated by this area of research. Certainly, excluding atmospheric work from OPR creates a self-fulfilling prophecy whereby PATM must bear solely the burden of funding the outer-planet atmospheric work and, therefore, will continue to a large percentage of funded outer planet atmospheric research.

The principle of eliminating overlap seems to be based on the notion that overlap within programs is inherently detrimental in all cases. Instead, we hold that carefully considered overlap of programs with differently organized scopes is essential to the health of the R&A program and is essential to meeting NASA's science goals that explicitly look to understand planetary bodies as complex, interacting systems. In 2006, The OPR program description stated:

> *The Outer Planets Research (OPR) program supports diverse scientific investigations that contribute to the understanding of the outer Solar System, including the giant planets, their satellites, and smaller solid bodies including comets, asteroids, and the Kuiper Belt. The program includes both data analysis from NASA missions and fundamental research.*

The objectives of the OPR program include:
• Enhancing the scientific return from the Galileo, Voyager, Pioneer, and Ulysses missions by continuing the analysis of their respective data sets through broadened scientific participation;
• Improving our understanding of the evolution of the outer Solar System, including the giant planets, their satellites, and other small bodies;
• Defining the dynamical processes operating in the outer Solar System;
• Providing further refinement of mission datasets to improve their usefulness to the general scientific community; and
• Creating data products useful to the broad scientific community.

Given that the outer planets have extensive atmospheres, that some of the most exciting, new outer planet findings are related to atmospheric processes (e.g., Titan's methane cycle and plumes on Enceladus), and that previous outer-planet missions (e.g., Galileo, Voyager, Pioneer, Ulysses) carried out substantial atmospheric studies, it seems almost inconceivable that the OPR program can meet its self-stated purpose and goals by excluding atmospheric research. Outer planet bodies exist as systems. Excluding the study of a major system component is self-defeating to the complete understanding of planetary bodies and weakens the OPR program. As currently implemented, OPR research cannot contribute as effectively to the understanding of "giant planets, their satellites and smaller solid bodies" as it could with the inclusion of atmospheric research (and Origins research).

The high percentage of outer-planet atmospheric research in PATM may also have a simple explanation. That is where the action is, and NASA should be directing resources to areas where mission dollars have gone, to where compelling scientific questions arise, and to where the overall scientific community (as determined by area of interest in proposals) feels there is good science to be done. To turn the argument on its head, the high percentage of outer planet atmosphere research in PATM shows the need for *more* resources in this area, not less.

Also, consider that high-quality proposals are perhaps being rejected in favor of potentially lower-ranked research when artificial barriers are imposed. In all years in which OPRP allowed atmospheres, those proposals ranked highly. In 2004, atmosphere proposals received much higher rankings than proposals on other topics (55% of atmospheres proposals were ranked Very Good (VG) or above; 22% of all proposals were ranked VG or above), yet a relatively large percentage of these VG atmosphere proposals did not get funded. Proposers of the VG proposals that were denied funding will likely turn to PATM as the only source of funding. In 2005, only 3 out of 16 VG proposals were funded in PATM.

Findings and Recommendations

In summary, it is our collective view that the removal of atmospheric research from consideration within the Outer Planets Research Program has had a detrimental impact on planetary science and on the fulfillment of NASA's strategic science goals. While the high percentage of outer planet research funded under PATM is undeniable, this consideration alone is not sufficient to exclude atmospheric research from OPR. PATM is not a *de facto* outer planets program when this sentiment is applied across the board to all combinations of NASA programs, and there are a persuasive number of reasons to reinstate atmospheric research into OPR. First and foremost, atmospheres are a critical part of the outer solar system, and an OPR program without atmospheres cannot address many of the important science topics listed in

NASA strategic planning documents. PATM is the only program that supports a broad array of outer solar-system atmospheric research. This constriction reduces the effectiveness of the NASA R&A program, impacts the ability of the OPR program to meet its stated goals and objectives, and risks the loss of critical scientific expertise, particularly junior researchers. Taken all together, the benefits of supporting atmospheric research in OPR significantly outweigh the disadvantages. It is important to note that the disadvantages can be mitigated and the advantages optimized by the Discipline Scientists, who work towards achieving program balance, rather than having a wholesale exclusion of a major component of outer-planet systems. In light of all the factors and issues raised in this paper, atmospheric research should be reinstated into the OPR program and recognized as a vital and necessary component of the OPR program. Specific findings are enumerated below.

Finding #1: PATM is not a *de facto* Outer Planet Research Program for atmospheric research. While PATM does fund a significant percentage of outer solar-system atmospheric work, the amount of overlap is completely in line with other NASA program combinations, including the overlap between OPR and PG&G. Other programs besides PATM fund a large percentage of outer-planet research and a large overall number of outer solar-system proposals.

Finding #2: Carefully managed overlap is healthy and necessary to a successful OPR program, as it is to the NASA R&A program in general. Outer planet research is by nature an interdisciplinary endeavor, with atmospheric science being one important component. As currently operating, the OPR Program cannot achieve its stated goals with the exclusion of atmospheric research. The overall quality of the OPR program, as indicated by the average ranking of the selected proposals, dropped when atmospheres were excluded from the program.

Finding #3: Exclusion of atmospheric research from OPR has had a detrimental impact on science and scientists. Proposal pressure within PATM and exclusion of atmospheric research from OPR has had a negative effect on outer-planet atmospheric researchers. Young and promising scientists are impacted most severely, having to rely solely on the highly competitive PATM program to fund their research. Senior scientists are limited in their ability to support students and post-docs, and this lack of resources negatively impacts NASA's ability to train the next generation of planetary scientists. Several compelling science topics, as indicated by the decadal study and other strategic planning documents, are no longer covered by the OPR program. Analysis of past datasets collected on outer-solar-system atmospheres is no longer covered by the OPR program, and such data may remain unarchived or unexplored with modern analysis techniques.

Finding #4: Research proposed within OPR should be funded based primarily on merit and relevance. Artificially excluding a major area of investigation from OPR has undoubtedly led to high quality research being rejected. Research should be funded based on its intrinsic merit and relevance to NASA's scientific goals. Programmatic balance can be invoked so as to prevent OPR from favoring one area of research too heavily.

Finding #5: The high number of outer-planet atmospheric research proposals submitted to and funded by PATM (and by the OPR program in its first two years) reflects the large number of atmospheric investigations conducted by past, current, and future planned missions and the broad

community interest in atmospheric science. NASA should be directing resources to areas where mission dollars have gone, to where compelling scientific questions arise, and to where the overall scientific community (as determined by area of interest in proposals) feels there is good science to be done. Limiting resources for these endeavors is counterproductive.

Recommendation: Atmospheric science research should be reinstated in the OPR Program. Doing so is consistent with these findings and provides substantial benefits to a balanced NASA R&A Program. With regard to the two primary reasons for excluding atmospheric research from the OPR Program, we find that PATM is not a *de facto* Outer Planets Program for atmospheric research when viewed in the context of other programs, and that exclusion of atmospheric research from OPR is not in the best interest of OPR, NASA, or the scientific community.