March 29, 2004

Dear Discovery Retreat Participants,

The following pages represent a summary of the discussion that occurred at the Discovery Retreat, held November 20-21, 2003, in Williamsburg, VA. Each of you has had several weeks to comment; I appreciate the input that has been given and have incorporated it into this summary. It is my hope that the lessons learned by various project teams, as captured here, will be instructive to current and future project teams without being restrictive. Please note that this is a summary only, not a consensus, and that each project will have its own unique challenges that may or may not respond to the implementation of these lessons learned.

Sincerely,
Susan Niebur
Discovery Program Scientist

Discovery Program Retreat 2003

Agenda

Thursday, November 20:

Headquarters Perspective

8:30	Welcome	Susan Niebur
8:45	Discovery in Context: Solar System	Jay Bergstralh
9:15	Discovery Program Structure	Steve Brody
9:45	Discussion	
10:15	Break	

Assessments

10:30	TMCO Reviews	Mike Stancati
11:00	Independent Assessment Teams	Lou Demas
11:30	Discussion	
12:00	Lunch Break	

Lessons Learned by Recently Launched Missions

1:00	Aspera-3	David Winningham
1:30	Contour	Bob Farquhar
2:00	Discussion	
2:15	Genesis	Don Sweetnam
2:45	Stardust	Rick Grammier
3:15	Discussion	
3:30	Break	

Lessons Learned by Missions in Development

3:45	Messenger	Robert Gold
4:15	Deep Impact	Mike A'Hearn and John Mcnamee
4:45	Discussion	

Friday, November 21:

Lessons Learned by Missions in Formulation

8:30	Dawn	Chris Russell
9:00	Kepler	Bill Borucki and Chet Sasaki
9:30	Discussion	
10:00	Break	

Program Updates

10:30	Education / Public Outreach	Shari Asplund
11:00	Planetary Data System	Bill Knopf
11:30	Deep Space Network	Belinda Arroyo
12:00	Lunch	
1:00	Launch Vehicles	John Schafer
1:30	Discovery Future Outlook	Susan Niebur
2:00	Adjourn	

Lessons Learned , as voiced at the 2004 Discovery Retreat
Please note that this list and the following summary capture the main lessons presented and topics discussed, but they have not been thoroughly vetted and do not represent a consensus among the projects.

Missions in Flight

1. Anticipate the unexpected with schedule and cost reserve.
2. Having something done is a lot better than having it scheduled.
3. Shared resources can be cost effective, but they may not be available when you want them. Avoid with careful allocation/planning/scheduling and communication.
4. Small missions don't have the luxury of high priority, co-location, and lots of full-time staff. Get an accessible server and a good "meet me" line.
5. Argue for co-location; be prepared for random distribution.
6. To a PM in Ops, there is no such thing as too much dV, Watts, CPU cycles, Mbytes, decibels, or dollars.
7. Flight system simulators are important.
8. Margin measurement in ops – hardware gradually needs less, but mission design always needs a lot.
9. There is a difference between real risk and perceived risk. You can't always argue perceived risk away with technical rationale.
10. Reviews have two purposes: technical assessment and organizational buy-in.
11. Reviews with HQ ought to be done by the PI, PM, and first line management team, to maintain accountability.
12. Reviews with HQ should avoid one size fits all presentations for missions in different stages of development.
13. Standards aren't always – there is frustration with templates that change.
14. DSN charges move from dollars to hours in late C/D.
15. Hire a broker to schedule DSN resources for the project.
16. Note that in some cases, lessons learned aren't. Recording them is not sufficient.
17. There is great value in performing in-flight rehearsals of critical events. This eliminates as many first-time events as possible prior to the critical event and reduces risk, as you fly as you tested.
18. Ensure you have sufficient reserves in operations (phase E). 15% is great. 5% is not sufficient. There may be unforeseen problems as you get to know the vehicle, unforeseen rehearsal opportunities, review board recommendations, and lessons learned from other projects that you'll want to implement to reduce risk.
19. Problems are an opportunity to build faith in the spacecraft and flight team, which can be invaluable in developing procedures to handle future problems.
20. Solar flare activity can (and will) affect your spacecraft. Be prepared and have contingency procedures to validate spacecraft health and resume normal operations. Realize that contention over shared flight teams, DSN resources, etc. may result.
21. Communication is critical. International partnerships have additional difficulties, such as time zone differences, cultural differences, and funding/authority

differences. Data archiving issues between NASA and international partners should be resolved early on.

22. Telemetry packetization should be done by the institution building the instrument. Otherwise, science information could be dropped or data not time-tagged correctly.
23. Software documentation deliverables in the plan were too optimistic.
24. Checkout time was inadequate for flight software updates and instrument operations.
25. Stardust camera optics contamination – see NASA Lessons Learned web site for details.
26. CONTOUR Mishap Investigation Board report is out and should be reviewed.

Missions in Development

1. Common payload support systems worked well. This allowed central production of the DPU, instrument processors, core software, and GSE. Qualified units were supplied to all instruments. DPUs were fully redundant, instruments single string. Only a single interface to the spacecraft was needed for the entire payload. This greatly reduced payload costs and facilitated payload testing.
2. Separate payload integration worked well. This allowed checkout of the entire payload before mounting to the spacecraft. The project was able to integrate the whole payload on the spacecraft in two days.
3. A major concern is the decay of the aerospace infrastructure. One project had many problems getting quality components, including circuit boards, Actel FPGAs, space-quality parts. In some cases, there is only a single supplier for high-risk items, like the IMU. Some single suppliers are non-U.S., which creates major ITAR delays for these components.
4. 36-month Phase C/D is problematic for recent missions selected that are much higher tech, not simple, focused spacecraft. This squeezes I&T and environmental testing time. If Phase C/D is not lengthened, the technology level of selected missions must be capped.
5. Descope options are usually unrealistic in Phase C/D, as it usually costs more to descope by CDR than complete the build. All descopes should be exercised by shortly after PDR.
6. Acceptable risk criteria are much more stringent today than a few years ago. Risk management strongly affects staffing, cost, and schedule.
7. The higher the level of the review, the lower the payoff. The most useful are the table-top reviews by working engineers/scientists.
8. Communication – the meaning of words is very culture dependent and may vary between scientists and engineers, institutions, and types of institutions.
9. Face-to-face communication is especially important.
10. It is crucial to spell out details in all areas of agreement and to understand why colleagues make the choices that they do. Different ways are not bad ways. Because of different styles and assumptions, true partnerships are very difficult to implement. But long experience working together teaches all

parties how to speak each others' languages.

11. The PM and PI must be personally compatible because they have to work together for a long time. Generally, the PM's strengths should complement the PI's. The PM should have experience working with the relevant partners.
12. The PM must understand and be committed to both the science and the cost and technical approach, from the Step 2 proposal, when roles are defined and implementation approach is chosen.
13. The PI should NOT ALLOW changes of PM by the center unless the PI sees a problem.
14. Partners should understand that different institutions have different goals. (e.g. profit, mission success across all missions, science). Listen carefully and understand the role of the mission in the partners' ensemble of goals.
15. Neither centers nor industrial partners believe in cost caps the way PIs do; institutions have a strong motive to buy in by keeping original budgets low.
16. Beware of the truly unexpected, such as partners going bankrupt, disappearing, accidents, and key personnel losses.
17. Don't spend reserves down to an arbitrary profile; save as much as possible. Don't spend reserves on things that were foreseen, like trade studies; put those things into the budget.
18. Don't count on much savings from heritage unless they are build-to-print (hardware) or used exactly as is, on the same platform (software). I.e., Don't believe all your own sales arguments.
19. A certain level of risk is built into the project during the proposal phase, as technical approach, cost and schedule reserves are defined. Changing ideas of technical risk (by project management, partners, or NASA HQ) will doom the project to go over budget.
20. Finding the right level of oversight for COTS vendors is difficult. Whether using a best efforts approach or rigid specifications approach, careful thought on the specifications is required. The appropriate approach will depend on the vendor.

Missions in Formulation

1. Effective communication is critical. Early discussions of problems avoids crises later.
2. Recognize that all agreements and plans change as situations change (e.g., schedule, budget, management, oversight, risk tolerance, AO protocols). Vendors often double their costs when your mission is selected.
3. Phasing of costs is critical.
4. Work fiscal problems as early as possible and be persistent.
5. Talk with other PIs and PMs and learn from their experience.
6. In the beginning, lose the CSR mentality of selling everybody including yourself. Stop deluding yourself that you are as good as you convinced yourself you were during the CSR period. You only thought you knew your requirements, schedule, and resources….

7. Start the process of risk management, as a means to control and maintain your reserves, as soon as possible.
8. Get the objectives and science requirements right. The degree of uncertainty will drive schedule and funding reserves.
9. Start getting a handle on what the challenges are going to be. Is there something different about this project?
10. Pick great staff! Get the best possible (experienced, dedicated, smart, positive) people for your team. The staff has to fit what you perceive to be the greatest challenges of the project.
11. Create an organization that matches the project objectives and the people you have. The organization will probably not be very different from a "standard" but paying careful attention to the nuances of YOUR organization pays dividends.
12. Start the requirements definition early but also start the conceptual design as soon as possible. You'll need it to beat the requirements against.
13. Allow individuals and the teams to do their work. Make sure they have adequate resources. Run interference for them. Keep the requirements as stable as possible. Provide "just right" review. If something isn't working don't wait too long to cut your loses.
14. If possible, think ahead of the team to what the future challenges are so you can provide guidance to them.
15. Fix critical project milestones to ensure the team focus. Change these as infrequently as is practicable.
16. Make sure that the roles and responsibilities remain clear.
17. Develop regular forums to discuss problems IN DEPTH to avoid the type of communication gap that doomed the Space Shuttle.
18. Remember to thank individuals and teams frequently and genuinely.
19. Keep your "Bosses" (HQ, parent institutions, project) informed of major things.
20. Allow plenty of time to work Headquarters issues. There are usually more players than one realizes.
21. Remember that we're all on the same team. We win or lose together.
22. Be flexible and make the best of the catastrophes that are certain to be visited on your project.
23. Good communications at all times, with all people, at all levels is the key!!!
24. Train more PMs by apprenticing younger people to current PMs. Their experience is crucial to mission success.
25. Good morale is critical to mission success. Implementing a space mission is very difficult, and tensions can reach high levels. Try to defuse tensions, not inflame them.
26. Discovery missions are cost capped, not value capped. Managers tend to manage cost not value, but small cost changes can affect value tremendously.
27. Value comes from the science measurements. Dropping an instrument usually makes a small delta in cost and a big delta in value. Dropping a target on an ion propulsion system mission can make a huge difference in value for small real savings
28. De facto the cost cap is by year. There is a temptation for the project to borrow money at usurious rates when emergencies occur. Headquarters reserves would

allow easier cash flow across FY boundaries. Recommend that HQ space Discovery missions sufficiently apart and manage some reserve at HQ.

29. Projects should be separated in time more and Headquarters should manage the resulting reserve.
30. It is difficult to identify good project managers for all missions at proposal, which results in a risk that the selected mission has an inexperienced project manager. Final selection of the project manager should occur after a project is selected.
31. Missions have a natural flow and optimum schedule. Pace of project often set by a few long-lead items that must be identified and procured in Phase B. Once a mission begins there is no clear break between phases.
32. Honesty, openness, and good morale are critical to mission success.
33. Independent assessment is a useful tool for HQ, the PM and the PI. However, peer review and assessment should be kept separate. Assessment teams should stick to assessment, not management.

E/PO Lessons Learned from NEAR, Mars Pathfinder, and Stardust

1. Build in adequate lead time when planning E/PO activities;
2. Planning for key events such as launch and encounter should begin one year ahead of time;
3. Planning for sample return landing activities should start right after launch;
4. The mission doesn't end when the samples land;
5. Involvement of PI, project management, and mission staff is essential;
6. Effective industry partnerships are crucial;
7. Field test education products and assure they are aligned with national standards;
8. Strengthen partnerships and planning with the museum/science center/planetarium community with regard to mission milestones;
9. Pursue thematic approaches for products, activities, and exhibits;
10. Focus on existing high leveraged opportunities; and
11. Make products widely available through NASA's distribution channels.

PDS-Project Lessons Learned

1. Flight Project interface to PDS requires proper coordination with Nodes and an understanding of PDS standards. The rejection of data sets during Peer Review has occurred. Improper interpretation of PDS standards has been an issue. The rework of data sets to appropriate standard(s) is both time consuming and costly
2. Late delivery of data sets to the PDS is not uncommon. This impacts PDS schedule of restorations, archive preparations, and data ingestion.
3. Future AOs will clearly reflect data delivery policy: Delivery of data to PDS must occur within six months of collection, allowing an exclusive data use period by Project PIs. Archiving with PDS is a requirement, not an option
4. Early involvement/interface with PDS simplifies product delivery/pipeline
5. A Proposer's Archive Guide (PAG) has been developed and is now provided by the PDS to assist in archive costing and interfacing with the PDS. A cost model is

available for estimates via Data Producer hyperlink at ***http://pds.jpl.nasa.gov***. The latest standards and sample archive plans are also available.

Independent Review Perspective: Top Ten Red Flags

1. Excessive scope / complexity;
2. Major management "issues";
3. Strained resources – mass, power, people, money, time;
4. Lack of schedule detail and performance measurement;
5. Incomplete / open requirements;
6. Cost and schedule reserves not spread properly;
7. Heritage overestimated or not acheiveable;
8. Concept of operations not defined early;
9. Risks not completely defined / adequately managed; and
10. New technology / development without solid backups.

Program Executive's Perspective:

1. Beware of a rush to meet milestones irrespective of the maturity of the "content" at the time; especially, to reach Confirmation ("hurry up" then do it over!). Must be enforced by managing organization/Governing Pgm Mgmt Council (GPMC).
2. Must have cost, schedule, and technical content in lock-step at the milestones, or you do NOT satisfy the milestone. Again, must be enforced by managing org/GPMC.

(Items 1 & 2 above are admittedly tough to avoid sometimes, especially with the drive to meet planetary windows.)

3. Beware of using a material (or mechanism, or technology) in an environment for which there is an inadequate knowledge base. Make sure you recognize the assumptions (implicit or otherwise) in the operating environment that comes with a part/material/process. May need to challenge or test validity of assumption.
4. Make sure you have a good understanding of what margins you truly have, and what they mean. Unsubstantiated flight allowable levels could drive you to do the wrong thing.
5. One must truly understand the state of cost reserves and what's really "unencumbered"! Example: Don't let contractor incentive fees be viewed as a potential part of reserves.
6. Nothing replaces solid systems engineering. Beware of the lack of thoroughness of systems engineering & management at "players" without significant NASA, or major aerospace, experience.
7. Past good performance is NO guarantee of success - beware of the hubris of folks coming off a "stellar" mission.
8. Use of independent review bodies – must ensure adequate peer-level ("shirt-sleeve") review, not just a "one-time" posse, every so often.
9. Can't emphasize enough the need to convey lessons-learned (including technical problems found & solved, hopefully) between missions, program participants, etc.

10. Must have a clear understanding of who's the finance "csar" overall for a mission & what financial management support a PI's university or institution provides.
11. Watch out for unintended consequences of incentives in contracts; they can drive behavior in unintended directions.

Discovery Retreat Themes

Communication

The importance of communication, both within the project and between NASA and the project was underscored repeatedly at this retreat. Several issues were brought forward. Many team members underscored the importance of being completely open, honest, and frank at all times. Even though doing so might reveal a weakness, addressing that weakness early and head-on is critical and can leverage experience and suggestions from others. There was a large discussion about "review" versus "assessment" and how all the various assessments (e.g. PDR, CDR) the project must go through, while often serving a narrowly focussed purpose, do NOT substitute for tabletop conversations with Independent Assessment Team (IAT) members and/or NASA. There is a conflict for the project: assessments are designed to demonstrate progress and likely success and thus project members are unlikely to use this forum to bring up problems or issues. Additionally, the assessment process established by NASA HQ and performed by The Aerospace Corporation was resented: NASA did not ask for input from the projects and they feel this was forced on them. Finally, the opinion was voiced that the standard format of certain of these assessments hindered progress in that it was not always appropriate to a given project at a given stage. There was a general lack of consensus on the best ways to address these issues. Informal emails, to a variety of people, are a good start. Regular updates of this sort were encouraged, though it was pointed out that when they do happen they tend to focus on technical issues only. Schedule and cost must surely be impacted, but are seldom addressed. The IAT process in general was appreciated and some projects were looking for an even higher level of involvement. Striking the balance between constant vigilance by an outsider and sufficient opportunity to exchange issues and ideas is a hard thing to do.

Reserves

There was a discussion about the general philosophy of reserve allocation and management. Several TMCO participants pointed out that when they see reserve (schedule in this case) lumped "at the end" or late in the project, they tend to have very little confidence that the project fully appreciates what likely issues may arise. Upon being advised that some projects take this approach, but that they aggressively manage schedule throughout and allocate slips as appropriate, TMCO indicated that that approach could be acceptable – as long as it is properly documented in the proposal or Concept Study Report (CSR). The notion that it is possible to have too much reserve came up: project members advised that the sense of abundance in one area often can lead to it being ignored, which in turn can actually lead to trouble. Additionally, general warnings about reserves came up: there is never enough money or time for software development; phase E costs more than you might expect; 15% reserve in phase E is a good idea - it allows for unscheduled opportunities to practice upcoming critical events; DSN costs

change part way through the project from dollars to hours, so that should be kept in mind. It was also generally felt that a dictated reserve percentage (e.g. Explorer's 20%) is not practical; justification of proposed reserves is more important than picking some arbitrary number. And though it is not really a reserves issue, it is important to point out that there is no such thing as a 'minor' modification when claims of heritage are made. General advice: if you don't have to change it, don't.

Foreign participation

One team present had extensive experience dealing with foreign partners. The different culture of operating does create some issues that need to be carefully monitored. Domestic team members must insist on being present during critical testing if not allowed to conduct the testing themselves. Foreign companies have much greater flexibility to 'change the rules' than we might expect, so constant vigilance is necessary. Working with a European country that is NOT an ESA member caused additional problems, as the weight of ESA was not behind any complaints they might have had with the industry partner. NASA might have been able to assist and teams should investigate options with HQ (such as piggy-backing on the mission MOU that might exist). The importance of the LOA could not be underscored enough. It needs to be very detailed and very specific and you must be ready to reference it frequently in order to get things done. Conversely, the presence of foreign CoIs and a good working relationship with foreign team members can often allow for informal smoothing of issues when the formal channel might not work.

ITAR is a huge issue. It is getting more and more difficult to get domestic piece parts and very often, it seems, a part that you think is domestic might actually come from a foreign supplier. This adds time and money - and if you are unlucky enough to receive a defective or broken part, RETURNING the piece is subject to ITAR also. It is never too early to start working the problems.

Escalation

There was general acknowledgement that the entire program had 'escalated' in terms of science goals, complexity of engineering, and costs. The first Discovery AO emphasized the need for focussed science. But it is now generally assumed that in order to get through the science gate, the proposed science must be highly ambitious. This in turn drives the engineering to be ever-more complicated, which drives up risk. As a result, all proposals now pretty much come in at the cost cap, leaving little room for growth and little ability to fix unanticipated problems. Technical reviews have increased and yet more missions find themselves 'in trouble'. The lack of a sufficient number of qualified PMs exacerbates the problem. Most people, however, seemed to accept that escalation was inevitable. This issue will be taken into account in planning the next AO solicitation and review process.

Program Office

Assigning the Program Office to JPL was met with pretty unanimous disapproval. There were concerns of conflict of interest. There was strong support for ensuring that independent assessment (independent of the program office) continue, and possibly

increase in visibility. In light of the recent CAIB report, it is important to show that assessment/oversight/review is happening in this program and that it is rigorous.