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WORKSHOP ON DISCOVERY LESSONS-LEARNED

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Lunar and Planetary Institute 3600 Bay Area Boulevard Houston TX 77058-1113
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WORKSHOP ON

DISCOVERY LESSONS-LEARNED

Edited by

M. Saunders

Held at
Washington, DC

June 14–15, 1995

Sponsored by
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Introduction

As part of the Discovery Program's continuous improvement effort, a Discovery Program Lessons-Learned workshop was designed to review how well the Discovery Program is moving toward its goal of providing low-cost research opportunities to the planetary science community while ensuring continued U.S. leadership in solar system exploration. The principal focus of the workshop was on the recently completed Announcement of Opportunity (AO) cycle, but program direction and program management were also open to comment. The objective of the workshop was to identify both the strengths and weaknesses of the process up to this point, with the goal of improving the process for the next AO cycle.

The process for initializing the workshop was to solicit comments from the communities involved in the program and to use the feedback as the basis for establishing the workshop agenda. By approaching the workshop in this manner, we were able to focus the workshop on the areas of highest interest. The workshop was designed to provide an opportunity for participants from each of the constituent groups (academia, industry, and government organizations) to present their own lessons learned, followed by four working sessions to consider issues relevant to each area and derive potential improvements to the process. The following four sessions were developed after reviewing and synthesizing both the formal feedback received and informal feedback obtained during discussions with various participants: (1) Science and Return on Investment; (2) Technology vs. Risk; Mission Success and Other Factors; (3) Cost; (4) AO/AO Process Changes and Program Management.

The chair of the workshop was Dr. David Bohlin from the Office of Space Science's Space Physics Division. Dr. Bohlin was the Chair of the Space Science Steering Committee, which reviewed the initial Discovery AO process to assure it was conducted properly. His previous experiences brought a well-informed independent approach to the workshop. We were also fortunate to have leading experts from each of the constituencies present their lessons learned as part of the initial workshop activities. These presentations were representative of the feedback received, positive and constructive, and highlighted the areas of greatest interest. The presenters focused their views on the areas that both enhanced their efforts to develop their proposals and those that inhibited their work, with the intention of ensuring that positive attributes were retained and the areas of concern were reviewed for improvements. Headquarters also presented lessons learned. Copies of each workshop presentation are included in this volume.

Following the presentations, workshop attendees separated into the four splinter group sessions to address the issues identified for that group, prioritize them, and develop potential resolutions to the most important ones. Each group was chaired by a representative from the communities represented who served as the spokesperson for the group. The sessions were extremely productive and drove straight to the heart of the issues. Crosscutting presentations were given in the morning on the second day, followed by further splinter group meetings. At the end of the morning the session chairs presented their preliminary findings.

The splinter group's presentations identified the principle issues discussed, potential solutions to the issues, and a number of alternative recommendations. These presentations revealed the interrelated issues among the different groups that must be integrated and synthesized into a coherent approach for them to be viable. To facilitate bringing the splinter group recommendations to closure, the workshop participants concurred with the establishment of a small steering group, composed of the four splinter group chairs plus several other representatives, to continue the work initiated at the workshop. The steering group was formed and assigned the task of completing their activities by the end of summer. Dr. William Boynton from the University of Arizona agreed to chair the steering group, and the membership included representatives from each of the three principal constituencies: academia, industry, and government organizations. The steering group was given the responsibility of adjudicating most of the comments and recommendations identified during the workshop and forming a complete integrated set of improvements for NASA to consider. The conclusions of the steering group are included in this report.

The activities of the Lessons-Learned workshop are having far-reaching effects on the Discovery Program as well as other similar programs in NASA. The issues, discussions, and preliminary recommendations of the workshop are being used in the Explorer programs and in new programs such as the Mission to Planet Earth's new program, Earth System Science Pathfinders. As all these programs use the same foundation of experiences, individual program implementation strategies are expected to converge, ultimately making the task of proposing to each different AO a similar process.

The success of this workshop is a direct result of input from the community, and the Office of Space Science wishes to thank all contributors to this process.

Logistics and administrative and publications support for this workshop were provided by the staff of the Lunar and Planetary Institute.

Program

Wednesday, June 14, 1995

8:00 a.m.	Introduction, Agenda	*Hampton Room*	**—David Bohlin**
8:15 a.m.	Program Status and Future Outlook		**—Jurgen Rahe**
8:35 a.m.	Science Community Perspectives 1. W. Boynton (Univ. of Arizona) 2. C. Russell (UCLA) 3. A. Binder (Lockheed/Martin)		
9:45 a.m.	Industry Perspectives 1. D. Roalstad (Ball Aerospace) 2. B. Clark (Lockheed/Martin) 3. G. Adams (Hughes) 4. J. Freitag (TRW) 5. D. Smith (Boeing) 6. D. Tenerelli (Lockheed/Martin) 7. D. Gump (LunaCorp)		
1:00 p.m.	Government / FFRDC Perspectives 1. S. Hubbard (ARC) 2. E. Davis (JPL) 3. L. Crawford (Applied Physics Lab)		
2:00 p.m.	Summary of Written Community Comments NASA Headquarters Perspectives		**—Mark Saunders** **—Mark Saunders**
2:45 p.m.	Splinter Group Objectives and Assignments		**—Mark Saunders**
3:30 p.m.	Splinter Group Sessions		
	1. Science and Return on Investments	*Calvert Room*	**—William Boynton (Chair)**
	2. Technology vs. Risk: Mission Success and Other Factors	*Embassy Room*	**—David Roalstad (Chair)**
	3. Cost	*Senate Room*	**—Lawrence Mitchler (Chair)**
	4. AO / AO Process Changes and Program Management	*Council Room*	**—Scott Hubbard (Chair)**

CHARTER: Develop recommendations for next AO

Thursday, June 15, 1995

8:00 a.m.	Splinter Group Sessions		
	1. Science and Return on Investments	*Calvert Room*	**—William Boynton (Chair)**
	2. Technology vs. Risk: Mission Success and Other Factors	*Embassy Room*	**—David Roalstad (Chair)**
	3. Cost	*Senate Room*	**—Scott Hubbard (Chair)**
	4. AO/AOO Process Changes and Program Management	*Council Room*	**—Lawrence Mitchler (Chair)**
10:00 a.m.	Plenary Session Splinter Group Reports and Discussions	*Empire Room*	
12:00 p.m.	Conclusions		**—David Bohlin, Mark Saunders**
12:30 p.m.	Adjourn		

Contents

Steering Group Recommendations

These recommendations of the Discovery Lessons-Learned Steering Group follow from a meeting in Washington DC on July 19 and a conference call on September 26. The membership of the steering group is William Boynton (University of Arizona, Lunar and Planetary Laboratory), Chair; Kevin Baines (Jet Propulsion Laboratory); Mary Chiu (Johns Hopkins University/Applied Physics Laboratory); Cynthia Faulconer (Lockheed Martin); Scott Hubbard (NASA Ames Research Center); Larry Mitchler (TRW Civil & International Systems Division); David Roalstad (Ball Corporation, Electro-Optical Subsystems); and Christopher Russell (UCLA, Institute of Geophysics & Planetary Physics).

ASSUMPTIONS

This section specifically does not contain the recommendations of the group, though we may agree with them. It states the ground rules of the environment in which we were working.

1. Though proposals could be grouped based on similar cost and evaluated independent of cost within that group, at some point low-cost proposals would have to compete with high-cost proposals with cost being a significant discriminator.

2. The new AO process will be the final selection; it will not select multiple proposals to be downselected later.

3. In the event the full \$150M is not available, the AO will state that it was targeted to proposals below a certain cost or spending profile, but the AO will never target just high-cost proposals (see rule number 1).

RECOMMENDATIONS

1. The proposal evaluation process shall take two steps. (a) The selection of successful proposals in the first step shall be based mainly on cost and a detailed science evaluation (including instrumentation). Information in the areas of technical approach and management shall also be evaluated to determine feasibility of the project. (b) The first step is a mandatory gate; only proposals selected by step 1 may be submitted for step 2. (c) The formula to be used for evaluation in step 1 shall be similar to the one used in step 2 as noted below.

2. Though a mathematical formula is proposed for the selection score, it is understood that the AA for Space Science will be able to use discretion to adjust for programmatic or other factors.

3. The formula for rating proposals following step 2 shall be:

$$\text{Score} = \text{ROI} \times \text{POS}$$

where

ROI = return on investment;

POS = probability of success;

$$\text{ROI} = \frac{(0.8 \times \text{Science} \times \text{Science Risk} + 0.1 \times \text{PA} + 0.1 \times \text{EO})}{(\text{Total Cost to NASA})}$$

PA = public awareness;

EO = educational opportunity

The science, PA, and EO scores shall be normalized by dividing all scores by the highest one in that category, i.e., the scores will range from 0 to 1 in each of these categories. (See recommendation 8 for details on applying science risk factors.)

Technology and small and small-disadvantaged business contracting plans shall not be part of the evaluation criteria.

The Total Cost to NASA is the proposed cost for all phases, A through E. It shall include direct costs, civil-servant costs, and launch-vehicle costs. Independent cost estimates determined by the review process shall be used only for accessing cost risk.

The probablility of success (POS) is determined by combining risk factors in the area of cost, technical approach, and management. The POS should describe the probability that the mission will succeed in meeting the cost and schedule targets and that it will succeed in delivering and servicing the science payload as required. (The probability that the science will be achieved is contained in the Science Risk term and is not considered here.) The individual risk factors are numbers ranging from 0 to 1, and they are to express the probability that the factor will allow the ROI to be to be realized, e.g., a cost risk factor of 0.98 indicates that there is little chance of a cost overrun; a technical risk of 0.3 indicates that the technical approach has serious flaws that make it unlikely that the mission will succeed. It should be understood that the risks in these areas are not independent, i.e., a poor management approach would certainly contribute to a cost risk. The evaluation process should combine all of these risks into the POS term, the probability of achieving the ROI.

4. For the first step in the process, the formula shall be modified such that PA, EO, and cost risk are not part of the evaluation. In addition, the combined weight of management risk and technical risk shall be reduced so that it cannot modify the ROI by more than a factor of 2 and technical risk shall be about twice as important as management risk. These criteria can be satisfied by limiting the dynamic range of technical risk to 0.4 (ranging from 0.6 to 1.0) and of management risk to 0.2 (from 0.8 to 1.0). Thus the formula for rating proposals following step 1 shall be:

$$\text{Score} = \frac{(\text{Science} \times \text{Science Risk}) \times (\text{modified POS})}{(\text{Total Cost to NASA})}$$

where

$$\text{modified POS} = (0.6 + \text{Technical Risk} \times 0.4) \times (0.8 + \text{Management Risk} \times 0.2)$$

5. The cost estimate in the step-one proposal should be considered to be a good-faith estimate of what the step-two proposal costs will be. Any growth between the first and second proposal shall have to be justified, and if not well justified, will contribute to an assessment of additional cost risk in evaluation of the step-two proposal. In no case may the costs increase by more than 15% between the first and second proposal. No form SF 1411 shall be required in the first-step evaluation.

6. The level of cost detail for step 2 shall be comparable to that requested in the first Discovery AO (see Table 1). The form SF 1411 shall be required only for the first phase to be funded, normally phase A.

7. The cost detail for step 1 shall consist of only the three exhibits required in the step-2 proposal.

8. The science evaluation shall not be based on simple adjectival grades. It should be scored using the science objectives listed in NASA and COMPLEX strategies as a guide. The score should reflect the number of objectives addressed, the importance of the objectives, and the thoroughness with which the objectives are addressed or answered. Determining the relative importance of different objectives may not always be easy, but it is noted that COMPLEX has consistently recommended a strategy of reconnaissance, followed by exploration, followed by intensive study with progressively greater science return from the more detailed investigations. The idea is that the later missions can build on the results of the earlier missions and return much higher science, but only if the groundwork is laid such that the more detailed mission can be designed to answer well-posed questions. Within these three categories, the COMPLEX and NASA strategies often ascribe priorities to different objects in the solar system, and to different objectives for a given object. These strategies can only be considered guides, and substantial discretion will need to be left to the scientific review panel. For example, because these documents may become dated based on U.S. or foreign missions that started after the documents were published, the panel can significantly reduce the importance of highly rated science that can be reasonably expect to be provided by another currently approved mission.

This score can be open ended in the sense that the more objectives satisfied, the higher the score. If one mission addresses twice as many objectives as another and they are addressed as well and are of equal importance, then that mission should score twice as high as the other mission.

The science risk reflects the probability that the science generated by the mission will ultimately be the science proposed. This risk should be assessed independent of the risks in the POS (discussed in recommendation #3). It should include risks associated with the instrumentation, the ability of the measurements to address the proposed science, the quality of the data management and archiving plan, and the quality of the science team. In order to permit the addition of one or more high-risk objectives to a mission, the science risk should be assessed and applied separately for each objective. For example, if a mission is proposed to an object that addresses two objectives very well and a third will only be addressed if some high-risk approach works, its science ranking would be higher than a similar mission that only proposed the same two objectives that could be achieved with little risk. (It should be noted, however, that if the reviewers determining the POS found that too much of management's attention was focused on the third objective, the overall rating could be lower.)

9. A suggested guideline for the AO schedule is:

- Step-1 proposals due 3 months after AO
- Step-1 results announced 2 months after due date
- Step-2 proposals due 2 months after results announced
- Final selection 3 months after step-2 due date

TABLE 1. Suggested step-two Discovery cost proposal contents.

Exhibits

1. Total program cost elements by phase by FY. (1)
2. Major tasks, total payload, and total spacecraft cost elements by phase by FY.
3. Flight subsystems (one level below total spacecraft) and instruments (one level below total payload) cost elements by phase by FY.

Supporting Data

1. Basis of estimates for exhibits 2 and 3. (2)
2. Major subcontractor data summary. (3)
3. Direct rates. (4)
4. Indirect rates. (5)
5. Other supporting data. (6)

Notes:

(1) Cost elements are labor hours, labor dollars, related payroll expenses, overhead, other direct costs, materials and material burden, major subcontracts, other subcontracts, general and administrative, and ICOM.

(2) The SOW defines the work/products to be provided for the CBS cell. Describe the method used to estimate the labor hours and cost, materials, and subcontracts. For hardware, include an equipment list for items greater than $1000 in value defining the major components and sources and necessary cost detail.

(3) Subcontractor summary includes task, identity, type, location, amount, contract type, adjustments and burdens.

(4) Direct rates by FY.

(5) Indirect rates by FY.

(6) Data necessary to evaluate proposal not provided elsewhere; such as conversions, escalation methods, cost centers, etc.

Minutes of the DLLSG Meeting

Attendees: William Boynton, David Roalstad, Larry Mitchler, Scott Hubbard, Cindy Faulconer, Mary Chiu, Mark Saunders

General background information was provided by Mark Saunders on the current NASA environment and on recent feedback on the Discovery Program provided by D. Goldin, A. Diaz, and W. Huntress. While these comments are not included in this summary, the overwhelming theme was that the Discovery Program was to emphasize low cost—a $150M program proposal would have to be EXCEPTIONAL. In addition, there would be no science "targeting" of proposals. Competition would be open to all disciplines, with both inherently less expensive science competing directly with inherently more expensive science.

M. Saunders stated that the following will be in the next proposal request: *Statement of Work for each Phase and Incentive Plan.* The Discovery Program may not have $150M available for each Announcement of Opportunity (AO). Saunders has stated that he would put in the amount available for each AO in the future, i.e., if only $75M is available, this will be stated up front in the AO along with a phasing of the funding.

W. Boynton suggested that the group initially plan to discuss three major topics: (1) Costs, what information (i.e., level of detail) is needed for proposal. (2) ROI equation (Return on Investment). (3) AO process (key point—one- or two-step process).

It quickly became clear that these three major topics are all interrelated and the discussions would have to iterate through these topics rather than make stand-alone decisions within these areas. The following summarizes the steering group meeting discussions in these three categories as well as conclusions about the Opportunity activities.

The group agreed that September 21 is the goal for completing the DLLSG activities.

AO PROCESS

A key decision was made fairly early was that the AO process would complete the competition phase. (In the first AO process there was a competitive phase A—this would not be the case in the next AO.) This decision was made to some degree based on W. Huntress' desire not to have another phase A competitive downselection, and was supported by the DLLSG. The rationale was that everyone wanted a definite decision made that would allow the winner to go forward and the nonwinners to move on to the next opportunity. Eliminate lingering lower-level effort, which tends to be inefficient and nonproductive.

The question of targeting the AO to a specific area was considered. The consensus was that if NASA determines in advance that there are reasons to do so, they should so state the areas of emphasis in the AO, but that the emphasis should not be exclusionary. The ability of the selection officer to exercise discretion when a clear case could be made was thought to be able to deal with most situations.

The group agreed that NASA needs to be as blunt as possible about available budgets and the desired type of mission, and should provide quantitative evaluation criteria so that industry does not waste valuable resources preparing proposals that will not get selected.

One-Step or Two-Step Process: The group concurred on the following overall goals of any change to the AO process: (1) Encourage growth, more participation (more proposals). (2) Lower life cycle costs. (3) Get "best" proposals possible. (4) Timeliness should also be considered.

Without defining the details of a two-step process, arguments could be (and were) made that #2 and #3 could be achieved by either a one- or two-step process. However, all agreed that given the decision that the AO process would decide the winner, only a two-step process would allow #1 above. Since the AO process ends the competition, enough information has to be given in the proposal to go directly to a contract. By definition then, the cost information, plans, statement of work, and so on must be detailed. Detail information drives up the cost of proposing, which can reduce the number of proposers (i.e., limited to those who can afford to spend large amounts of internal funds for B&P).

There were arguments that life-cycle costs could be reduced by either a one-step or a two-step process. It is true that if the two-step is not defined in such a way that the first step of the two-step process is at a significantly reduced cost, then lower life-cycle costs may not be achieved. (While not stated explicitly during the discussions, it is assumed here that the information content of the two-step process must be the same as that of the one-step process. The challenge is to define the minimum content needed for the first step of the two-step process.)

As an aside, with reflecting upon this later, there are some simple ways to test lower life-cycle costs. They rely on many assumptions, which can result in many scenarios. Three sample scenarios are given in the attached appendix.

While there are an infinite number of scenarios that can be imagined, the ones in the appendix illustrate a key point: A two-step process, even one with a relatively expensive first step (half of expected one-step process cost), reduces total life-cycle costs to the proposers as long as the total number of proposers stays constant. The most likely way a one-step process reduces the life-cycle costs is by reducing the number of proposers—an exclusionary measure that is directly counter to promoting growth and participation of the overall community.

It is still a valid point that a grossly ill-defined two-step process could result in increased life-cycle costs (to proposers as a group). The information content of the first step has to be reduced to decrease the cost of preparation—the minimum goal should be to reduce the first step of a two-step process to one-half of a one-step proposal.

A decision was made to use a two-step process (contingent on not defining a overly costly first step of the two-step process).

The group felt that the number of missions to proceed to step 2 should be in the range of six or seven missions. The group, however, also recommended that reason and logic be used. In other words, if five are closely spaced in the evaluation with all others way behind, then go with five. If eight are closely spaced, etc., you may want to go with eight. The idea was to keep the number of step-2 proposals large enough to ensure that interesting and implementable missions make it through but not too large that the AO LCC is big.

Contents of First and Second Steps: The definition of the contents of the first and second steps of the two-step process did not progress to final conclusions, but general agreement was reached on the basic contents. Three basic options were considered in the beginning for the first step: (1) Science only evaluation. (2) Science and technical approach evaluation (no cost or management). (3) Mini proposal.

While not fully discussed for definite decision, the general consensus seemed to be that the first step would be to downselect, not just rank proposals. It also seemed to be general consensus that a mini-proposal with emphasis on the science was the best, and a full science peer review panel was required to evaluate step-one proposals. However, there still needs to be a mechanism to ensure that the mission would not be more costly than presented. This meant that step one needs to include some level of detail on mission implementation and design in order to determine if the science mission was feasible and do-able. This generally requires the PI/industry/center teams to be formed and presented in step one. Based on these conclusions, there was a general consensus that the same evaluation criteria should be used for both steps one and two.

Bogeys were selected for page count of the step one proposal for each of the major topics as follows:

- Science including instrumentation, 25 pages
- Technical Approach including mission design, 10 pages
- Cost information, 5 pages
- Management Plan, 5 pages

The recommendation for the step-two proposal focused on a proposal content similar to the original AO, particularly since the outcome would be a mission selected for flight. This proposal, though, would build on the step-one proposal, particularly in the Science criteria. The content of the proposal might be as follows:

- Full up proposal with only changes to science (maybe 100 pages)
- More detail on implementation and design, management, and cost
- Smaller science panel to evaluate
- Evaluation based on ROI formula (same as step-one formula)
- Orals and questions as part of step-two evaluation (if necessary)
- Proposals must show all deltas (changes) from step one and step two. This is advised to avoid "buy-in" in step one.

Timeliness: Some discussion took place on the time needed for the two-step process. Following bogeys were discussed but not finalized:

- First-Step Responses 3 months after AO release
- First-Step Evaluation Completion 2 months after responses due
- Second-Step Responses 2 months after downselect
- Second-Step Selection 3 months after responses due
- Total time from AO release to final selection 10 months

COST DETAIL

There was some discussion on the cost detail needed for both the first and second step of the two-step process. There was general consensus that the cost detail for the first step should be limited to a budgetary estimate from the proposer with backup information at the discretion of the proposer up to five pages. Level of detail, e.g., WBS level, was not decided. L. Mitchler was to provide some detailed suggestions on the final cost detail needed through second step. Mitchler's response is attached (see section on Annotated Cost Instructions).

There was some discussion on penalties if the cost estimate provided for the second step was much greater than that of the first step. However, it was recognized that penalties were difficult to define. A higher cost has a built-in penalty given the ROI definition, which will be discussed below. However, there seemed to be some concern that a proposer could "buy-in" with a lower cost to get through the first step, and prevent a more realistically costed proposal getting to the second step. Blatant "low-ball" costs can most likely be flagged by reviewers and this should not be a real problem. However, "optimistic" costs vs. "pessimistic" costs may be difficult to distinguish given the fact that the first step is designed to contain less detail using a proposer's budgetary estimate. By nature, these estimates are probably only good to about 25%, and this must be recognized by the reviewers—that is, cost-risk evaluation for the first step must be very coarse. Saunders stated that it is probably best to downselect from the first step based on the top competitive range, rather than have an absolute maximum or minimum number to go to the second step. Given a competitive range selection and a coarse cost-risk criteria, an "optimistically" costed proposal could be within the competitive range of a "pessimistically" costed proposal, given that all other evaluation factors are the same. This would depend in part on the coarse cost-risk criteria. In fact, this might be a good litmus test for the coarse cost-risk criteria development. Saunders stated that there could also be a statement within the AO that allowed reviewers to downgrade proposals that had significant increases in cost between the first-step proposal and the second-step proposal. This allows the reviewers some latitude for evaluating cost changes between the two steps, while putting proposers on notice that such changes must be explained and could be counted against them. Realistically, with the ROI, any proposer with "optimistic" costs in the first step would be weeded out with higher costs in the second step given consistent science scores. Such a proposer only incurs more internal cost without winning final selection—not a sound business practice. This is a tough problem, and there may not be a perfect solution.

While not discussed at any length, a proposer's past performance should be given due consideration for the cost risk assessment. A copy of the latest was provided to Saunders and Mitchler.

RETURN ON INVESTMENT (ROI)

Boynton handed out a write-up of the definition of the ROI. There was general consensus that the ROI was a good way to ensure that only proposals that were of high quality across ALL categories would receive high scores and that "ROI" should be the basis for evaluation in each step of the AO process. (There was some perception stated at the workshop that a lower science score could be masked by higher scores in other categories such as cost. This should not be the case with a multiplicative scoring system.)

Boynton's proposal for Return on Investment was represented by the following formula:

$$\mathrm{ROI} = \frac{(0.8 \times \text{Science Value} \times \text{SciRisk} + 0.1 \times \text{Ed} + 0.1 \times \text{PA})}{\text{Total Cost to NASA}}$$

The definition of each of the above criteria is defined below.

Science Value: Science value is to be determined primarily by how well the proposed science objectives address the priorities determined by the strategy of the National Research Council (NRC) Committee on Planetary and Lunar Exploration (COMPLEX) and NASA's strategic plans. The score should reflect the breadth of the proposed investigation (how many objectives are addressed), the depth of the investigation (how thoroughly the objectives are addressed), the importance of the investigation (the priority of the objectives that are addressed), and the quality to which the objectives are addressed (the extent to which the proposed measurements are sufficient to address the objectives).

Another more subjective factor to include is the anticipated impact that the investigation will have on the field. It is suggested that the value for this factor be put on a linear scale with a high-quality mission (such as Voyager or Apollo) being 10 and a modest mission (such as Clementine) being 1. This is not a scale from 1 to 10; missions could have values greater than 10 or less than 1.

In order to use these scores in the algorithm, it will need to be normalized to unity. This can be accomplished by dividing all scores by the score of the highest ranked mission.

The way cost should be entered into the equation was still up for debate. One alternative was to have several (approximately three) bins of comparable cost, and once a mission was in a particular bin, cost would no longer be a discriminator against other missions in the same cost bin.

Science Risk (SciRisk): This term should be expressed as something that approximates a probability (from zero to one) and is determined primarily from instrumentation and the quality of the science team.

Technology Infusion was discussed as it relates to the science objectives and was agreed that technology infusion should not be given a separate score. The rationale for this is that the use of the new technology should already manifest itself by increasing the science or reducing the risk and would thus get into the score with an appropriate weight.

Ed and PA: These are Educational Program Activities and Public Awareness and their evaluation scores would be similar to the original AO.

FINAL EVALUATION SCORE

The final evaluation score should be a combination of ROI and Mission Risks based on the following formula:

$$\text{Score} = \text{ROI} \times \text{Risk}$$

where:

$$\text{Risk} = \text{Management Risk} \times \text{Cost Risk} \times \text{Technical Approach Risk}$$

Like science risk, these three terms should be expressed on a scale from zero to one and should be in the form of a probability. These terms will describe the probability that the criteria will cause the anticipated Return on Investment not to be achieved.

This scoring system does factor in costs at the 50% level. While this may not be what some parts of the community wants to hear, it is consistent with the current realities of NASA. And if the final algorithm to be used is provided in the AO, then everyone at least knows how the determination is being made. It also uses an assessment of science "value" for selection purposes, a theme that has always been associated with the Discovery Program.

OPPORTUNITY

The group agreed that the evaluation process must find a way to balance the technology vs. risk issue so that proposals are not up-checked for new technology/technology insertion and down-checked for risk at the same time. As mentioned in the ROI discussion, the group felt that technology should not be a separate evaluation factor since technology infusion would be driven by the science needs. Missions accomplishing great science by using new technology would be rewarded in their science grade. Risks associated with the new technology would be considered in the technical approach evaluation.

The group felt that technology transfer was a factor that did not enhance the overall evaluation and should be eliminated.

In general there was a consensus that that the SB/SDB factor imposes solutions that may not be optimal or most cost effective and the factor should also be eliminated.

The group also seemed to agree that the education and public awareness factors should be evaluated independently and included in the return on investment calculation.

OUTSTANDING QUESTIONS, ISSUES, AND CONCERNS

As noted in the text above, there were no final conclusions drawn by the DLLSG. The group agreed that further work would be done through telecons and e-mail until a final overall consensus could be reached. The members agreed that the next discussion should take place in mid August.

Several questions, issues, and concerns were expressed that would need further consideration. These were:

- Does the two-step process really reduce the life cycle cost of the AO?
- Will the two-step process take too long to implement?
- Will the two-step process let people through step one that shouldn't get through? And will it inadvertently shut out missions that really should progress to step two?
- Should the evaluation formula be multiplicative or additive? We discussed the idea that with "additive" some missions can survive that have major holes (because they make up points in other areas).

APPENDIX

COMPARISON OF TOTAL COSTS FOR ONE-STEP AND TWO-STEP AO PROCESSES FOR VARIOUS SCENARIOS

Below are some simplified calculations for evaluating relative costs of the one- and two-step AO process. Others may have different ways of viewing these... any alternatives would be interesting to discuss. I just used these to give me some insight into the sensitivities of various factors.

Scenario 1: Assume number of proposers are the same regardless of AO process—choose 28; assume that a downselect occurs after the first step; choose 10 for second step. Choose an average proposal cost of $1M. Assume that the first-step cost of the two-step process is half the cost of a one-step process.

One-step process: Proposals cost $1M to each proposer, total cost is 28 × $1M = $28M.

Two-step process: First step cost $0.5M to each proposer, first-step cost is 28 × $0.5M = $14M. Second-step cost is $0.5M to each proposer, 10 × $0.5M = $5M. Total cost for two-step = $19M.

Total costs to proposers as a group are lower in this scenario for two-step.

Scenario 2: Assume number of proposers are different—that number of proposers willing to risk $1M in the beginning is subset of 28—choose 14. Other assumptions the same as Scenario 1.

One-step process: Proposals cost $1M each, total cost is 14 × $1M = $14M.

Two-step process: First-step cost is $0.5M each, cost is 28 × $0.5M = $14M. Second-step cost is $0.5M each, cost is 10 × $0.5M = $5M. Total cost for two-step is $19M.

Total costs to proposers as a group are lower for the one-step process, but this is achieved only by the reduced number of proposers willing to "risk" the higher costs—a smaller "group." This is an exclusionary scenario that directly counteracts one of the goals of the AO process, which is to promote growth and participation.

Scenario 3: Same as Scenario 1 but with an increase in cost for the second step of proposal. Assume number of proposers are the same regardless of AO process—choose 28; assume that a downselect occurs after first step; choose 10 for second step.

One-step process: Proposals cost $1M to each proposer, total cost is 28 × $1M = $28M.

Two-step process: First-step cost is $0.5M to each proposer, first-step cost is 28 × $0.5M = $14M. Second-step cost is $0.75M to each proposer, 10 × $0.75M = $7.5M. Total = $21.5M.

Again, total costs to proposers as a group is less for the two-step process. However, it illustrates a very possible scenario in which the downselect winners incur more individual costs in a two-step process vs. a one-step. However, the increased costs per individual proposers are not necessarily mandatory and are somewhat under the proposer's control.

Annotated Cost Instructions

This copy of the Discovery AO cost instructions is annotated with questions and suggestions. In our opinion, the instructions are generally straightforward and appropriate for the second step of the next Discovery Program competition. We have made suggestions where we thought it would reduce the proposer's efforts or ease the evaluation process while still providing adequate data for evaluation.

II. COST PLAN

The cost plan should provide information on the anticipated costs for all phases of the mission. It should also describe the plans for tracking and controlling costs, or reference the applicable portions of Volume II or the Management Approach section.

The inflation index provided in Appendix E should be used to calculate all real-year dollar amounts, unless an industry forward pricing rate is used. If something other than the inflation index is used, the rates used should be documented.

A. Preliminary Analysis (Phase A) Cost Estimate. This section provides a detailed cost proposal for performing the Phase A Study. Detailed plans for the study should be described, but reference may be made to the Technical Approach Section of Volume II.

In completing this section, the following instructions will apply:

1. Contract Pricing Proposal.

(a) The cost proposal. It will include, as a summary of total proposed Phase A costs, a completed SF 1411, as included in Appendix C.

It is our understanding of the FARs that a 1411 is only required if there is no competition. In the case of Discovery there most likely will be much competition during both steps. A 1411 triggers certain cost proposal requirements regardless of the text of the cost proposal instructions. The 1411 may require more cost data than necessary or desirable.

(b) The SF 1411 must be signed by the proposer's authorized representative.

No comment.

2. Cost Elements Breakdown. To effectively evaluate the Phase A cost proposal, NASA requires costs and supporting evidence stating the basis for the estimated costs. The proposal will include, but is not limited to:

(a) Direct Labor.

(1) Explain the basis of labor-hour estimates for each of the labor classifications. Are labor classifications really useful?

(2) State the number of productive work-hours per month.

No comment.

(3) Provide a schedule of the direct labor rates used in the proposal. Discuss the basis for developing the proposed direct labor rates including the cost centers involved; the forward-pricing method (including midpoint, escalation factors, anticipated impact of future union contracts, etc.); and element included in the rates, such as overtime, shift differential, incentives, allowances, etc.

Cost centers needs to be defined. The term is ambiguous. We suggest that cost center be defined as a company, a NASA center, a university, etc. That is, each member of a team be defined as a cost center.

(4) If available, submit evidence of Government approval of direct labor rates for proposal purposes for each labor classification for the proposed performance period.

No comment.

(5) If Civil Servant labor is to be used in support of the Phase A study, but is not to be charged directly to the investigation, then this labor must be considered as a contribution by a domestic partner, subject to the same restrictions as other contributions by domestic or foreign partners (i.e., the sum of such contributions should not exceed approximately one-third of the Phase C/D development cost to NASA).

Trying to price contributions from civil servants was a problem. If total cost to NASA is to be the criteria then this contribution must be estimated. Perhaps the next AO could provide a formula based on Civil Servant labor hours.

(b) Direct Material. Submit a breakdown of material and parts, including basis for estimates and sources of supply, if known. Describe any pricing factors added to material prices, such as scrap, rework usage, etc.

Is this detail necessary? We suggest just a total materials cost for each priced CBS cell.

(c) *Subcontracts.* Identify fully each effort (task, item, etc.) to be subcontracted, and list the selected subcontractors, locations, amount proposed and types of contracts. Explain the adjustments, if any, and the indirect rates (or burdens) applied to the subcontractors' proposed amounts. Describe fully the cost analysis or price analysis and the negotiations conducted regarding the proposed subcontracts.

This level of detail seems appropriate for major subcontracts (<$500K), but not for all subcontracts.

(d) *Other Direct Costs.*

(1) Travel, Relocation, and Related Costs. (a) Indicate destination, number of work-trips, duration, and purpose. Specify total proposed cost of each trip.

Is this detail useful? We suggest number of work-trips, duration, and purpose along with total cost for all trips not individual trip cost.

(b) Explain or submit current company policy regarding the reimbursement of travel and relocation costs and the accounting treatment of such costs as direct costs or indirect expenses. Submit copies of Government approvals of such policies, as appropriate.

No comment.

(2) Computer. Describe the type of computer, the extent of usage, the rates, and the amounts. Explain where associated labor costs (programmers, operators, etc.) are included in the proposal.

This requirement seems to be a hangover from the old mainframe days. Nowadays, with rare exceptions, we only use PCs. Suggest that we just include the cost as a line item under ODC.

(3) Consultants. Indicate the specific task area or problem requiring consultant services. Identify the proposed consultants, and state the quoted daily rate, the estimated number of days, and associated costs (such as travel), if any. State whether the consultant has been compensated at the quoted rate for similar services performed in connection with Government contracts.

No comment.

(4) Other. Explain and support any other direct costs included in the Phase A proposal in a manner similar to that described above.

No comment.

(e) *Indirect Costs.*

(1) List all indirect expense rates and their respective cost centers used in the proposal. Indirect expense rates (in the context of this AO) include labor overhead, material overhead, general and administrative (G&A) expenses, and any other cost proposed as an allocation to the proposed direct costs.

No comment.

(2) If the proposal includes support services for which off-site burden rates are used, provide a schedule of the off-site burden rates. Include a copy of the company policy regarding off-site vs. on-site effort.

No comment.

(3) If available, submit evidence of Government approval of any/all projected indirect rates for the proposed period of performance. Indicate the status of rate negotiations with the cognizant Government agency, and provide a comparative listing of approved bidding rates and negotiated actual rates for the past five (5) fiscal years.

No comment.

(4) Identify separately any independent research and development expenses included in the G&A rate.

This requirement is unclear. We do not want to provide JR&D details in the proposal. Our G&A rates, which do include JR&D, are negotiated and approved by the Government.

3. *Phase A Time-Phased Summary.* Prepare a summary of the total Phase A estimated costs summarized by cost elements and time-phased by month. Note that direct labor hours and rates should be shown by category (e.g., engineering, manufacturing, etc.). Overhead (or fringe) applied to this labor may be shown by cost category or in total. Materials amount and subcontract amount should include burdens, as appropriate, and should be shown in total. Other direct costs should be shown in total. G&A and other indirect costs (such as internal research and development charges) should be shown as appropriate.

Is the cost spread by labor category by month really useful? For Phase A/B, we suggest that total cost and total labor hours for each CBS is most useful for evaluation. The CBS should be correlated with the SOW so it is possible to relate cost and labor to each part of the

SOW. Total cost, time phased by month or fiscal year, can also be provided. The SF 1411 does require time phasing. If the 1411 is not required then the Discovery program office can decide on the appropriate level of cost detail.

If the Phase A study has been completed, provide the actual cost data in the same level of detail as requested for estimated costs, to the extent possible.

No comment.

B. Technical Definition (Phase B) Cost Estimate. This section provides a cost estimate for performing the Technical Definition (Phase B) study. Plans for the study should be described, but reference may be made to the Technical Approach section of Volume 11.

If the Phase B study has been completed, provide the actual cost data in the same level of detail as requested for estimated costs, to the extent possible.

1. Completing this section, the guidelines for Phase A apply except that the Contract Pricing Proposal is ONLY REQUIRED FOR THOSE INVESTIGATIONS PROPOSED TO BEGIN IN PHASE B.

Same comments as for Phase A apply.

C. Design/Development Phase (Phase C/D). This section provides a detailed cost proposal for performing Design/ Development Phase C/D. Plans for the Design/Development phase (Phase C/D) should be described, and a correlation of the costs with the technical approach should be included. Reference may be made to the Technical Approach section of Volume 11.

This paragraph should just state that the costs should be correlated to the technical and management approach defined elsewhere in the proposal.

In completing this section, the following guidelines will apply:

1. Phase C/D Cost Breakdown. A Cost Breakdown Structure (CBS) for every year of the Design/Development Phase (Phase C/D) must be included in the proposal. This CBS shall be to the subsystem level (level 3) for the flight system, and for all other cost items at least the system level (level 2). The value of all reserves, contributions, the cost of launch vehicles and services, and any facility and equipment costs shall also be included.

Defining a level (level 2, level 3, etc.) causes us to create a CBS that is different than we usually use and makes it more difficult to relate to a SOW. We prefer that the instructions state something like:

Costs and BOEs shall be provided: to the subsystem level (ACS, Propulsion, etc.) for the spacecraft and to the instrument level for the payload. All other costs and BOEs shall be provided at the major task level (program management, systems engineering, etc.).

Regarding TDs and BOEs.

The SOW should be the TDs. It is redundant and perhaps confusing to require a SOW and TDs. The SOW defines the work/products to be provided for each CBS cell.

The BOE describes the methods and sources used to estimate the labor hours, cost, materials, and subcontracts at the required level. For hardware the BOE includes an equipment list with the major components their sources and heritage and cost detail where appropriate. The BOE needs enough detail so an evaluator can make a reasonable assessment of the validity of the cost proposal. Detailed material lists (resistors, wire, etc.) should not be required. A total materials cost should be adequate.

The Design/Development phase should be summarized by major elements of cost for each cost category in the CBS. The elements of cost for the Phase C/D cost estimates should include the following, as a minimum.

No comment.

(a) Direct Labor. List by labor category, with labor hours and rates for each. This should correlate with the workforce staffing plan discussed below in Section 2. If Civil Servant labor is to be used, but is not to be charged directly to the investigation, then this labor must be considered as a contribution by a domestic partner, subject to the same restrictions as other contributions by domestic or foreign partners (i.e., the sum of such contributions should not exceed approximately one-third of the Phase C/D development cost to NASA).

See previous comments on labor categories and civil servants.

(b) Materials. This should give the best estimate of the total cost of the bill of materials. Identify separately the estimated cost of major items, if known.

Major items should be defined. We suggest that major items be defined as important components of a subsystem (gyros, a computer, fuel tank, etc.) or costing more than some amount, say $ 100K.

(c) Subcontracts. List any major subcontracts (anticipated and known), and the basis for estimated costs.

Major subcontracts >$500K.

(d) Other Direct Costs. Include launch vehicles and services, facilities, and equipment. Any costs that are not covered elsewhere, including insurance, travel, etc., should be itemized here.

Itemization should be at a summary level by major category.

(e) Indirect Costs. This includes all overhead, general and administrative, fee, and any other miscellaneous expenses related to the overall business.

No comment.

2. *Provide a preliminary workforce staffing plan.* One that includes all management, technical (scientific and engineering), and support staff by fiscal year.

Perhaps this overall staffing plan is enough data on labor classification that cost by labor category is not required in a. above.

3. *The cost estimate.* It shall include all burdens and profit/fee in real-year dollars by fiscal year, assuming the inflation rates used by NASA (provided in Appendix E) or specifically identified industry forward-pricing rates.

No comment.

4. *Provide a description of the cost-estimating model(s) and techniques used in your Phase C/D cost estimate.* Discuss the heritage of the models applied to this estimate including any known differences between missions contained in the models and key attributes of the proposed mission. Include the assumptions used as the basis for the Phase C/D cost and identify those that are critical to cost sensitivity in the investigation. Discuss the project risks that result from an uncertainty analysis of the cost estimate and provide the attendant total cost estimate range these risks create. Discuss the methodology by which all cost risks will be identified, tracked, and mitigated by the technical management process applied in this investigation. Identify any "discounts" assumed in the cost estimates for business practice initiatives or streamlined technical approaches. Describe how these have been incorporated in the cost estimate and will be managed by the investigation team.

Suggest this paragraph be deleted. If a proposer uses models he/she can describe them in the BOEs. Risk analysis can be required as part of the technical and/or management sections.

5. *Provide a funding obligation plan.* One for the proposed funding requirements of the investigation by annum keyed to the work schedule.

No comment.

6. *Provide a schedule for accomplishing Phase C/D activities.* All funded schedule margins should be identified.

Schedules should be part of the management section but could be duplicated in the cost section.

7. *Contract Pricing Proposal.* (ONLY REQUIRED FOR THOSE INVESTIGATIONS PROPOSED TO BEGIN IN PHASE C/D).

No comment.

(a) The cost proposal. It will include, as a summary of total proposed Phase C/D costs, a completed SF 1411, as included in Appendix C.

Only required if there is no competition.

(b) The SF 1411 must be signed by the proposer's authorized representative.

No comment.

D. Mission Operations Phase (Phase E) Cost Estimate. This section provides a cost estimate for performing the Mission Operations for Phase E. Reference may be made to the Technical Approach section of Volume II. In completing this section, the guidelines for Phase C/D apply.

The C/D comments apply here.

E. Total Mission Cost (TMC) Estimate. This section should summarize the estimated costs to be incurred in Phases A through E including the following:

1. *Preliminary Analysis Study, Phase A.*
2. *Technical Definition, Phase B.*
3. *Design and Development Phase, Phase C/D.*
4. *Mission Operations and Data Analysis Phase, Phase E.*
5. *Launch vehicle, upper stages, and launch services.*
6. *Mission-unique costs to the Deep Space Network and other ground system costs.*
7. *Cost of activities associated with technology transfer and programs for social or educational benefits (if not incorporated in any of Phases A through E).*

This section should include: Detailed plans for all aspects of the mission not discussed elsewhere in this volume, including the launch vehicle, upper stages, and launch services; Deep Space Network and other ground systems; activities associated with technology transfer and programs for social or educational benefits. Reference may be made to the Technical Approach section of Volume II. In completing this section, the following guidelines will apply:

No comment.

1. Funding Profile Versus Time. A summary of the Total Mission Cost time-phased by fiscal year must be included in the format shown in Figure D2. Dollar amounts should be shown in real-year dollars. Total Mission Costs should be summarized in both real-year and FY92 dollars in the last two columns of this table. This summary should represent the optimum funding profile for the mission. Assets provided as contributions by international or other partners should be included, and clearly identified, as separate line items.

No comment.

2. Total Mission Cost Breakdown by Institutional Category. A summary of the total costs to NASA for the investigation, broken down by institutional categories (i.e., educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies) and using the template in Figure D3, should be included. Participation by small, minority- or women-owned, and/or otherwise disadvantaged businesses should also be highlighted, as should participation by historically black colleges and universities or by other minority institutions. Indicate the page(s) in the proposal where the participation of each institution is documented.

No comment.

F. Tracking and Phasing of Schedule Margins and Cost Reserves. Specific margins and reserves in cost and schedule should be identified by phase and year and the rationale for them discussed. The specific means by which costs will be tracked and managed should be defined. Specific reserves and the timing of their application, if needed, should be described within the proposal. This should include the strategy for maintaining reserves as a function of cost-to-completion. All funded schedule margins should be identified. The relationship between the use of such reserves, margins, potential descope options, and their effect on cost, schedule, and performance should be fully discussed.

This important requirement, which should also include a fee plan, probably belongs in the management section as part of the management plan. This is suggested because the reserve and management plan should be evaluated by management experts rather than cost experts.

Workshop Presentations

Science Community Perspectives

William V. Boynton, University of Arizona —

What Was "Right"?

Selection was by the book

- Politics had little to do with the selection
  - Exception: Getting Congress involved was deplorable
- Weighting factors were followed

Great care was taken to have a very rigorous review
Debriefings were very valuable and informative
AO was thorough and explicit

What Was Wrong?

Selection was by the book

- Weighting factors were followed
- Evaluation criteria were wrong (obviously subjective)

Community is in the dark as to what was selected and why

- Other than initial press release, I know of no description of the missions
  - Exception: Binder was liberal with passing out fact sheets
- What are the science goals?
  - How are they going to achieve them?

What is their education and outreach program like?
Other nonproprietary information would be useful

Perception = Reality?

Don't know

- More information from NASA would help

Science community support will be important for program to succeed (or continue)

- Code SL uses scientists to satisfy NASA's goals for the nation
- Scientists use NASA to allow them to advance their scientific understanding and create new knowledge for students

Openness at this point would allow the community to assess what is REALLY good and what is bad about the program and make suggestions for change

Science Community Attitude

Originally very enthusiastic about the Discovery Program

- ❖ As a way to do good science
- ❖ As a way to get project management more responsive to science
  University as a lead institution was an important part of that
- ❖ Peer-reviewed missions were thought to be a good idea
  Got mission selection out into the open

Much of the science community is now soured on the Program

- ❖ Rightly or wrongly
- ❖ Feels that cost was given too much emphasis
- ❖ Feels that many first-rate missions were passed over
  - Selected missions were not like those being recommended by committees
  - Selected missions were not "mainstream" but could have been

Perceived / Real Problems

Not a university-based program

- ❖ Originally Discovery sold as a partnership with universities, industry, and government with universities as the lead
- ❖ Evaluation made it difficult to run one of these from a university, even one with experience with large space projects
  - This was fair that the lesser experience of a university with big projects compared with, for example, JPL, be given some weight to compensate for the added risk
  - But there appeared to be no offsetting strength in having a university lead to balance
  - If NASA sees no advantage in the Discovery Program having more of a university component than past missions, it should state that explicitly

Difficulty in getting a competent review panel

- ❖ Most knowledgeable investigators were involved in proposals
- ❖ Requirement to eliminate even the hint of a conflict kept good people off the panel
  - Scientists could probably review the quality of the science but would be unable to judge the likely success of the approach

More Perceived / Real Problems

No way to fold programmatics and long-range strategy into selection decision

- ❖ Strategy means looking over the very long term (10–15 years) to formulate a program that gets the data necessary to answer the big questions
- ❖ National Academy of Sciences sets the strategy
- ❖ NASA is charged to implement the strategy
- ❖ Science evaluation (presumably) was on basis of its intrinsic merit and not much weight given on how it helps fill in the strategy

Opportunity was a sham
- Evaluation weights did not reflect the public rhetoric coming from NASA
- Pluses for use of new technology did not balance minuses from risk
- Education and public outreach were worth less than two percent of score

More Perceived / Real Problems (Costs)

Cost given too much emphasis
- Formal weight was only slightly greater than science
- Science was probably not ranked with the full dynamic range of cost (i.e., suspicion is that most science was good to excellent)
- Future cost to implement the NASA strategy not considered (for example)
  - A $200M mission with "very good" science that addresses half of the first-order science objectives for a body
  - A $300M mission with "excellent" science that addresses all the objectives
  - If the former is selected, another $200M mission is needed for a total cost of $400M vs. only $300M to do the one complete mission

More Problems with Cost Evaluation

Evaluation of cost on the basis of what NASA says it will cost, rather than what the proposer says, seems strange for a cost-capped program
- What is the award; what the proposer requests or what NASA thought it would take?
  - If the former, than it makes no sense to do the evaluation on the basis of the NASA-estimated cost
  - If the latter, it seems unreasonable for NASA to award more than the proposer asks for when its estimate is higher, and it seems unfair to award less, if its estimate is less than the proposer asked
  - But if the evaluation is based on a low NASA-determined cost, it seems unfair to the other proposers that the evaluation be based on one number and the award be given on the basis of another
  - If the policy is to award no more than what is asked, the evaluation should be on those costs and the appropriate risk assigned to success on the basis of the proposed cost

What Should NASA Do?

Decide what goals they want the program to accomplish for the nation
- Is education and outreach really important?
- Is technology transfer and infusion really important?
- How important is the small and small/disadvantaged business involvement?
- How important is university and student involvement?
  - Currently it is less important than minority involvement
- Is it really business as usual with missions being managed by NASA centers?
- Structure the program to reflect these goals

Make the words from NASA reflect the reality

Publish details on the missions

- From proposal: fact sheets, executive summary, science, opportunity, management

Evaluate costs on the basis of proposed costs and the risk of the proposer being able to do it at the proposed cost.

C. T. Russell, University of California, Los Angeles —

Discovery Experience

San Juan Capistrano

- ❖ PI—Venus Orbiter - IR/Lightning/Ions
  - ◆ Not selected
- ❖ Co-I—Mercury Orbiter - Imaging/Lidar/Magnetosphere
  - ◆ Selected for pre-phase-A study

Announcement of Opportunity

- ❖ PI—Diana - SEP mission to Moon and Comet
  - ◆ Not selected
- ❖ Co-I—Hermes - Mercury Orbiter
  - ◆ Not selected
- ❖ IDS—VESAT - Venus Orbiter - IR
  - ◆ Not selected

NEAR

- ❖ Team member, magnetometer

Science Advisory Experience

Space and Earth Science Advisory Committee
Space Science Board
Committee on Data Management and Computation
Planetary Science Data Steering Group
Numerous ad hoc studies
Participant in many planetary missions

- Apollo 15
- Apollo 16
- Pioneer Venus Orbiter
- Vega 1, 2
- Phobos
- Galileo
- Mars 96
- Cassini
- NEAR

The First Two Discovery Missions

Mars Pathfinder

- Seemingly arbitrarily chosen
- Principally an engineering mission
- Strong non-U.S. science contribution
- JPL appears to be managing it well
- Dead-end project

NEAR

- Had strong science support
- No apparent competition for spacecraft
- No apparent competition for mission operations
- Science team brought on late in project
- APL is doing a good job
- Should be a good first asteroid mission

San Juan Capistrano

The Numbers

- 73 Submissions
- 4 Selection panels
- 2 Ratings

The Process

- Oral presentation
- Evaluation of 10-page white paper
- Rapid decision on 10+ winners

The Result

- Surprise
- Uneven assessments by panels
- No coherence to selected program
- Obvious holes - lunar
- 10+ underfunded teams

Pre-Phase-A Study

- Too little money
- Too long a period
- Much thought and discussion
- Ideas and designs matured
- Seemed principally a holding pattern until the real program began
- Most progress when AO was imminent

The Draft AO

- Released in early 1994
- Helped guide final directions of pre-phase-A studies
- Enabled problems in instructions to be removed, reducing cost of proposal preparation and providing better balance in technical vs. cost sections of the proposal
- The resulting AO was good document
- The delay in the release of the AO was disconcerting
- The lowering of the cost cap after the AO was released was inexcusable

Selection Criteria in AO

- "Cost and Management" will have approximately the same importance as "Science, Technical Approach, and Opportunity"
- Science will be rated at approximately the same weight as the combination of Technical Approach and Opportunity
- Technical Approach will be weighted significantly more than opportunity
- Cost will be more important than Management

Lessons Learned

Science Objectives

- Neither NASA's nor the Academy's planetary exploration strategy was factored into selection.
- Quality of science was assessed but not the quantity. For example, two bodies completely explored were no more important than one body explored.
- Science ratings were quite different than we were used to experiencing.

Past Rankings	**Category**	**Result**
Excellent	1	May receive funding
Very Good	2	Consolation prize
Good	4	Kiss of death

Discovery Rankings	
Excellent	ok
Very Good	ok
Good	ok

Lessons Learned

Evaluation Process

- Science evaluation took place week of fall AGU meeting. The week most active planetary scientists are fully committed.
- Potential first-rate evaluators had to decline to participate due to prior commitments.
- Errors in interpretation and misunderstandings of the proposals occurred but no questions were asked. One of these misunderstandings was thought to be fatal for Diana!
- The one question that I was asked was addressed clearly in the proposal.
- It was clear early that the evaluation process was flawed.

Lessons Learned

Costing

- Costing is a very inexact science.
- Industry and NASA Centers are not very frank with each other about costs.
- Unexpected and unexplained costs were added by JPL at the last minute.
- Cost models were used to evaluate proposals that may have favored one set of approaches over another unfairly.
- Cost models are not available for SEP.
- Different proposers took different approaches to determining costs.

Lessons Learned

New Technologies

- Cost risk.
- Schedule risk.
- Cost models overprice new technology, especially SEP.
- Use of new technology is a net negative in proposal evaluation, no matter how important the introduction of that new technology.
- Solar Electric Propulsion would open up a whole new era of planetary exploration at reduced costs, yet it might as well have been the introduction of a new washer as far as evaluation was concerned.
- Use of old technology was rewarded.

Lessons Learned

Expense

- Discovery proposal preparation can be very expensive.
- Perhaps $0.5M was spent by many of the teams.
- Very good pre-phase-A studies resulted.
- Since selection did not seem to reflect the depth of the pre-phase-A study, much effort seems to have been wasted.
- If only "high-level" concepts desired then AO should say so.
- Community cannot afford the expense required to prepare Discovery proposals at this level on a continuing basis.

Lessons Learned

Partnerships

- Discovery mode necessitated partnerships: industry, centers, universities.
- Partnerships require meaningful sharing of responsibilities—ownership of part of the effort.
- Meaningful sharing of responsibility means complex organization charts.
- Complex management with checks and balances is viewed as a negative.
- A meaningful partnership with split responsibilities was a negative in the evaluation process.

Lessons Learned

Science Centers: Friend or Foe?

- ❖ Goddard and JPL have scientific as well as engineering efforts.
- ❖ These centers look out for their scientists.
  - ◆ do not work on competing efforts
  - ◆ refuse to assist unless center scientists involved
- ❖ These centers do not provide partial assistance, e.g., operations but not program management.

Conclusions

- ❖ Many mistakes appear to have been made in the evaluation process this time.
- ❖ Even if there were no mistakes, many questions whether in the presently constrained environment whether we can afford to fund merely good science.
- ❖ We need to learn how to correctly cost modern spacecraft, built in competitive environments. Too much of our cost experience is based on situations where funding was not capped and there was no competition.
- ❖ We need to learn how to evaluate science return quantitatively so that the science per dollar is known and factored into the evaluation process.
- ❖ Excellent selections will lead to a strong, continuing Discovery program.
- ❖ Merely good selection will lead to dissatisfaction with the program and its eventual demise.

Industry Perspectives

D. Roalstad, Ball Aerospace —

THE DISCOVERY PROCESS IS INNOVATIVE AND PROGRESSIVE

Improvements Experienced

IPDT is a winning ingredient formulation process.
- No force fits (some exceptions)
- Avoidance of intermediary functions
- Avoidance of institutional demands
- Smallest possible team

PI leadership for high science return
- Direct control of trades to maximize science
- Responsibility with authority

Manageable Programmatic Guidelines
- Cost and schedule (risk, technology, science, trades)
- Contingency management (PI responsibility)

Improved Procurement Process
- Demonstrated so far
- Improvements possible from recommendations

Progress has been made — "Lessons Learned will refine"

Cost — A Primary Issue of Concern

Can science return per dollar be determined?
Should cost outweigh science for AO selection?
Is AO proposal detail cost information meaningful?
Are innovative ideas squelched with early cost emphasis?
Should AO proposal cost information be eliminated?

Cost discriminators should be based only on well-studied concepts and engineering details.

B. C. Clark, Lockheed/Martin —

Discovery Missions — The Concept

A New Way of Thinking

- ❖ Mind-stretching
- ❖ Lag time in generating concepts
- ❖ Are we all in sync yet?

Architecture Fostered New Competitive Approaches

- ❖ Academia/industry/government forced on equal footing
- ❖ Emphasis on minimization of cost and complexity

Revolutionary Jump Beyond Performance-Based Specs

- ❖ Team defines the goals, program, and solutions
- ❖ Teams formed around program's needs (altruistic division of work tasks)

Essential to the Future of Planetary Science

- ❖ Multiple opportunities hold the scientists in the field
- ❖ Multiple opportunities foster industry interest and investment

What We Did

Outstanding Set of Worthy Missions

- ❖ Existence proof of excellent science at affordable levels

Multiple Potential Winners Led to Distributed Effort

- ❖ Major involvement in 8 missions (7 spacecraft, 1 integrated payload)
- ❖ Minor involvement in 2 other missions

AO Response was a Major Effort

- ❖ Not the typical AO; much more like an RFP and not unexpected
- ❖ Standardization of responses was not as feasible as hoped
- ❖ Work effort was excessive, but irrevocably locked into several proposals

Delays in AO Issuance was Major Perturbation

- ❖ Resulted in additional expense
- ❖ Difficult to keep team on track

Smaller, Less Complex is Indeed Cheaper

- ❖ Avoid big-program syndromes
  (exponentiation of communications and conservatisms)

Principle Investigator as Leader

Wide Range of PI Characteristics
- Ranged from instrument/experiment specialists to theoreticians
- Ranged from hands-on to hands-off approaches to management
- How can/did the evaluation team consider these variations?

Relationships of PI, Project Managers, and S/C Managers
- Academia/industry/government in novel relationships
- Stimulated revolutionary thinking

Good-PI Dilemma
- Each felt their science objective was sure winner
- Highly competent PIs already very busy; some also have talent for management
- PIs not always comfortable with highly structured schedules (science sets its own pace)

Team Building
- Scientists became engineers; engineers became scientists
- Badgeless, altruistic attitude developed

The Evaluation

Thoroughness Matched the Effort
- Large, systematic team evaluation commensurate with large, detailed proposals

Debriefs were Outstanding
- Thorough, specific, definitive
- Extremely valuable for assisting future actions

Focused Science
- The 1 to 3 instruments concept (San Juan Capistrano) not propagated to the AO
- Unclear if highly-focused science was favorable as expected . . . some downchecks from scientists (Catch-22 situation)

The Future

Evaluating the Science/Cost Ratio
- Cost is easy
- Science vs. science is more difficult to evaluate numerically
  - Begin with rank-ordering
  - Use adjectival descriptors (is the investigation essential? amount/fidelity of information? breadth of applicability?)
  - Pivotal to assign as large a point spread as possible

Should There Be a "Small Mission Set-Aside?"

- ❖ Balance between cheapest missions and more rewarding/more expensive missions
- ❖ Don't throw the baby out with the wash

Do Mars or Outer Planet or Asteroid Missions Have a Chance?

- ❖ Mars Surveyor Program
- ❖ Pluto Flyby Program
- ❖ NEAR Mission
- ❖ New Millennium Program

Relationships to Other Programs

- ❖ Mars Surveyor Program
- ❖ New Millennium Program
- ❖ Overlaps of mission goals/targets

Additional Recommendations

Consider a Multistep Process

- ❖ *Step 1:*
  Screening to reduce the field to a reasonable number of semi-finalists (8?)
  25 total pages, combined science/technical/outreach/management/cost
  (defer Outreach to Step 2)
  45 days to prepare and submit
  45 days to evaluate and down-select
- ❖ *Step 2:*
  Proposal using the '94 AO level of detail
  60 days to prepare and submit
  60 days to evaluate and down-select
- ❖ *Steps 3 and 4:*
  Proceed as currently planned (run-off between two or three finalists)

Cost Categorization and Definitization for Step 1

- ❖ Example: Nearest $25M increment estimated cost
- ❖ Clarify criteria: Total mission cost vs. peak funding vs. C/D funding

Cost Floor

- ❖ Hitting a barrier for several highly interesting and important missions
- ❖ Law of diminishing returns

J. Freitag, TRW Space and Electronics Group —

Discovery Program Represents a New Way of Doing Business

The Discovery Program was characterized by new ideas

- ❖ Fly a mission every 12 to 18 months
- ❖ Cap costs at $150M
- ❖ PI led partnerships with industry and government centers

Overwhelming response from industry, academia, and government centers

❖ San Juan Capistrano	73 Submissions
❖ NASA funded pre-phase-A studies	11 Missions
❖ Response to AO	28 Responses
❖ Chosen for implementation	1
❖ Chosen for phase A studies	3

It is encouraging that NASA has organized this workshop

- ❖ New ideas produced overwhelming response—and selection shock
- ❖ Without revisions, will the next AO receive the same response? Has it impacted Midex and New Millennium?

Discovery is one of several "new ways" of doing business with NASA

- ❖ Can these other "new ways" help refine the Discovery process?

Workshop Charter: Develop recommendations for the next AO

How Can TRW Contribute to the Goals of this Workshop?

Reaffirm Support and Enthusiasm for the Discovery Program

Encourage implementation of selected missions

- ❖ Allow selected teams to demonstrate their proposed competence
- ❖ Support notion that teams live up to their proposed responsibility
- ❖ Terminate when performance does not meet proposed performance

Identify issues for splinter group discussion

- ❖ Science and Return on Investment
- ❖ Technology vs. Risk: Mission Success; and other factors
- ❖ Cost
- ❖ AO/AO Process Changes and Program Management

Science and Return on Investment Issues

- ❖ Will current emphasis on low cost and risk reduction encourage conservative science for the next round?
- ❖ Should proposed Discovery Missions relate to NASA-defined solar system objectives and be evaluated according to their proposed achievement?
- ❖ Should the metrics of science return on investment be applied to all Code S-type programs?

Technology vs. Risk: Mission Success; and Other Factor Issues

- Were programs selected on their ability to propose acceptable risk, or the conservatism of the evaluation process?
- What is the impact on future AO responses when higher-risk missions are penalized during the evaluation process?
- If evaluators find a risk is unacceptable, should proposers be allowed to present additional data to show the risk is tolerable or there is an adequate risk mitigation?

Cost Issues

- Given the heavy weighting of cost during the evaluation, does a cost cap make sense or should a target cost be specified?
- Should the proposal/evaluation process be modified to allow the proposers to demonstrate cost credibility through new ways of doing business?
- Are current cost models adequate for evaluating 28 diverse mission proposals?
- Can incentives and penalties be built into the process that encourage more realistic proposals?

AO/AO Process Changes and Program Management Issues

- Are the length of the Discovery process and the investment resources required to support the process excessive?
- Would completion of science evaluation prior to partnership proposal preparation process reduce program process time and investment?
- Given the 24 proposals that were not winners, what is the basis for resubmitting any of these again? Would the same evaluation process be used in the next round?
- How does the Discovery "new way" of doing business relate to other NASA "new ways" of doing business?
- Will the New Millennium Program impact the AO content for the next round of Discovery?

Summary Comments

Discovery must do **more** science for **less** money

- Current climate: less money for science
- More knowledge is always better
- But what is the limit?

American needs a sense of priorities to guide diminished spending

- Federal R&D budget decline leads to industry budget decline
- Balancing federal budget and corporate efficiency must not jeopardize future

Can metrics be applied to **adequacy** of R&D spending

- American competitiveness in solar exploration
- Value of result vs. investment

Contributions from young scientists to maintain continuity of talent and progress

D. Gump, LunaCorp —

LunaCorp

- Founded in 1989 to find private funding for space exploration
- Formed Lunar Eclipse Software subsidiary in 1993
  - Authored/published *Return to the Moon* CD-ROM in 1993
  - Authored/published *Mission: Planet Earth* CD-ROM in 1994
- 1998 Lunar Rover Mission
  - Will land two teleoperated rovers on the lunar surface
  - Red Whittaker of Carnegie Mellon University Robotics Institute is designing and building the rovers
  - Mission cost is $150 million
  - Revenue from entertainment, television, corporate, and research customers
  - Public participation is key component of mission
    - Mission Control will be at theme park
    - Theme park visitors will drive the rovers live and explore via telepresence

Data Purchase as Discovery Option

- Discovery rules should allow the purchase of science data from commercial missions as alternative to NASA-managed projects
- Rules excluded LunaCorp in last round
- LunaCorp has offered NASA lunar surface data for low cost
  - $300,000 per payload pound
  - $7,000 per dedicated rover time
- Data purchase is only strategy likely to secure New Start funding from Congress

Data Purchase Contracts

- Data purchase contracts should have same progress payments and completion penalties as NASA-managed projects
  - Majority of contract money is paid out prior to launch
  - Launching the mission satisfies most contractor requirements
  - Successful return of data releases the final 10% of the contracted amount
- To protect government, the data seller must post bonds to guarantee repayment if mission doesn't launch. This should constitute the only financial test the company must satisfy.
- In comparing proposals, the costs should be all-inclusive:
  - Including cost of launch vehicle and launch site/range
  - Including estimates of the government's self-insurance costs
  - Including mission operating costs

THE LUNACORP TEAM

Thomas F. Rogers, chairman of the board. As Pentagon's Deputy Director of Defense Research and Engineering, he was responsible for the general design and deployment of the first global satellite communications sytem.

David Gump, president. Mr. Gump is founding publisher of *Space Business News*, author of *Space Enterprise: Beyond NASA*, and former marketer for Geostar Messaging Corporation.

Victoria Beckner, public relations and marketing manager. Ms. Beckner is a former political consultant, and as a NASA contractor she headed up public relations for the Microgravity Science and Applications Division. She is the founder and former editor of *Microgravity News*.

James Dunstan, executive vice president. Mr. Dunstan is a partner at Haley, Bader & Potts, an Arlington law firm active in communications and space law.

Rick Tumlinson, director. President of the Space Frontier Foundation in New York.

Philip Culbertson, advisor. Mr. Culbertson is a former general manager of NASA.

Walt Anderson, director. Founder of Mid Atlantic. He is now chairman of Esprit Telecom, the first pan-European carrier in the newly deregulated communications market in Europe.

Dr. William C. Stone, director. Dr. Stone is the developer of the MK-2R backpack, a computer-controlled diving rebreather.

Scott Carpenter, advisor. During the Mercury program, Scott Carpenter was the second American to reach orbit, piloting his Aurora 7 capsule in May 1962.

Paul J. Coleman, Ph.D., advisor. Professor of space physics at UCLA and President of the Universities Space Research Association, a 76-university consortium.

Patrick Quentin Collins, Ph.D., advisor. Former consultant at the European Space Agency's Research and Technology Centre, he has taught at Imperial College in London since 1983 and is currently a visiting professor in Japan.

Allan S. Hill, advisor. At Boeing and Northrup Space Laboratories, Mr. Hill designed and developed the Burner II and IIA Thor and Atlas upper stages and the Saturn S-IC booster stage.

Edward J. Martin, advisor. During his fifteen years at the Communications Satellite Corp. (COMSAT), Mr. Martin's posts included Vice President, Technology Management, and Vice President, International Operations.

George E. Mueller, Ph.D., advisor. Dr. Mueller is President of the International Academy of Astronautics. He was NASA's Associate Administrator for Manned Spaceflight from the start of the Gemini program through the second Apollo landing.

For more reference, see Popular Science, June 1994 issue, and Newsweek, December 5, 1994 issue.

Government / FFRDC Perspectives

G. Scott Hubbard, NASA Ames Research Center —

AMES CENTER PERSPECTIVE
Summary

Discovery is an excellent Program (a number of people deserve credit for making it happen)
Don't make drastic changes
Fine tune a few areas

Ames Support for Discovery: Past, Present and Future

Past:
Planetary science and project development at Ames consistent with Discovery

- Small/medium projects (Pioneers 6–13, Galileo probe), numerous PIs and instruments
- Development approach has been teaming with industry
- Minimize requirements growth, be cost effective, utilize small management oversight team

Participated in first Discovery Science Working Group in December 1989; all subsequent SWGs and workshops

Present:
Involvement in current Discovery project development

- Developed Mars Pathfinder (MESUR) mission concept at Ames in 1990
- Collaboration with JPL on Pathfinder entry/descent/landing system and instrumentation

Discovery AO selections—Ames-related involvement

- Lunar Prospector: NASA Center and Co-Investigator
- Venus Multiprobe Mission and Stardust: Co-Investigators

Future/Summary:
Discovery represents a unique opportunity for planetary missions

- Open competition peer review is the best mechanism for selection
- Process is complementary to proposed Ames Institute

Discovery AO General Comments

AO accommodated a wide range of proposals

- Diverse scientific and technical interests should be maintained

Overall, the AO was clear and provided the background and guidelines necessary to write the proposals

- Some repetition could be eliminated and details improved

The importance of science/cost ratio was not fully appreciated by all proposers

- Prior instrument AOs were based primarily on science excellence
- Future AOs should maintain the emphasis on cost containment

Proposals required significant resource commitment

- Necessary aspect to yield high-fidelity cost data, but may limit participation

Discovery AO Detailed Comments

Rapid procurement process was enabled by Discovery process

- Certification (SF-1411) of cost data was key to rapid contract award
- Funding level uncertainty and delay in funding arrival at center slowed process
- For consistent interpretation of "selection statement" might seek statement from HQ procurement

Some budgetary terms were confusing

- For example, cost vs. price, "contributed cost" vs. "actual" dollars
- Provide more clarification in future AO

Small Business and Small Disadvantaged Business goals were very challenging

- Could lead to significant risk in management complexity; performance should be reviewed as program progresses

Program Management Plan was not approved prior to the AO release

- The draft plan should be finalized and published

The requirements to incorporate new technology and minimize risk are contradictory

- Need further discussion of the role of new technology

Provide cost requirements in a more easily understandable format

- Mixture of FY92, real year and current year costs were confusing

Ames and Discovery: Summary

Overall Discovery AO process was very positive

Discovery AO allowed a broad range of proposals

- Maintain this aspect

Continue to emphasize cost-effective science

- Science/$$ is the bottom line for healthy future

Fine tune process in certain areas

E. Davis and E. Kieckhefer, Jet Propulsion Laboratory —

Observations, Thoughts, Issues

- Generally the Discovery concept is valid and is working
- Improvements can be made in the process, some significant—focus on these
- Discovery was a huge paradigm shift with significant and steep learning curve—but now we know, and it will be easier the next time
- Overall, the amount of effort and/or investment required to get to the final outcome was too high
    - Significant NASA, industry, and JPL investments
- Continue to form partnerships early—PI, IP, and JPL
    - Wait until final AO to form proposal teams
    - Use draft AO period to check the science, cost, and players to confirm proposal concept validity
- Don't change goal posts in the middle of the process
- Focus on the AO; eliminate other up-front effort
- Have a draft AO with final AO 60 days later and allow 90 days for proposal preparation; stick to the schedule
- Simplify the AO and the proposal outline and contents—provide a very clear concise definition of the required proposal contents and only ask for information once and only that needed for evaluation
- Select the next Discovery Mission starts (#5 and #6) directly from the proposals; don't do a two-phase selection or down-select
- The Discovery process with partnering/teaming and NASA HQ selection greatly streamlines the procurement process
- Continue and improve the JPL Locomo thrust and workshop
- Continue dialog with industry to improve partnering and teaming arrangements
- Find a better way to link the Discovery Program's outcomes with Code SL's fundamental science goals
- The evaluation outcome did not meet expectations with regard to technology infusion/application
- The phase A funding shortfall was a rude surprise; don't do this again
- Must support the selected missions' negotiated funding profile

L. J. Crawford, E. L. Reynolds, and R. W. Farquhar, Applied Physics Lab, Johns Hopkins University —

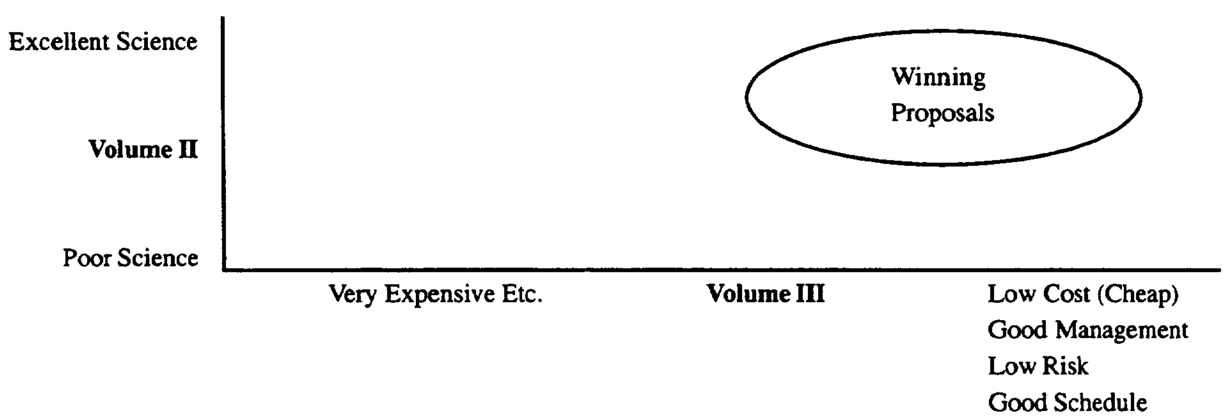
JHU/APL Proposal Involvement

- COmet Nucleus TOUR (CONTOUR)
- Near Earth Asteroid Returned Sample (NEARS)
- REndezvous with a COmet Nucleus (RECON)

Presentation Outline

- Announcement of Opportunity
- Evaluation Process
- Debriefing Process
- Technology vs. Risk
- Evaluation Criteria
- Science vs. Cost
- Program Management

NASA's Discovery Program Selection Process



Major Shortcomings

Concept of "Highest Science Per Unit Cost" is fundamentally flawed.

- Cannot establish minimum "science floor"
- Drives community to "lowest common denominator" science

Reliance on model to provide government-generated costs was unfortunate.

- Model over estimate costs
- Models do not reflect new ways of doing business

Use of industrial contractor (SAIC) in evaluation process was inappropriate.
Minimal use of contractor's past performance in source selection not in step with current government trends.

- Minimum weight of 25% for past performance is new federal guidance

Alternative Discovery Selection Process

Establish two or three classes of Discovery Missions, then don't compete on basis of cost (will max science for each category)

Launch Vehicle	C/D Cost Range ($FY92)
1. Delta-2	100–150
2. Med-Lite	50–100
3. Pegasus	<50

Compete missions within each class.
Science value is primary factor in selection.
Discovery Program would include some mix of mission classes [content of mix: TBD].

Announcement of Opportunity

Too much information was requested (e.g., cost)
Not enough page allotment for amount of information requested
Next AO should contain numerical weights for each selection criteria
Use only "one year dollars," not several, e.g., 92, 94, real year

Evaluation Process

- Evaluation process was defined and describable.
- Scatter-chart approach instantly removed missions viewed as moderately expensive and very expensive, even though they had excellent science and remained under the $150 M cost cap.
- Aggressive missions with substantial science return were penalized because they were compared with simpler, cheaper missions primarily on the basis of cost.
- Use of industrial contractors like SAIC in evaluation process is inappropriate.
- Use of contractor-demonstrated performance in evaluating ability to deliver (cost, schedule, technical performance).
- Reasonableness of contractor cost estimates.
  - Don't just use government cost estimates derived from models (models are known to overestimate).
  - New guidance issued by the Office of Federal Procurement Policy (OFPP) recommends using past performance (weighted at a minimum of 25%) for source selection in government contracts [ref. Federal Contracts Report 0014-9063/95, 5/8/95].
- Process was very much business as usual and did not reflect new ways of doing business.
  - Hard to see that innovation was rewarded.

Debriefing Process

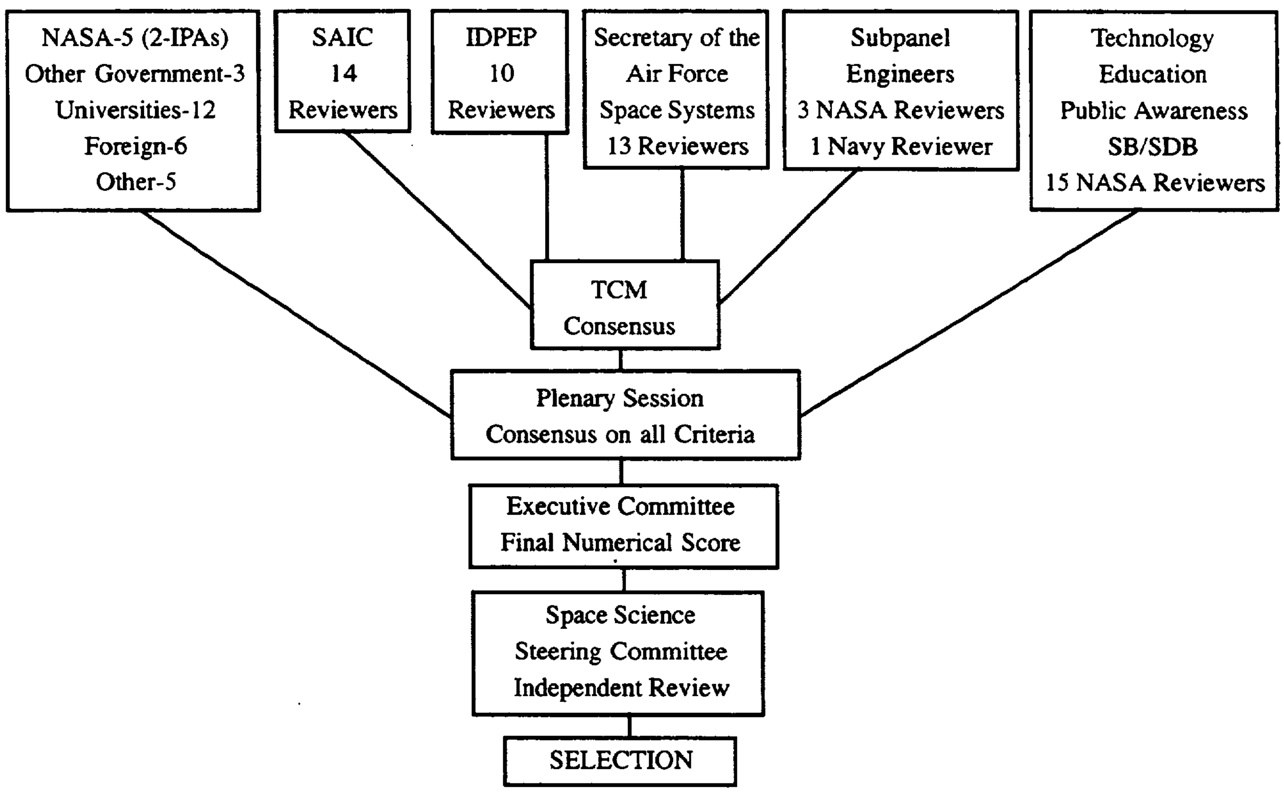
- Debrief sessions were very useful, informative, open, well executed.
- State the weighting factors for each category.

Technology vs. Risk

- Proposals were both rewarded and penalized for new technology insertion.
- Discovery originally used verbiage like acceptable risk.
- NASA obviously wanted low cost, low risk; science no longer a primary driver.

Evaluation Criteria

- Science value should be increased above 25%.
- Vol. II and Vol. III proposal scores should be developed independently if similar approach is used in future.
  - The technical, cost, and management evaluation team helped to determine both Vol. II and Vol. III scores!!



Science vs. Cost

- Concept of "highest science per unit cost" fundamentally flawed. Drives community to "lowest common denominator" science.
- Cost should not be the overriding factor for mission selection.
  - Establish whether program is within cost cap and then ignore costs as a selection criterion.
- Science should override all other factors if costs are within caps.
- Establish classes within Discovery so as to not penalize aggressive missions.

Program Management

- Cost models.
  - Models used for evaluation should be given to all proposers.
  - Cost data should have no page limit.
  - Since models were used to determine cost, why was so much cost detail required?
- NASA may have established a new cost cap for Discovery by accepting a $59M program.
  - If left unchanged, a void of science missions that exceed the $100M cap would be created.
- NASA allowed too much visibility of the selection process—consequence was that other criteria could not be factored into process.

Summarized Written Community Comments

Mark Saunders, Discovery Program Manager, NASA Headquarters —

Community Response

- Written comments were limited:
  - 2/3 of comments were submitted by Evaluation Panel membership
  - 1/3 submitted by members of Discovery missions
- 2/3 substantial verbal comments during debriefings; not covered here
- 1/3 comments came in four varieties: compliments, criticisms, suggestions for improvements, and questions

Compliments

- Discovery approach continues to be positive and AO implements Discovery goals/approach
- Teaming approach with PI in charge is efficient and effective
- Shifting risk management to teams puts mission assurance where it belongs

Criticisms and Suggestions for Improvement

AO

- AO needs refinement to be more effective; too excessive for this stage
  - Responses cost too much
- Conduct some form of two-step process that selects a small number of proposers from a summary proposal; request additional info from selected group
- Mission cost should not be the overriding factor for mission selection; the best science within the "cap" should override all other factors
- Page limits penalized aggressive missions since more information was required to describe missions

Science

- It appears that the central guiding principle of Discovery getting the most science for the dollar was not utilized in the evaluation process
  - A credible means of computing science per dollar is needed
- A minimum threshold for science, as well as other criteria, should be established
- The science evaluation should be based on the established Solar System Exploration priorities
- Science criteria weight was too low; should have been at least 50%
- Some policy for extended missions is needed

Technical Approach

- Considering technical risk in both the technical approach and cost criteria is double jeopardy
- Instruments should be considered as part of the technical approach
- New technology should not have been penalized in technical approach, since phases A and B are there to deal with these issues

Opportunity

- SB/SDB participation, as well as other opportunities, may be too immature to include in the AO

Management

- Organizational experience was not considered in the evaluation of proposals

Cost

- AO required costing detail, which is inconsistent with stage of definition
- Complete and accurate cost evaluation of 28 proposals was an impossible task
  - Sufficient documentation typically takes thousands of pages
  - Cost-estimating techniques are not sufficient discriminators
  - Cost model used in evaluation is inaccurate and not suitable
- Exclusion of organizational cost performance was a fundamental flaw
- Setting a cost target, as the mid-point, as well as the cost cap might help
- Provide incentive/penalties to encourage accurate proposals

Questions

- How can more challenging scientific objectives be rewarded instead of penalized?
- How should the 24 missions not selected consider their chances in the next round?
  - Some feedback from NASA would be helpful
- How does Discovery relate to other NASA programs, e.g., New Millennium, PIDDP, etc.?
- How does new instrument development play?
- Should cost even be a criterion?
- A number of questions were asked about the evaluation process and results

NASA Headquarters Perspectives

Mark Saunders, Discovery Program Manager, NASA Headquarters —

General

- AO, evaluation methodology, and evaluation process worked, but can be improved
- Resource investments by both proposers and evaluators were extensive
  - Some other process needs to be explored to reduce investments
- Execution of contracts was quick, but can be improved by requiring statement of work as part of proposal
- In current environment, there are some program constraints that are nonnegotiable
  - Method that allows big and small missions to compete against each other is required
  - Assuring adequate cost estimating protects both NASA and proposers

AO

- Despite statements in AO and repeated attempts to advise community about importance of low cost, some never appreciated its significance
- Five evaluation criteria worked well, but could be assembled differently:
  - Science and Return on Investment (ROI)
  - Probability of achieving scientific objectives
    - Technical Approach
    - Management Approach
    - Experience
    - Likelihood of making it within cost and schedule
  - Other factors, e.g., opportunity
- Identifying weights of criteria would have helped proposers
- Providing funding profile would have helped proposers
- Since we plan to release AOs every 18–24 months, we should limit launch window or provide 2 flight opportunities with specific windows for each

Evaluation Methodology

Science

- Prioritizing intrinsic merit of various targets/objectives would have helped both sides
- Simple evaluation method for science, when combined with other criteria, may not have completely represented spectrum of science quality
- Mail reviews would have been nice but would have lengthened process
- Having cost weighed slightly more than science achieved our goal of making small, modest science missions competitive with more expensive/extensive science missions, but there may be better algorithm for science ROI

Technical Approach

- Assessment of risk is valid, and is necessary constituent of technical approach
  - May be better way of balancing risk vs. technology infusion and scientific scope
  - Dependent on overall acquisition strategy that may differ from AO to AO
- Some info was more important than others; would help to reduce data to that which is most important

Opportunity

- Too much may have been expected at this stage in areas of technology transfer, education, public affairs, and small/small-disadvantaged businesses
- Most important is degree of commitment to each in terms of organizational and financial resources
- Technology infusion might have more emphasis in future solicitations

Management

- Worked well, but certain areas could be adjusted to help proposers, e.g.:
  - Considering key position qualifications as well as key personnel experience
- Some info was more important than others; would help to reduce data to that which is most important

Cost

- Absolutely most difficult area to evaluate; struggled with both techniques and consistency with program objectives
- Conducted multitude of sensitivity analyses to confirm conclusions
- Despite assertions to contrary, cost analysis techniques used did not skew conclusions
- Another way to assess cost that assures fairness to all proposers and NASA is welcome
  - "Trust Me" (not assessing cost) will not serve either side well

Evaluation Process

Diverse science and technical teams provided sufficient viewpoints to assure fairness across all proposals and consideration of new ways of doing business

Executive committee participation from start to end was beneficial and reduced overall labor and time

Revising evaluation flow and better allocating resources would improve evaluation process

A two-step process, similar to MIDEX AO, is possible while still achieving Discovery objectives

Two-step Process — one option

Step #1:

1. Submit first half of proposal, which encompasses science proposal including mission design; include one-page summary of proposed cost; include basic management organization and team membership
2. Evaluate science and ROI; select subset to proceed to step #2

Step #2:

1. Submit second half of proposal, which includes technical approach; management and cost sections plus any changes to science
2. Evaluate step #2 proposals based on three criteria previously described: (1) Science and ROI; (2) Probability of achieving scientific objectives; (3) Other factors (Opportunity)

Note: Other factors (Opportunity) could be included in either step depending on emphasis

Timeline:	Step #1 proposal preparation	3 months
	Step #1 proposal evaluation	2 months
	Step #2 proposal preparation	2 months
	Step #2 proposal evaluation and selection	3 months

Splinter Group Sessions

Science and Return on Investment (ROI) — W. V. Boynton

Return on Investment should be determined by the following formula:

$$ROI = 0.8 \times Sci \times SciRisk + 0.1 \times Ed + 0.1 \times PA$$

Science Value (Sci)

Science value is to be determined primarily by how well the proposed science objectives address the priorities determined by the strategy of the National Research Council (NRC) Committee on Planetary and Lunar Exploration (COMPLEX) and NASA's strategic plans. The score should reflect the breadth of the proposed investigation (how many objectives are addressed), the depth of the investigation (how thoroughly the objectives are addressed), the importance of the investigation (the priority of the objectives that are addressed), and the quality to which the objectives are addressed (the extent to which the proposed measurements are sufficient to address the objectives).

Another more subjective factor to include is the anticipated impact that the investigation will have on the field. It is suggested that the value for this factor be put on a linear scale with a high-quality mission (such as Voyager or Apollo) being ten and a modest mission (such as Clementine) being one. This is not a scale from one to ten; missions could have values greater than ten or less than one.

In order to use these scores in the algorithm, it will need to be normalized to unity. This can be accomplished by dividing all scores by the score of the highest ranked mission.

The way cost should be entered into the equation was still up for debate. It was felt the best way was to have several (~3) bins of comparable cost, and once a mission was in a particular bin, cost would no longer be a discriminator against other missions in the same cost bin.

Ed and PA are Educational Program Activities and Public Awareness

Science Risk (SciRisk)

This term should be expressed as something that approximates a probability (from zero to one). It is determined primarily from instrumentation and the quality of the science team.

It was felt that Technology Infusion should not be given a separate score. The rationale for this is that the use of the new technology should already manifest itself by increasing the science or reducing the risk and would thus get into the score with an appropriate weight.

The final score should be a combination of ROI and Risk.

$$\text{Score} = \text{ROI} \times \text{Risk}$$
$$\text{Risk} = \text{Management Risk} \times \text{CostRisk} \times \text{Approach Risk}$$

Like science risk, these three terms should be expressed on a scale from zero to one and should be in the form of a probability. These terms will describe the probability that the area will cause the anticipated Return on Investment not to be achieved.

The question of targeting the AO to a specific area was considered. The consensus was that if NASA determines in advance that there are reasons to do so, they should so state the areas of emphasis in the AO, but that the emphasis should not be exclusionary. The ability of the selection officer to exercise discretion when a clear case could be made was thought to be able to deal with most situations.

Technology vs. Risk: Mission Success and Other Factors — D. Roalstad

The thrust of this splinter session was to identify those technology vs. risk issues as they relate to mission success and other factors. First we had to define what constitutes mission success and the other factor elements. These elements include technology transfer, technology infusion, SB/SDB infusion, education, and public awareness.

A process established for the session was to list all technology vs. risk issues relating to mission success and other factors we could think of. Reviewing these issues with at least a subjective assessment of priorities, we developed a preliminary set of recommendations. These issues and recommendations were then presented in a plenary session to the fall workshop. An attempt has been made in this report to capture the comments received, but I'm sure more thoughts will be generated in the months ahead.

Following are charts summarizing the session results:

DEFINITIONS AND SCOPE

Mission Success is determined by accomplishing the floor science defined by the proposing PI.

Floor Science is defined as the minimal science the PI is willing to fly.

OTHER FACTORS

- Technology Transfer
- Technology Infusion
- SB/SDB Requirements
- Education
- Public Awareness

ISSUES

- Take risk but don't fail perception is a conflict.
- Technology demonstration before science mission — is that necessary?
- How much should science missions push the technology envelope?
- What reliability level is adequate for mission sources?
- How is science downgrade vs. risk treated?
- Go/No Go vs. 2% weighting factor on other factors.
- Other factors — goal vs. objective.
- Reasonable levels for other factors.
- Acceptable launch risk level.

ISSUES DISCUSSION

- There is a perception that the agency cannot accept any failure that is in conflict with statements to accept higher risk levels. This environment results in a gap between proposers and reviewers on what is acceptable—very subjective at best.

- There is a growing concern that technology must be demonstrated (e.g., New Millennium) before use on a science mission. Science by its very nature tends to utilize new technology that is unique to the PI's science, which has been under development in university laboratories. Technology output has been one of the best added-value products of science missions.

- Reasonable reliability levels of parts subsystems and systems can be prescribed and achieved for science programs to mitigate risk.

- Science objectives can be reduced from the desired level to the floor with a logical plan should risk assessments dictate. The PI now has responsibility and authority to manage with firm guidelines.

- The AO implies that there is a 2% (approximately) weighting factor applied to other factors, yet the perception is that a Go/No Go criterion is applied to the proposal evaluation.

- Other factors are currently defined as objectives for the proposers with excessive levels. Would goals be more appropriate with reasonable levels?

- Launch risk levels are as important to the mission as is the space segment hardware—what is acceptable?

RECOMMENDATIONS

- Mission success should be defined as accomplishing the floor science established by the PI. The PI will propose science levels for accomplishment that are in excess of the minimum below which he would not fly. Therefore, the "floor" level of science is the minimal level of science the PI believes to be scientifically justifiable for flight. Should he not be able to achieve this level of performance within other program guidelines, he would terminate the program.

- Discovery Mission should be science driven, not technology driven. However, new technology is generally essential to the science objectives proposed. New technologies proposed should be identified and a development plan provided that will bring these technologies to level 6 by phase C/D start and level 8 by launch. (Ref. NASA Code R document for technology development state.) Launch services should demonstrate these same levels.

- Other factor elements are generally a result of social-political mandates on the program and can be managed. The consensus, however, was that the SB/SDB levels of 8%/8% for a total of 16% of program value is excessive and that all other factors should be established as goals rather than firm objectives. All functions, as currently mandated, can be accomplished at added expense to the program and could detract from the primary science focus. For maximum efficiency on achieving lowest cost we want high focus and the shortest possible schedule.

- Cost growth is the risk element in having to perform other factors where minimal experience exists for levels that are significantly above those previously experienced. For one-of-a-kind types of missions, the technology problems are most difficult to manage, requiring highly focused team attention. Forcing work into the SB/SDB adds to subcontracts management and communication burden as a schedule and cost risk.

- The bottom line from our session was that other factors could be managed as is with some cost and schedule risk to the program. The preference was to recommend goals rather than objectives and to reduce SB/SDB requirements to more reasonable levels; 8–10% total. Perhaps a more efficient process can be established that doesn't place an abnormal burden on the science team that is desperately trying to maintain focus.

Cost
— G. S. Hubbard

Note on Models

Models useful for sensitivity and risk analysis for:
- a given mission
- by a given team
- a specific management plan
- similar system requirements

When making comparisons between different proposals the modeler is forced to make many subjective estimates.

Note on Cost Proposal Instructions

The devil is in the details — small changes in wording can greatly change the amount of work required with little added value.

Suggested weighting:

	Step One	Step Two
Science	70	20
Technical	20	25
Management	10	25
Cost Risk	0	30
Opportunity	N/S	N/S
Cost	Categorized	Not Scored

Step Two Evaluation
- Evaluation criteria — science, technical, management, cost risk *(absolute cost is not scored)*
- All proposal evaluated together WRT same criteria
- Evaluate cost risk by analysis of proposal data (do not evaluate on basis of probable cost models)
- Questions and orals are a required part of the process to ensure complete understanding of the cost risk
- Rank proposals and submit to source selection authority (SSA)

SSA has ranked list with cost for each.

Suggested Two-Step Process

Step One

- Open solicitation—purpose to narrow field
- Limits on mission cost, launch date, other program ground rules
- Primarily evaluated on value of science WRT published NASA goals
- Proposals grouped in 3 or 4 cost bins
- Best 2 or 3 proposals in each bin selected for step 2
- Cost proposal consists of total mission cost estimate at second level WBS spread by year and assumptions and rationale to support of basis of estimate

Step Two

- Evaluation weighted differently than step 1
- Cost proposal consists of detailed phase A cost estimate and priced options for phases B, C/D, E
- Priced options consist of SOW, WBS to level 3 (subsystem), summary BOEs at level 3, time phased by year, manpower spread, and no 1411

Goals

- Reduce LCC of the AO
- Expand science opportunity by reducing cost of entry
- Provide equal opportunity for missions of different size
- Provide alternative to should cost models for evaluation

AO/AO Process Changes and Program Management — L. Mitchler

AO/AO Process/Program Management

- 14 attendees (broad representation)
- Defined charter
- Identified 21 issues
- Synthesized to 7 problems
  - What problem will we solve?
- Top problems discussed
  - Life cycle cost of AO
  - Science in the hands of scientists
  - AO clarity
  - Big and small missions
- "Solutions" discussion begun

Problems/Recommendations

1. How to reduce "life cycle cost of AO"?
   All resources (t & $) and still get best proposals.
2. How to clearly communicate the intent of AO?
   Requirements
   Evaluation/scoring/criteria (RFP vs. AO)
   Simplify
   Including support services (DSN)
3. Ensure AO reflects complex strategy and connect to other programs.
4. Ensure science/ROI expressed in next AO
5. Selection IPDT—e.g., DSN assets common loop
6. Should NASA revisit cap on "contributed costs"?
   Commercial
   International
   United States
7. Upfront IA spending to minimize later problems
   Meet funding profile
   Guideline available funds

Problem: Big Mission vs. Small Missions
Should there be different AO categories?

Assumption: There are different and inherent complexity and cost missions.

Proposed Solutions:

1. NASA state maximum cost to be spent on given AO defined/constant boundary conditions well before AO.
2. Separate cost category AOs.

- ❖ Adapt to changing environment
  - ◆ Mercury
  - ◆ Lander
  - ◆ Rendez
  - ◆ Lunar
  - ◆ NEO
- ❖ Big vs. small missions
- ❖ During selection process
- ❖ Cost/risk
- ❖ Cost/science ROI

Problem: Life cycle cost of AO/Science in hands of science

Proposed Solutions:

1. Science validation.

    Compulsory
    I-U + concern cat
    Pub results and definitions
    Not a screening

Pros:

Science/Science
Early Validation
Doesn't Screen

Cons:

Bidding War
Postpones Teams
Doesn't Screen

Process Solutions

1. No substantive change/constant criteria two step
2. Science validation
3. Two-step downselect

Pros:

Reduces full proposal cost
Get best science

Cons:

Too long?
Encourages buy in?
Decouples from cost?
Still require some study investment

- ❖ AO only
- ❖ Based on firm science floor
- ❖ NTE cost

Summary

- More time required for definitive recommendation.
- Whatever we do should maintain cognizance of cost-constrained environment.
- Watch the Midex experiment.

DISCOVERY LESSONS LEARNED

Discovery Philosophy

- Keep "Faster, Better, Cheaper" Theme
- Keep average cost/mission ≤ $80M
- Keep mission plans simple
- Keep payload ≤ 3–4 instruments
- Let other Code S programs do more costly missions
- Do not have 2 or 3 cost classes

Announcement of Opportunity

- Delete repetition
- De-emphasize "Opportunity"—let us do our jobs without being "politically correct"
- Do not expect so much for a Phase A study
- Do not expect "ROM costs" to be "not to exceed"
- Do not change rules, i.e., ROM + 15% became ROM

Evaluation

- Was "fair and equitable"
- Leave it as is
- Do it on time

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