Reducing NPR 7120.5D to Practice: Preparing for a Life-cycle Review[1][2]

Randall L. Taylor
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109-8099
818-354-1865
Randall.L.Taylor@jpl.nasa.gov

Abstract—In March 2007, NASA issued revised rules for space flight project management, NPR 7120.5D, "NASA Space Flight Program and Project Management Requirements." Central to the new rules was the construct of Key Decision Points, maturity gates that the project team must pass in order to continue development. In order that the KDP decision be fully informed, the NPR required, as entrance criteria for the gate, the generation and delivery of specified planning, technical, and cost/schedule documents (gate products) and a life-cycle review by an independent Standing Review Board.

Gravity Recovery And Interior Laboratory (GRAIL) was the first Jet Propulsion Laboratory (JPL) project initiated under these new rules. NASA selected GRAIL through a competitive Announcement of Opportunity process and funded its Phase B Preliminary Design effort. The team's first major milestone was a JPL institutional milestone, the Project Mission System Review (PMSR), which proved an excellent tune-up for the end-of-Phase B NASA life-cycle review, the Preliminary Design Review.

Building on JPL experience on the Prometheus and Juno projects, the team successfully organized for and conducted these reviews on an aggressive schedule. Key actions were taken to proactively interact with the SRB, produce high-quality gate products with stakeholder review, generate review presentation materials, and handle a myriad of supporting logistical functions.

A review preparation team was established, including a Review Captain and leads for documentation, information systems, and logistics, and their roles, responsibilities and task assignments were identified. Aids were produced, including a detailed review preparation schedule and a comprehensive gate products production table. Institutional support was leveraged early and often. Implementation strategy reflected the needs of a nationally-distributed team, as well as applicable export control and IT security requirements.

This paper gives a brief overview of the GRAIL mission and its project management challenges, provides a detailed description of project PMSR and PDR preparation and execution activities, including positive and negative lessons learned, and identifies recommendations for future NASA (and non-NASA) project teams.

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1. INTRODUCTION

In December 2007, NASA selected the Gravity Recovery And Interior Laboratory (GRAIL) mission to initiate Phase B, Preliminary Design & Technology Completion. As stated in the GRAIL Concept Study Report, "GRAIL will precisely map the gravitational field of the Moon to reveal its internal structure 'from crust to core', determine its thermal evolution, and extend this knowledge to other planets." [3]

Specifically, GRAIL will place twin spacecraft in a low-altitude, near circular polar orbit about the Moon. It will perform high-precision rate-rate measurements between the orbiters using a Ka-band payload. The spacecraft-to-spacecraft range-rate data (changes in separation distance between the orbiters) provides a direct measure of lunar gravity. [4] GRAIL will conduct science operations for approximately 90 days, which would constitute three mapping cycles. There are six lunar science investigations associated with the science phase:

[2] IEEEAC paper #1531, Version 6, Updated December 15, 2008

(1) Map the structure of the crust and lithosphere.

(2) Understand the Moon's asymmetric thermal evolution.

(3) Determine the subsurface structure of impact basins and the origin of mass concentrations (mascons).

(4) Ascertain the temporal evolution of crustal brecciation and magmatism.

(5) Constrain deep interior structure from tides.

(6) Place limits on the size of a possible Lunar core. [5]

Minimum mission success will be achieved by accomplishing the first four investigations (the science floor). Full mission success will be achieved by accomplishing all six investigations (the baseline mission).

GRAIL is led by the Principal Investigator (PI), Dr. Maria Zuber of MIT, assisted by the Deputy PI, Dr. David Smith of NASA Goddard Space Flight Center (GSFC). JPL provides project management, systems engineering, safety and mission assurance, the science instruments (one on each orbiter), mission design, the mission system, and gravity science analysis. GSFC also performs gravity science modeling and data analysis. Lockheed Martin (LM) provides the twin spacecraft and performs assembly, test and launch operations. ULA provides the Delta II Heavy launch vehicle and associated launch services. Sally Ride Science conducts the education and public outreach program. Many subcontractors support the team. The NASA Discovery Program Office at Marshall Space Flight Center is responsible for funding, technical direction, and surveillance of project progress and risk status. The project would be the first one at JPL conducted under the new NASA rules for program and project management.

2. NASA REQUIREMENTS FOR LIFE-CYCLE REVIEWS

In March 2007, NASA issued revised rules for space flight program and project management, NASA Procedural Requirements (NPR) 7120.5D, "NASA Space Flight Program and Project Management Requirements." NPR 7120.5D established a single project life-cycle applicable to both human and robotic missions, with specific project phases (see Figure 1). GRAIL performed pre-Phase A on bid and proposal funding, completed Phase A with partial NASA funding, and performed Phase B with NASA funding.

Central to the new rules was the construct of Key Decision Points (KDPs), maturity gates that the project team must pass in order to continue development. At the KDP, the cognizant Decision Authority determines whether the project will proceed into the next phase, remain in its current phase with specific work to be completed, or be discontinued.

In order that the KDP decision be fully informed, the NPR requires, as entrance criteria, specific gate products and control plans. (Some gate products were already required under NPR 7120.5C and other Agency command media.) The 32 gate products include headquarters and program products (ones the project must obtain from NASA); technical products; planning, cost, and schedule products; and KDP readiness products (ones generated after the life-cycle review but before the KDP). Additionally, the NPR requires that the project's progress and readiness be assessed at a project life-cycle review(s). The assessment is performed by an independent Standing Review Board (SRB). In the case of a project, like GRAIL, in Phase B, the project must establish an Integrated Baseline (integrated technical/schedule/cost package) which the SRB evaluates. (In later phases, the SRB evaluates the project's performance against the confirmed Phase B baseline).

3. PRACTICE: PROJECT MISSION SYSTEM REVIEW

For competed missions selected via an Announcement of Opportunity (AO) process, the submission of the Concept Study Report constitutes fulfillment of the Phase A gate product requirements. [6] The NASA Technical, Management, Cost (TMC) evaluation panel serves in lieu of a SRB to support the selection decision by the cognizant NASA Associate Administrator at the end of Phase A.

Because there is no System Requirements Review (SRR) or Mission Definition Review (MDR) during Phase A for competed missions, JPL institutional management has established an internal health-check review, the Project Mission System Review (PMSR). The objectives of the PMSR are to evaluate "the preliminary planning, driving requirements, mission and system concepts, and estimated life-cycle cost to assess the maturity of the project and the progress made toward mission and system definition." [7] The key is whether the project has a sound concept and a solid Phase B work plan (including trade studies and risk reduction activities) that are likely to lead to a successful Preliminary Design Review (PDR).

The GRAIL project schedule for Phase B extended for 12 months (January – December 2008), with an early PMSR (April 2008). Slower-than-planned staffing of the project team due to resource conflicts with other projects made it more difficult than expected to prepare for PMSR in only three months.

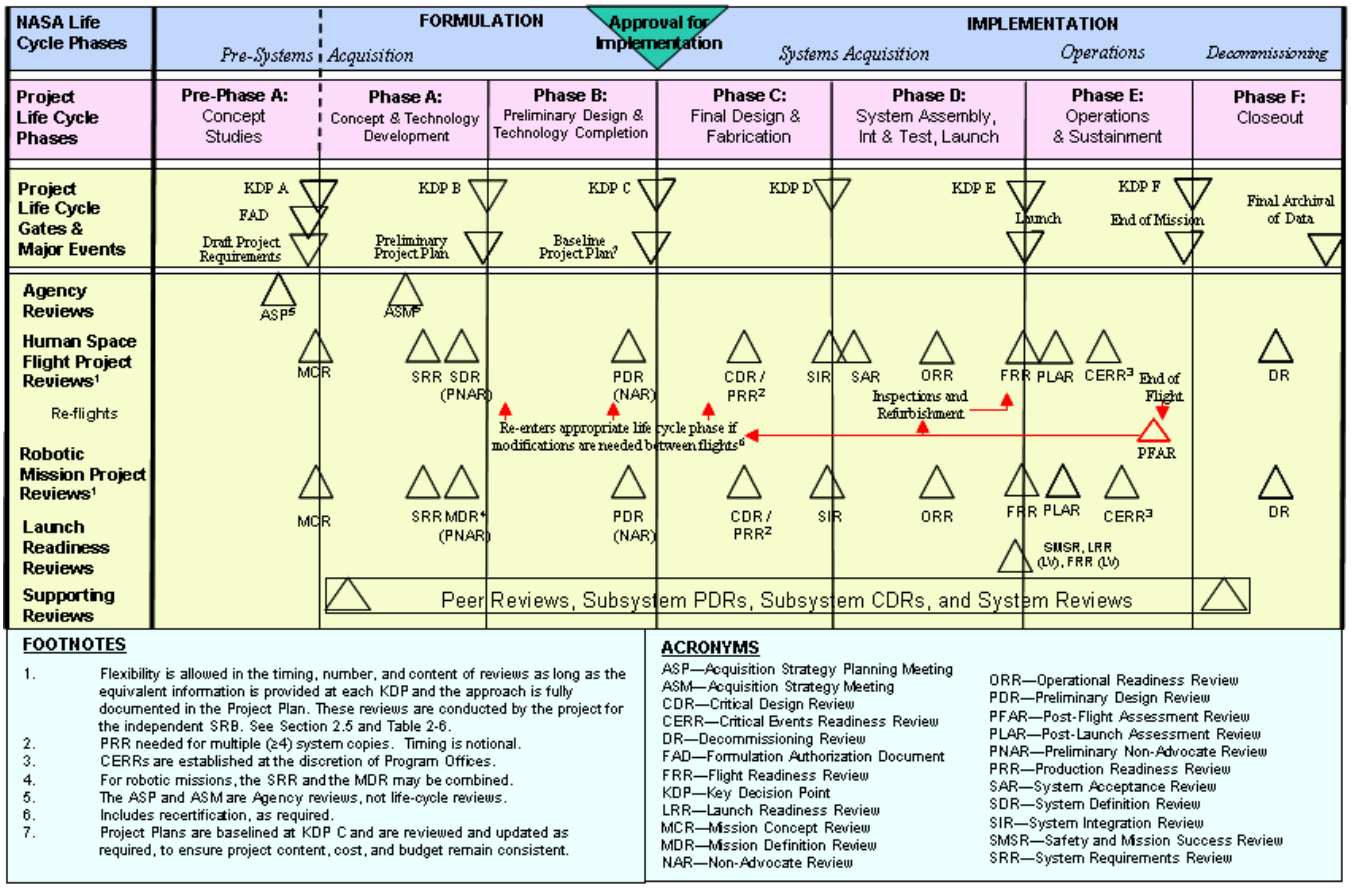


Figure 1 - The NASA Project Life Cycle

The PMSR has defined scope and success criteria and suggested agenda topics. The project team took the approach that it would provide those NPR 7120.5D gate products required of an assigned mission (i.e., no AO process) as well as the gate products institutionally established by JPL for a PMSR (documented in JPL's Gate Products Matrix.). A number of these gate products had been prepared in preliminary form for the TMC site visit in August 2007.

PMSR preparation involved four "threads" of activity:

Requirements development

Gate products generation

Presentation materials generation

IT and logistics

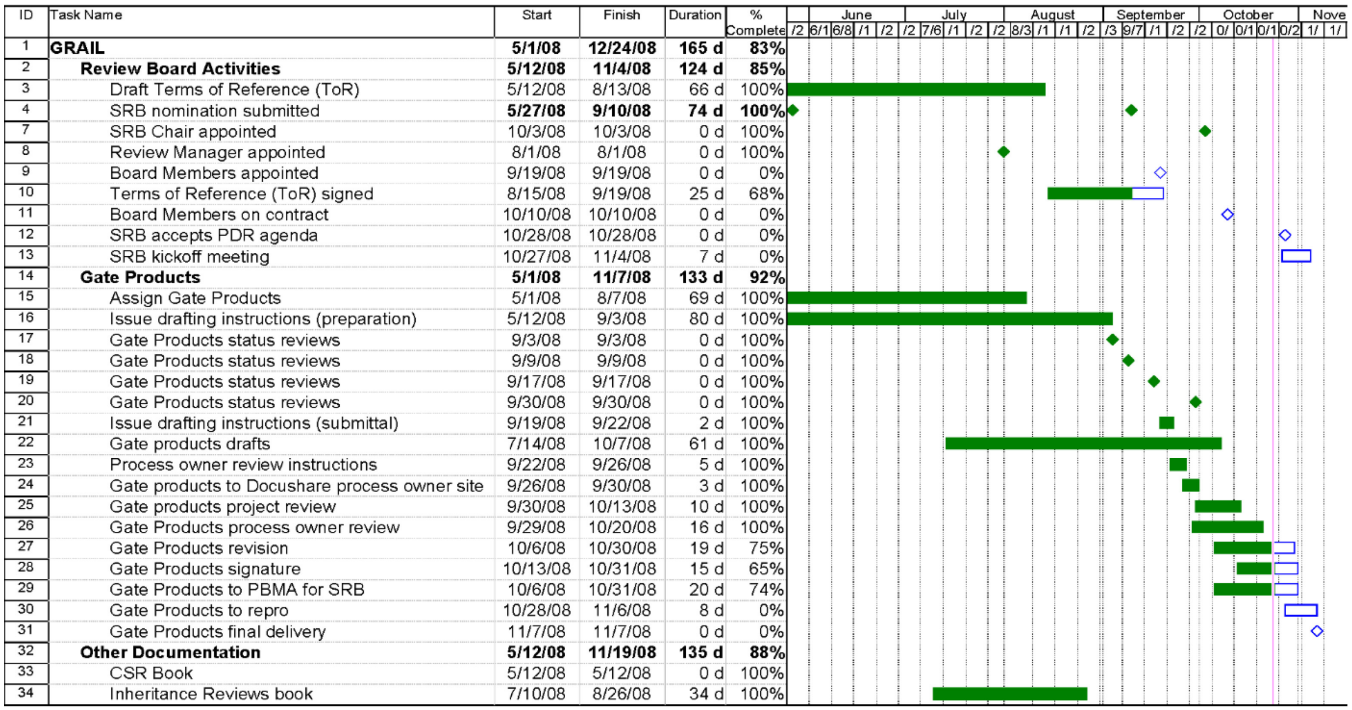
Lessons learned – what worked, what didn't work, and what could be done better – were identified in post-mortem sit-down sessions, and an improved process, described below, was implemented for PDR preparation. (As will be discussed, the PDR would entail two additional "threads", one specifically relating to the SRB construct.)

4. ORGANIZATION: ROLES AND RESPONSIBILITIES

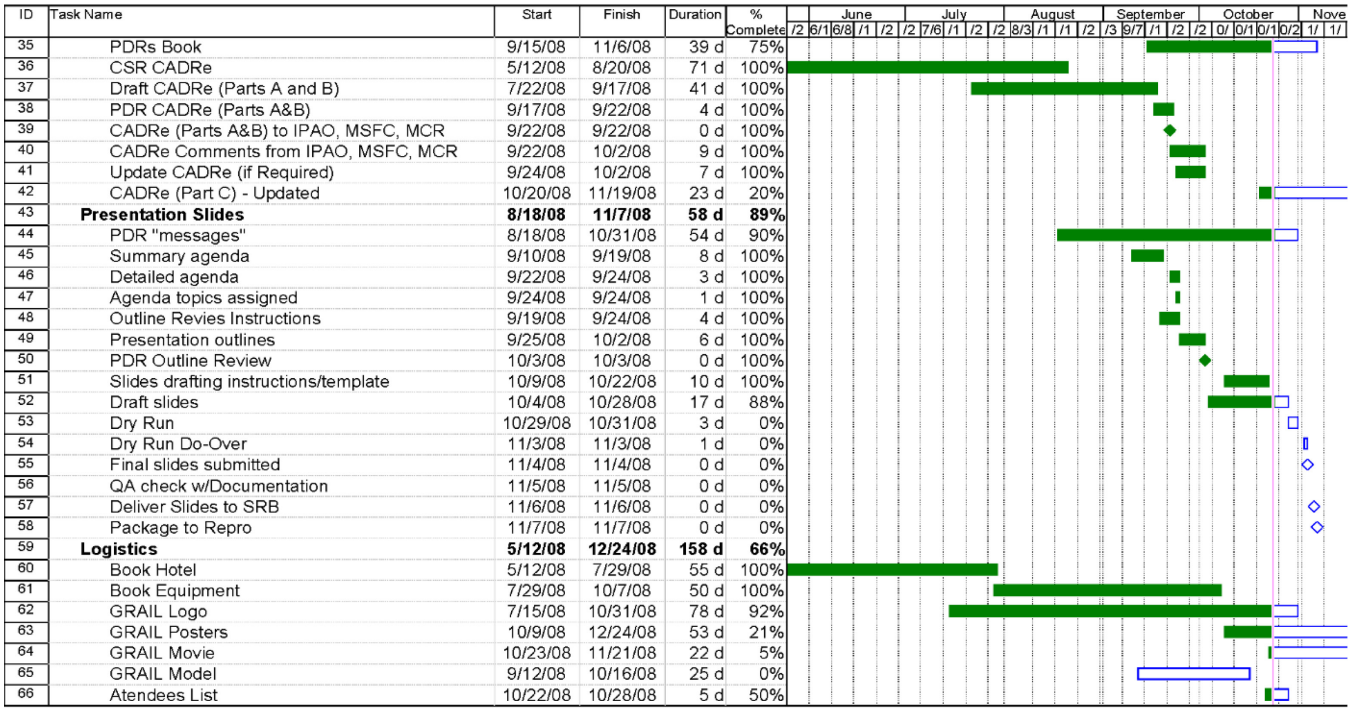
Following the lead of the Prometheus project, GRAIL designated a Review Captain (RC) to lead the preparations for PMSR and PDR. GRAIL expanded upon the Prometheus model by adding leads for documentation, information systems, and logistics. They were aided by key supporting personnel, both project and institutional, and assisted as required by the PI and the Project Manager (PM).

The Review Captain role was performed by the Project Acquisition Manager (the author). (On Prometheus, it was filled by the Mission Assurance Manager.) The RC led the review preparation team. He was in charge of gate product and presentation materials instructions, guidelines, interpretations, and content review. He was supported by the Project Schedule Analyst as well as the leads. He supported the PM in interactions with the SRB.

The Documentation Lead (DL) represented the institutional Documentation Services organization. She was responsible for gate product and presentation materials formatting, editing, and production and was supported by other technical writers and a reproduction contractor. The Information Systems Lead (ISL) was the project's Information Management Engineer.



ID	Task Name	Start	Finish	Duration	% Complete
1	**GRAIL**	**5/1/08**	**12/24/08**	**165 d**	**83%**
2	**Review Board Activities**	**5/12/08**	**11/4/08**	**124 d**	**85%**
3	Draft Terms of Reference (ToR)	5/12/08	8/13/08	66 d	100%
4	SRB nomination submitted	**5/27/08**	**9/10/08**	**74 d**	**100%**
7	SRB Chair appointed	10/3/08	10/3/08	0 d	100%
8	Review Manager appointed	8/1/08	8/1/08	0 d	100%
9	Board Members appointed	9/19/08	9/19/08	0 d	0%
10	Terms of Reference (ToR) signed	8/15/08	9/19/08	25 d	68%
11	Board Members on contract	10/10/08	10/10/08	0 d	0%
12	SRB accepts PDR agenda	10/28/08	10/28/08	0 d	0%
13	SRB kickoff meeting	10/27/08	11/4/08	7 d	0%
14	**Gate Products**	**5/1/08**	**11/7/08**	**133 d**	**92%**
15	Assign Gate Products	5/1/08	8/7/08	69 d	100%
16	Issue drafting instructions (preparation)	5/12/08	9/3/08	80 d	100%
17	Gate Products status reviews	9/3/08	9/3/08	0 d	100%
18	Gate Products status reviews	9/9/08	9/9/08	0 d	100%
19	Gate Products status reviews	9/17/08	9/17/08	0 d	100%
20	Gate Products status reviews	9/30/08	9/30/08	0 d	100%
21	Issue drafting instructions (submittal)	9/19/08	9/22/08	2 d	100%
22	Gate products drafts	7/14/08	10/7/08	61 d	100%
23	Process owner review instructions	9/22/08	9/26/08	5 d	100%
24	Gate products to Docushare process owner site	9/26/08	9/30/08	3 d	100%
25	Gate products project review	9/30/08	10/13/08	10 d	100%
26	Gate Products process owner review	9/29/08	10/20/08	16 d	100%
27	Gate Products revision	10/6/08	10/30/08	19 d	75%
28	Gate Products signature	10/13/08	10/31/08	15 d	65%
29	Gate Products to PBMA for SRB	10/6/08	10/31/08	20 d	74%
30	Gate Products to repro	10/28/08	11/6/08	8 d	0%
31	Gate Products final delivery	11/7/08	11/7/08	0 d	0%
32	**Other Documentation**	**5/12/08**	**11/19/08**	**135 d**	**88%**
33	CSR Book	5/12/08	5/12/08	0 d	100%
34	Inheritance Reviews book	7/10/08	8/26/08	34 d	100%



ID	Task Name	Start	Finish	Duration	% Complete
35	PDRs Book	9/15/08	11/6/08	39 d	75%
36	CSR CADRe	5/12/08	8/20/08	71 d	100%
37	Draft CADRe (Parts A and B)	7/22/08	9/17/08	41 d	100%
38	PDR CADRe (Parts A&B)	9/17/08	9/22/08	4 d	100%
39	CADRe (Parts A&B) to IPAO, MSFC, MCR	9/22/08	9/22/08	0 d	100%
40	CADRe Comments from IPAO, MSFC, MCR	9/22/08	10/2/08	9 d	100%
41	Update CADRe (if Required)	9/24/08	10/2/08	7 d	100%
42	CADRe (Part C) - Updated	10/20/08	11/19/08	23 d	20%
43	**Presentation Slides**	**8/18/08**	**11/7/08**	**58 d**	**89%**
44	PDR "messages"	8/18/08	10/31/08	54 d	90%
45	Summary agenda	9/10/08	9/19/08	8 d	100%
46	Detailed agenda	9/22/08	9/24/08	3 d	100%
47	Agenda topics assigned	9/24/08	9/24/08	1 d	100%
48	Outline Revies Instructions	9/19/08	9/24/08	4 d	100%
49	Presentation outlines	9/25/08	10/2/08	6 d	100%
50	PDR Outline Review	10/3/08	10/3/08	0 d	100%
51	Slides drafting instructions/template	10/9/08	10/22/08	10 d	100%
52	Draft slides	10/4/08	10/28/08	17 d	88%
53	Dry Run	10/29/08	10/31/08	3 d	0%
54	Dry Run Do-Over	11/3/08	11/3/08	1 d	0%
55	Final slides submitted	11/4/08	11/4/08	0 d	0%
56	QA check w/Documentation	11/5/08	11/5/08	0 d	0%
57	Deliver Slides to SRB	11/6/08	11/6/08	0 d	0%
58	Package to Repro	11/7/08	11/7/08	0 d	0%
59	**Logistics**	**5/12/08**	**12/24/08**	**158 d**	**66%**
60	Book Hotel	5/12/08	7/29/08	55 d	100%
61	Book Equipment	7/29/08	10/7/08	50 d	100%
62	GRAIL Logo	7/15/08	10/31/08	78 d	92%
63	GRAIL Posters	10/9/08	12/24/08	53 d	21%
64	GRAIL Movie	10/23/08	11/21/08	22 d	5%
65	GRAIL Model	9/12/08	10/16/08	25 d	0%
66	Atendees List	10/22/08	10/28/08	5 d	50%

Figure 2 – PDR Preparation Schedule

She was responsible for architecting the file formats and data repositories for gate products and presentation materials and for establishing access privileges for project team members, including two foreign persons. She was supported by the project Configuration Management Engineer, Project Librarian, and institutional Export Technical Representative. The Logistics Lead (LL) was the Project Secretary. She was responsible for review site selection, arrangements, and equipment needs, as well as support services for the attendees.

The teams developed aids as needed to keep track of activities and/or support the content providers. Versions of the aids were created for the PMSR; they were improved based on lessons learned for the PDR. The master schedule aid is provided as Figure 2.

5. PRE-PDR REVIEWS

Preparation for the PDR involved six "threads" of activity:

(7) Requirements development

(8) Pre-PDR reviews

(9) Gate products generation

(10) Presentation materials generation

(11) IT and logistics

(12) SRB support

The team identified in Section 4 served in a support role to requirements development and pre-PDR reviews. The cognizant designers and product delivery engineers and scientists performed the required activities, as explained below.

NPR 7120.5D requires. as gate products for a PDR, "Program Requirements on the Project" (known for robotic missions as Program Level Requirements Appendix) and "System Level Requirements". [8] The former are considered Level 1 requirements (the contract with the customer). The latter are considered Level 3 requirements, which for GRAIL consisted of requirements on five systems (flight system, spacecraft, payload, mission system, and science data system). Although not specifically called out by NPR 7120.5D as a gate product, clearly one could not generate Level 1 and 3 requirements without also generating Level 2s, and in fact JPL levied this as a gate product for both PMSR (preliminary) and PDR (final). Additionally, it was necessary to generate the "key driving" Level 4 requirements to guide Phase B activity.

Requirements development was led by the Project Systems Engineer. A Requirements Engineer was responsible for the Level 2 requirements (Project Requirements Document) and the flight-ground Interface Control Document. The system engineers for each of the five systems were responsible for their Level 3s. The PM and PI were personally involved in the Level 1s. Requirements were brainstormed in a series of concurrent engineering "pit sessions" prior to the PMSR and refined by off-line and working group sessions thereafter. The key was to have mature requirements to support the pre-PDR reviews.

There were two batteries of project-convened reviews between the PMSR and PDR. Each review had a formal review board, Requests for Action (RFAs), board report, and project response to findings and RFAs, which were reported out at the subsequent Project PDR.

Inheritance reviews were conducted May – June 2008. GRAIL had been proposed as a high-heritage mission, with no new technology required. This had been given a coarse verification during Phase A through a Preliminary Inheritance Review and was now confirmed at the spacecraft subsystem and instrument assembly levels. All 13 of these reviews were reported out at the Flight System Inheritance Review in July 2008. (An alternative avionics approach was evaluated at a special inheritance review the following month.)

Pre-PDR reviews were conducted August – October 2008. These were similarly applied to each spacecraft system and instrument assembly, and were also held for requirements; mission design and navigation; verification and validation; and Assembly, Test and Launch Operations. Comprehensive Level 4 requirements were employed in these reviews. The products of these reviews constituted the project technical baseline for PDR.

A detailed list and schedule of the GRAIL pre-PDR reviews is provided as Figure 3.

6. GATE PRODUCTS

NPR 7120.5D specifies the delivery of named gate products and control plans as a prerequisite to holding the end-of-phase life-cycle review. These are identified in Tables 4-3 and 4-4, respectively. [9] In addition, JPL as an institution requires additional gate products for the space flight projects it manages, contained in a JPL Life cycle Gate Products List.

Gate products are documents. Many of them are plans; notably, the 15 control plans in Table 4-4. The other gate products (Table 4-3) are divided into four groups:

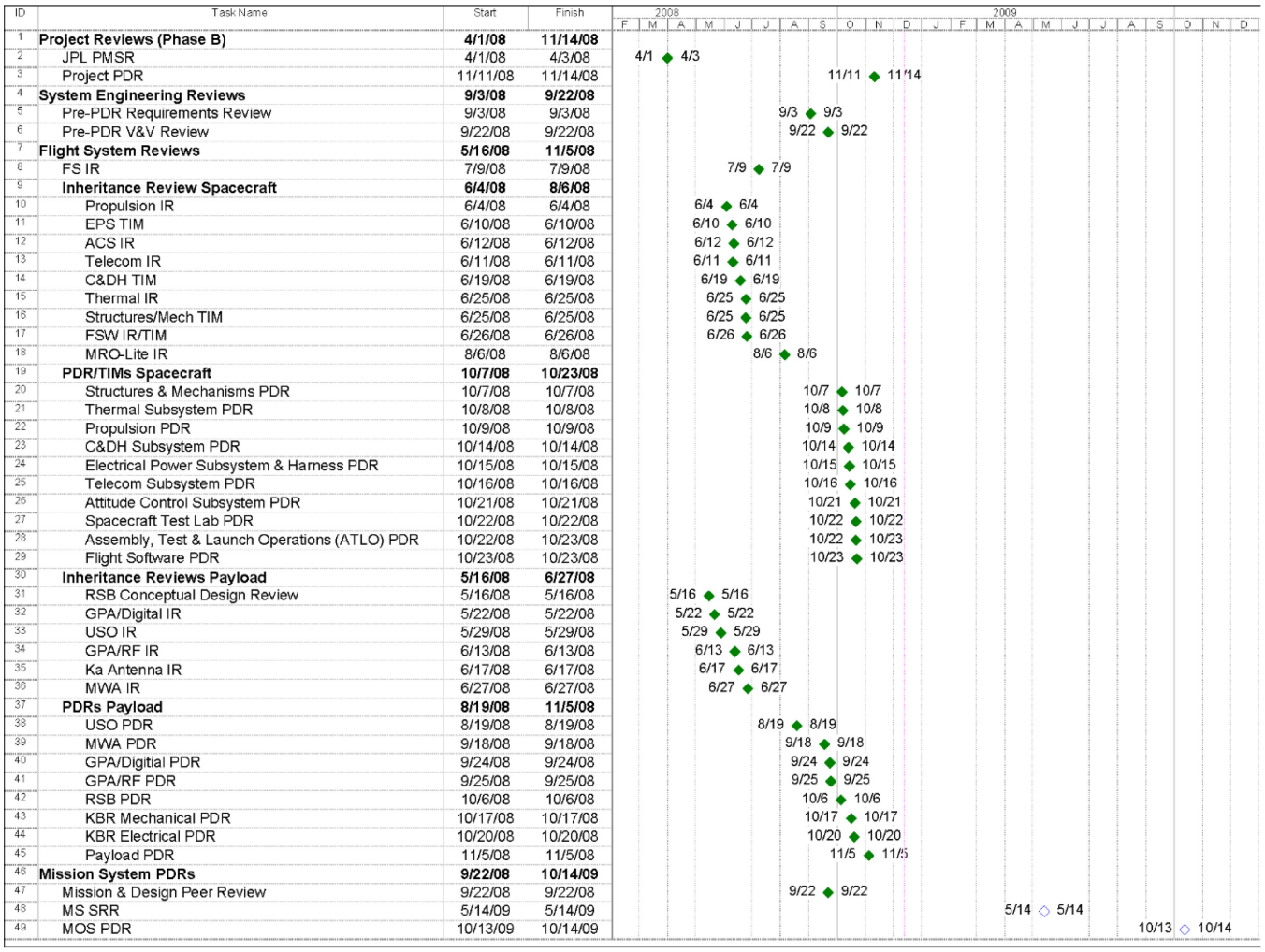
(1) Headquarters and Program Products – products that are receivables from the sponsor (though in some instances inputs are required from the project)

(2) Project Technical Products – products that the project must generate (some of which are produced in the normal course of business, others because they are prescribed, either for regulatory purposes or otherwise)

(3) Project Planning, Cost, and Schedule Products – additional products that the project must generate (again, some come as part of business as usual)

(4) KDP Readiness Products – products that are produced after the life-cycle review but prior to the KDP (only one of which, the Project Manager Recommendations, is by the project; the others are from the SRB and oversight organizations).

In some cases the NASA or JPL gate products are identified by no more than a title. In these instances, the Review Captain worked with the JPL Project Support Office to come up with a reasonable interpretation of what the requirement meant.



ID	Task Name	Start	Finish
1	**Project Reviews (Phase B)**	**4/1/08**	**11/14/08**
2	JPL PMSR	4/1/08	4/3/08
3	Project PDR	11/11/08	11/14/08
4	**System Engineering Reviews**	**9/3/08**	**9/22/08**
5	Pre-PDR Requirements Review	9/3/08	9/3/08
6	Pre-PDR V&V Review	9/22/08	9/22/08
7	**Flight System Reviews**	**5/16/08**	**11/5/08**
8	FS IR	7/9/08	7/9/08
9	**Inheritance Review Spacecraft**	**6/4/08**	**8/6/08**
10	Propulsion IR	6/4/08	6/4/08
11	EPS TIM	6/10/08	6/10/08
12	ACS IR	6/12/08	6/12/08
13	Telecom IR	6/11/08	6/11/08
14	C&DH TIM	6/19/08	6/19/08
15	Thermal IR	6/25/08	6/25/08
16	Structures/Mech TIM	6/25/08	6/25/08
17	FSW IR/TIM	6/26/08	6/26/08
18	MRO-Lite IR	8/6/08	8/6/08
19	**PDR/TIMs Spacecraft**	**10/7/08**	**10/23/08**
20	Structures & Mechanisms PDR	10/7/08	10/7/08
21	Thermal Subsystem PDR	10/8/08	10/8/08
22	Propulsion PDR	10/9/08	10/9/08
23	C&DH Subsystem PDR	10/14/08	10/14/08
24	Electrical Power Subsystem & Harness PDR	10/15/08	10/15/08
25	Telecom Subsystem PDR	10/16/08	10/16/08
26	Attitude Control Subsystem PDR	10/21/08	10/21/08
27	Spacecraft Test Lab PDR	10/22/08	10/22/08
28	Assembly, Test & Launch Operations (ATLO) PDR	10/22/08	10/23/08
29	Flight Software PDR	10/23/08	10/23/08
30	**Inheritance Reviews Payload**	**5/16/08**	**6/27/08**
31	RSB Conceptual Design Review	5/16/08	5/16/08
32	GPA/Digital IR	5/22/08	5/22/08
33	USO IR	5/29/08	5/29/08
34	GPA/RF IR	6/13/08	6/13/08
35	Ka Antenna IR	6/17/08	6/17/08
36	MWA IR	6/27/08	6/27/08
37	**PDRs Payload**	**8/19/08**	**11/5/08**
38	USO PDR	8/19/08	8/19/08
39	MWA PDR	9/18/08	9/18/08
40	GPA/Digitial PDR	9/24/08	9/24/08
41	GPA/RF PDR	9/25/08	9/25/08
42	RSB PDR	10/6/08	10/6/08
43	KBR Mechanical PDR	10/17/08	10/17/08
44	KBR Electrical PDR	10/20/08	10/20/08
45	Payload PDR	11/5/08	11/5/08
46	**Mission System PDRs**	**9/22/08**	**10/14/09**
47	Mission & Design Peer Review	9/22/08	9/22/08
48	MS SRR	5/14/09	5/14/09
49	MOS PDR	10/13/09	10/14/09

Figure 3 - A detailed list and schedule of the GRAIL pre-PDR reviews

For example, the NASA technical product Missions Operations Concept in Table 4-3 was invoked by a single sentence stating, "Develop and document a baseline mission operations concept." [10] Because the Review Captain had served as one of the lead authors on NASA's NPR drafting team, he had an understanding of what the Agency was most interested in (i.e., that the project knew how the flight system was intended to operate so that operational risks were understood and design features were included in the technical baseline and implementation cost estimate). In other instances, the NPR provided specific guidance for authors (e.g., Appendix F. 3 is a comprehensive Project Plan template, including instructions for each of the supporting control plans) or provided a suitable pointer (e.g., "Develop a *preliminary* orbital debris assessment in accordance with NASA Safety Standard 1740.14." [11])

In many instances JPL provided templates that could be readily adapted for project use. A key example included an Institutional Project Review Plan (providing the standard reviews, and their convening authority, objectives, scope, success criteria, and timing) and a supplemental Project Review Plan template to fill in the specific review dates, review board chairs, project-initiated peer reviews, etc. An example of a different sort was the Acquisition Plan template, which provided basic principles, options for system contracted and in-house project implementation modes, and instructions/examples for how to fill in the specifics of the project's procurements and non-procurement agreements, surveillance approaches, etc. Some plans did not have JPL templates, so the GRAIL authors either developed their own (e.g., Security Plan) or adapted from another robotic mission (e.g., Science Data Management Plan modified from that of the Juno project). It was very valuable to have institutional assets available to the already-busy authors. In turn, the GRAIL PMSR and PDR document set will provide a helpful resource for future projects to consider.

For the Project Plan and a number of identified planning documents (including most but not all of the NASA control plans and some additional documents, e.g., Spacecraft System Implementation Plan), JPL requires internal review by the cognizant JPL process owner. This factored into the planning schedule for documents, for which three groupings were identified:

(1) Group 1 – NASA gate products – required to be delivered to the NASA SRB in advance of the life-cycle review (some of which also required JPL process owner review)

(2) Group 2 – JPL gate products requiring process owner review (14 day review cycle, though not always met in practice)

(3) Group 3 – JPL gate products not requiring process owner review

In all cases, GRAIL self-imposed a policy that all documents would receive some form of internal review. This was to ensure quality and consistency and that the team really understood its collective baseline and implementation approach. The method of internal review was determined by the project key staff. In a number of cases, the document in question was created through a concurrent engineering process, so no additional internal review was needed. (For example, the monthly Risk Board meetings were the vehicle for producing the Significant Risk List, and concurrent engineering "pit sessions" produced the Level 2 Project Requirements Document.) In the other cases, the document author was given the opportunity to nominate one or more project reviewers (and could add a line organization reviewer(s) if desired) and the Review Captain and Project Manager could add additional names if appropriate – but all reviewers had the same 14-day time limit for providing comments. "Silence constitutes acquiescence." [12] Because the Review Captain had been part of the NPR team, he personally reviewed most of the NASA deliverables.

Important assistance was provided by the Documentation Lead and her support team. She provided GRAIL-formatted document shells, including cover page, signature page, change log, introduction, applicable and reference documents, and acronyms list, in addition to text page headers and footers. This was frequently supplemented with custom work with figures, tables, and other graphics. The Information Management Engineer, Configuration Management Engineer, and Project Librarian provided the electronic library and data management system repositories for collection, configuration management, and ultimately configuration control of the controlled documents and, in the case of the pre-PDR review materials and review board reports, controlled records. The Project Secretary coordinated document signatures, both on-site and remotely from a nationally distributed team.

Keeping track of over 100 gate product documents is difficult, so the team created a tracking matrix by adding fields to the JPL Gate Products List. The tracking matrix included the following fields:

(1) Fields from the Master List

a. Seq Number
b. WBS Element
c. FPP Section (reference to JPL Flight Project Practices section that specified the product)
d. Products (title)
e. Maturity level required (e.g., at MDR/PMSR and at PDR) (in many instances with supplemental instructions in footnotes)

(2) Fields added by the GRAIL team

a. Template available?
b. PMSR version? (i.e., did we already have a version at the previous review?)
c. Assigned to (author)
d. Project Staff Lead (project key staff person the author reports to, unless the author is key staff)
e. Process Owner Review? (i.e., was such review required)
f. Project Informal Reviewers (by name, or alternative method)
g. D- Number (JPL official tracking number for released documents)
h. Due Date (dependent on the Group above, or occasionally specified otherwise, e.g., CADRe is due 60 days prior to the KDP [13])
i. Status
j. Comments (e.g., rationale for why a product was Not Applicable to GRAIL, or was included in another product, or would be the subject of a JPL waiver)

The tracking tool evolved from the PMSR version through Phase B and proved to be extremely useful. Several rows and columns from the actual GRAIL PDR tracking tool are provided as Figure 4.

7. PRESENTATION MATERIALS

It would not be a life-cycle review without PowerPoint slides, so planning was required in the area of presentation materials.

Some key lessons learned from the PMSR influenced the planning. One technique that was very helpful was the Outline Review, discussed below, so it was fine-tuned for the PDR preparation push. On the other hand, the flow of the presentations at PMSR proved somewhat disjointed, which proved a disadvantage when trying to explain to its review board the validity of a non-traditional mission development and operations approach. (One error in judgment had been to defer the payload session until the key presenter could return from travel, so information that was important to air on the first day did not get covered until the third.) So the draft agenda for the PDR was subsumed under a straightforward flow:

Seq Number		PRODUCTS			Template Available?	PMSR Version?	Assigned to	Proj Staff Lead	Process Owner Review?	Project Internal Reviewers	Due Date	Status	Comments
			SDR/MDR	PDR									
NASA/Program *(NASA/Program Products Requiring Timely Inputs from Projects)*													
N	1	Project Formulation Authorization Document or equivalent					NA	NA		NA	NA	NA	
N	2	Project Level 1 Requirements (Program Plan Appendix 3)	Final (Under configuration control)	Update (if required)	NASA SMD's	Yes	Lehman ©	Lehman ©		Previously done	3-Oct	SIGNED	
N	3	NASA NEPA Compliance Documentation (including EIS if required)		Environmental Asessment.			Graham ©	Price ©		Lehman	10/3/2008	Memorandum for the Record signed; SMD AA to act after PDR	EA only (EIS not required)
				Environmental Impact Statement (If required).			NA	NA		NA	NA	NA	EIS not required.
N	4	Interagency and International Agreements (Note 6)		Final			Taylor ©	Taylor ©		NA	10/3/2008	NA	No NASA international agreement required for Dr. Wieczorek per SMD direction
N	5	S/W IV&V Plan (if IV&V is required)	Preliminary	Final			Larson ©	Price ©	Yes			IV&V Center changed their mind and want to support GRAIL. Kickoff telecon held Oct. 14, starts Plan development.	Will be late due to late NASA IV&V decision. Can probably have draft ready for PDR.
N	6	LS ICD (Note 7)		Preliminary			Gallagher ©	Gallagher ©				See comment	Per Note 7, timing is negotiated with LSP; current date is in 2009.
N	7	Acqusition Strategy Meeting (ASM) minutes (If Applicable)	Final (Note 27)				NA	NA		NA	NA	NA	Not required per Note 27.
N	8	Planetary Protection Certification	Final			Yes	Alkalai ©	Price ©		NA	NA	SIGNED	Certification letter from NASA PPO, GRAIL is Cat. I, with no further requirements
N	9	Range Safety Risk Mgt Plan		Preliminary			Vongsouthy ©	Bell ©		NA	NA	NA	NASA Range Safety has determined not applicable to GRAIL
Project Management													
PM	1	Task Plan	Phase B (Note 2)	Phases C/D	NMO/CMO's		Raymond ©	Raymond ©		Lehman, Taylor		Per agreement with Program Office, will do this after Task Plan for Phase B extension	Also need 2-month Phase B extension Task Plan, to accommodate Confirmation Review schedule
PM	2	Project Plan	Preliminary ready to sign	Final	Yes	Yes	Lehman ©	Lehman ©	Yes	Previously done	26-Sep	SIGNED (SMD signatures come after PDR)	

Figure4– Sample Gate Products Tracking Matrix

(1) Day 1 – What is GRAIL? (covering science & science implementation; instrument measurements; project management & resources; requirements, technical challenges, & risks; mission design; business management; and compliance status)

(2) Day 2 – What Will Fly? (flight system, payload, spacecraft, and the 8 spacecraft subsystems)

(3) Day 3 – What Supports It? (education & public outreach, project systems engineering, safety & mission assurance, Mission Operations System/Ground Data System, verification & validation, launch system, and Phase C work plan)

(4) Day 4 – SRB Deliberations (with 90 minutes for supplementary project presentations as required by the SRB).

The daily theme and associated detailed presentations were expected to make the material easier to follow by providing a logical structure. It would also have the side benefit of allowing more points to be spoken only once, thereby putting less presssure on the time allocations for the presenters.

The Outline Review was held six weeks before the PDR, which was further in advance than had been the case for the PMSR. This was largely because of the need to conduct it prior to the battery of pre-PDR reviews, but turned out to be of great benefit for making important decisions early. The major ground rule of the Outline Review was that no one was allowed to show full-text vugraphs. (The project manager had already written his detailed slides, so he was instructed to de-text them and bring in outline materials only.) The presenters were required to show the title and key points for each slide they planned to produce and to indicate what photographs, tables, graphics, video clips, etc. they would use. They were not allowed to brief the slides, only to give 1 - 2 sentences on what the message of the slide was intended to be. A mini-review board (Review Captain, Project Manager, and Flight System Manager) asked questions and gave suggestions, assisted by the rest of the key personnel. Results of this one-day activity included: moving certain material from one presentation to another and eliminating duplication, revising the flow of presentations across the three days, identifying types of slides that should be standardized (e.g., Agenda slide, Summary of Previous Reviews slide), recategorization of slides from primary to backup (and vice versa), adjustment of time allocations, etc. By not having full text in front of the audience, there was no hazard of getting bogged down in

details or wordsmithing; everyone got a comprehensive view of the project as a whole, including strengths, accomplishments, issues requiring work, and more.

A Dry Run was held two weeks before the PDR. It was scheduled for a full week (less a half-day to support the SRB Kickoff Meeting, discussed below), with a "Do-Over Day" the following Monday to cover any presentation that might require significant rework. (Three subjects were directed to have a do-over.) Instructions were sent out in advance, including Dry Run agenda and slide preparation instructions. The Documentation Lead and her support team produced slide templates (for title slide, agenda slide, generic text slide, generic graphics slide with captioning, and issues and concerns slide). To the maximum extent possible the Dry Run agenda matched the planned PDR agenda. The time allocations were identical to those penciled in for the PDR, and the presenters briefed their slides as if this was the real event. The mini-board peppered them with questions or issues. Following each presenttation, a round table comment-and-critique period of 15-30 minutes analyzed what went well, what needed improvement, and whether any revisions were required. This enabled the collective wisdom to be captured in real time without a lot of paperwork and without overlooking valuable inputs.

After the Dry Run, finalization instructions were issued. The proposed final slides were QA scrubbed by a small team (RC, DL, ISL, and Export Technical Liaison). They were then sent for hard-copy reproduction in parallel with burning as DVDs for projection at the review. In addition, they were uploaded electronically to the SRB per the delivery schedule negotiated with the SRB.

8. INFORMATION TECHNOLOGY AND LOGISTICS

In the bustle of doing design work and cost estimation, writing and rewriting gate products, and holding inheritance reviews and PDRs, it is easy to lose sight of the behind-the-scenes tasks that facilitate a successful review. IT and logistics cannot be afterthoughts.

The Information Systems Lead and her team were responsible for the engineering environment that was used for the daily activities of the project: team meetings, access to the latest configuration items, e-mails, status reporting to NASA, etc. It is too late to establish the project library and product data management system and electronic conferencing capability a few weeks before the life-cycle review. These capabilities are needed at project authorization to proceeed, simply to get work done. When it comes time to prepare for the first life-cycle review, access issues have been resolved, bugs are fixed, and everyone is fluent in the applications, so utilizing them for review preparation actions is not an issue.

For the PDR itself, additional IT actions were required. Some of these related to supporting the SRB, and are discussed in Section 9. Other concerned ordering the right kind of IT assets for the review. Because the review was held off-base (to eliminate the need to deal with visitor approval processing, limited parking, and potential scheduling conflicts for the only auditorium large enough for the expected atttendance), laptop computers, printer, projectors (dual), screens, power strips, wireless authorization, laser pointers, etc. needed to be lined up. Some were rented from the hotel, others brought from the base. The systems had to be loaded with files from the master DVDs. Young employees from JPL volunteered to arrive early to be trained to run the computer projectors for half a day and then observe a real life-cycle review for the rest of the day. (As a training experience, it was desirable to have different high-potential candidates in each day – excluding Day 4.)

Similarly the Logistics Lead and her team had many items to juggle. Identifying and negotiating with a local hotel for plenary session room, SRB caucus room, room set up, hotel-supplied equipment and services (including all-important caffeine) began early and necessitated repeated visits and other communications. Negotiating government rates for a block of rooms for NASA and NASA contractor attendees was included. Producing a list of proposed attendees required many decisions. (For example, the project's partner organizations and the customer and the SRB would be represented, but which if any of their subcontractors; how many from each one; what about other interested parties such as members of a Laboratory-sponsored career development program or line managers whose employees work on GRAIL.) Foreign persons (there were two) required additional precautions (they had to be excluded from specific sessions). Operating a registration desk, keeping track of daily attendance (as a controlled record), and simply taking care of whatever needs the attendees identified was equally important. Again, young volunteers provided half-days of no-cost staffing in return for observing a major review.

9. SRB COORDINATION

Problems arise when the first time an independent review board interacts with the project occurs is at the actual life-cycle review. Opportunities for pre-review interaction on GRAIL included SRB establishment, Terms of Reference (ToR) negotiations, documentation submissions, and Kickoff Meeting participation.

NPR 7120.5D establishes a process whereby SRB members are collectively agreed upon by the Convening Authorities. In the case of GRAIL, the project and the Center (JPL) nominated four members of the SRB. They were two Center employees, one retired employee, and the PI of a predecessor project, from the University of Texas. They

were familiar with GRAIL because three had served on the PMSR review board and the fourth had assisted the project team as a proposal consultant during Phase A. Just like the SRB Chairperson (SRBC), Review Manager (RM), and other members, they were all independent of the project and met the Agency's competence and conflict of interest standards. A lesson learned for future projects is to start the board staffing process early and understand any special standards of the Decision Authority (e.g., that the Chairperson should not be from the cognizant Center).

ToR negotiations are important because they pre-establish the ground rules for the life-cycle review (including review objectives, scope, success criteria, and schedule) and any required pre-work (e.g., documentation deliveries). Negotiating the agenda for the review also helps to ensure a match between what the project plans to present and what the SRB really needs. This includes materials to support any special assessment identified by one of the Convening Authorities and included in the ToR. (The GRAIL SRB was tasked to make one specific evaluation, regarding whether Phase B design changes had been appropriately incorporated into the project's Phase C/D work plan.)

Early document deliveries allow SRB members to gain familiarity with the project, particularly the maturity (or lack thereof) of its technical, schedule, and cost baseline. Submittals are electronic to an SRB repository; this can be by means of granting the SRB access to the project's electronic library, or, as in GRAIL's case, by the project uploading files into the SRB's own resource. (In this case, the NASA Process Based Mission Assurance (PBMA) site.) The ISL and Librarian received access privileges and set up a user-friendly file structure (traceable to the 7120.5D gate products and control plans tables), then uploaded the products as they were completed and signed. Per request of the SRB Chairperson, the project also uploaded all of the pre-PDR reviews records, including presentation materials, review board reports, and RFAs.

The Kickoff Meeting (October 30, 2008) provided face-to-face introduction of the project key staff to the SRB. It included an overview briefing of the salient features of GRAIL and included a special tour of engineering model hardware being tested in a flight relevant environment. The Chairperson specifically requested that the project discuss a) what had changed since the Phase A Concept Study Report and why, and b) what things kept the project manager up at night. The Review Manager requested that the project summarize its readiness status against the PDR entrance criteria and the delivery status of the 7120 gate products and control plans. The project requested that during the review the Board distinguish between RFAs and Requests for Information (RFIs) – the project provided forms for both, which the SRB adopted – and be careful to specify which findings, if any, were to be considered issues affecting passing the KDP (as opposed to items to be worked off during Phase Ç).

Weekly working telecons prior to the kickoff meeting facilitated good communication and ensured that important action items were not allowed to linger. Participants included the PM and RC from the project, SRBC and RM from the SRB, the NASA Headquarters Program Executive, and NASA Program Office personnel.

10. Recommendations And Future Applications

The NPR 7120.5D SRB construct is new. The SRB process is evolving and the projects are at some risk with respect to changing requirements, some written and some unwritten; some from their home institution, some from NASA Independent Program Assessment Office (IPAO), some from the specific experiences of the particular SRB Chairperson.

The Center can establish a project review support function or office to assist a project in getting ready for its first life-cycle review. These personnel can provide valuable suggestions as to what is desirable and undesirable to go into a ToR, explain the then-current rules on SRB staffing, and keep up a continuing dialogue with IPAO, the NASA Chief Engineer, and the NASA Directorates. This can identify best practices from other reviews as well as items to look out for. The Centers do not have a uniform way of performing the support function – JPL's is additional duty for some members of its Project Support Office – but the key is to have some organ ready to help the project when it first approaches this uncharted territory.

The Project can establish a Review Captain and/or Review Team to focus on the life-cycle review preparation as its major focus. The personnel can be project personnel, institutional staff, or a mix – GRAIL used a mix – but the key is to have someone in charge to identify all required activities in a timely manner, establish an early interface with the SRB, and map out an efficient methodology and schedule for getting everything done during a period of heavy activity.

The Center and/or the Project can create or adapt aids to make the preparation job earlier. An Agency-wide sharing of SRB process lessons learned and aids would be most helpful.

Specific lessons learned include:

(1) Ensure that the SRB Chairperson and Review Manager are appointed early and maintain a regular dialogue with them.

(2) Ensure that the SRB members are appointed early enough to support the Kickoff Meeting and review key project documents prior to the life-cycle review.

(3) Interact between the Kickoff Meeting and the life-cycle review on required inputs for the Independent Cost Estimate and the Independent Schedule Assessment.

(4) Negotiate the life-cycle agenda with the SRB Chairperson and Review Manager, particularly looking for instances where their home institutions use different terms for topic areas and/or require gate products or pre-reviews at different times from your institution's rules.

(5) Appoint the project's Review Team early, generate a master schedule of review activities linked to the project's Integrated Master Schedule, provide aids, and regularly communicate progress, issues, and problems with the PI, PM, and Program Office.

(6) Identify specific approaches for requirements development, pre-reviews, gate products generation, presentation materials development, and IT and logistics.

11. SUMMARY

The GRAIL Project established and effectively utilized a preparation team for life-cycle reviews. They and the project team completed all necessary activities in the areas of pre-PDR reviews, gate products, presentation materials, IT and logistics, and SRB coordination. This greatly facilitated a successful Project PDR and subsequent confirmation of the project to begin Phase C. <14>

REFERENCES

[3] Gravity Recovery And Interior Laboratory (GRAIL) Mission Proposal, June 2007, p. D-1.

[4] (same as above)

[5] (same as above, but p. D-2)

[6] NASA Procedural Requirements (NPR) 7120.5D, NASA Space Flight Program and Project Management Requirements, March 6, 2007, section 4.4.2, footnote 16.

[7] Jet Propulsion Laboratory Institutional Project Review Plan, Rev. 1, June 3, 2008, section 8.2, Table 8-2.

[8] NPR 7120.5D, Table 4-3.

[9] NPR 7120.5D, Tables 4-3 and 4-4.

[10] NPR 7120.5D, section 4.5.2 b. (5).

[11] NPR 7120.5D, section 4.5.2 b. (10).

[12] Tom Gavin, JPL Associate Director for Flight Projects and Mission Success, announced at Cassini RFP Pre-ship Review meetings.

[13] NPR 7120.5D, section 4.5.2 c. (3).

[14] The author acknowledges the invaluable assistance of the GRAIL Review Team: Susan Deligiannis, logistics lead, Claire Marie-Peterson, documentation lead, Julie Reiz, information systems lead, Suzanne Sinclair, librarian, and support team, as well as assistance from the JPL Project Support Office. The author also thanks Dr. Maria Zuber, PI, and David Lehman, PM, for the opportunity to work on this project.

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BIOGRAPHY

Randall Taylor *is the Project Acquisition Manager for the Gravity Recovery And Interior Laboratory (GRAIL) robotic lunar mission study. He was the Project Acquisition Manager for the Prometheus Project at JPL, which was developing a revolutionary new-development nuclear electric propulsion (NEP) spacecraft for deep space exploration. Prometheus utilized a unique co-design approach to spacecraft development by JPL, the DOE Office of Naval Reactors, Northrop Grumman, and five other NASA Centers. He served as Procurement Manager for the Mars Pathfinder Project, which successfully landed the first rover on Mars. In his 26 years at JPL, other key assignments have included contract negotiator for Deep Space Network 34-meter antennas in the U.S., Australia, and Spain, and supervisory and management positions responsible for flight project procurement personnel. He has negotiated contracts with Russian and Swedish organizations and supported international agreements and subcontracts with German, Danish, and Italian organizations. He served on the NASA Program Management Council Working Group (PMCWG), which wrote NASA Policy Guidelines (NPG) 7120.5A and .5B, the NASA Integrated Action Team (NIAT), and the NPR 7120.5D Team. He received B.A. and J.D. degrees from UCLA and is a member of the State Bar of California and is a Certified Professional Contracts Manager.*