James Webb Space Telescope (JWST) Independent Comprehensive Review Panel (ICRP)

FINAL REPORT

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ICRP Approvals

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1. Foreword

The James Webb Space Telescope (JWST) was endorsed in the 2000 Astronomy Decadal report as its top-ranked project; JWST was widely recognized as the next Great Observatory to replace the Hubble Space Telescope (HST). The Decadal recommendation was accepted by NASA and work on the Observatory began soon thereafter with support from Congress and the Office of Management and Budget (OMB). JWST had a prolonged technology development period following the selection of the prime contractor in 2002. It is difficult to predict how long it will take to develop a new technology, and during the period from 2002 to 2008, JWST struggled with several cutting-edge developments. These developments took longer and consequently cost more than forecast during Formulation, prompting NASA Administrator Michael Griffin to note that JWST had been underfunded during that period. Nonetheless, enthusiasm for the scientific potential of the Observatory, building upon the continuing scientific discoveries of Hubble, has led to great interest in completing and launching JWST. The recent 2010 Astronomy Decadal Survey, for instance, reaffirmed the scientific importance of JWST. As Senator Barbara Mikulski noted in her letter requesting an independent review of JWST, "The James Webb Space Telescope will be the most scientifically powerful telescope NASA has ever built—100 times more powerful than the Hubble, which has already rewritten our textbooks." The required technology challenges have successfully been met and JWST is poised to deliver on that promise. As the panel set up by NASA in response to the request from Senator Mikulski, the ICRP recognizes the widespread support for this mission, but also the frustration that its continual budget problems have engendered. Given the importance for NASA to deliver this major space project at the cutting edge of technology, the Panel took an objective, thorough look at this Project and how it was managed with the goal of providing recommendations that will lead to a successful launch for JWST at the smallest additional investment by the nation.

2. Executive Summary

The problems causing cost growth and schedule delays on the JWST Project are associated with budgeting and program management, not technical performance. The technical performance on the Project has been commendable and often excellent. However, the budget baseline accepted at the Confirmation Review did not reflect the most probable cost with adequate reserves in each year of project execution. This resulted in a project that was simply not executable within the budgeted resources.

Budgeting

The estimate to complete the JWST Project at Confirmation was understated for two reasons. First, the budget presented by the Project at Confirmation was flawed because it was not based upon a current bottoms-up estimate and did not include the known threats[1]. As a result of poor program and cost control practices, the Project failed to develop a reasonable cost and schedule baseline.

Second, the reserves provided were too low because they were established against a baseline budget that was too low, and in addition, because of budget constraints, were too low in the year of Confirmation and the year following (less than 20%) the two highest expenditure years. Leadership at Goddard Space Flight Center (GSFC) and NASA Headquarters failed to independently analyze the JWST Project's performance and recognize the flawed baseline.

The reserve situation was recognized as a problem at the time, as was a degree of optimism in the integration and test (I&T) budget, which prompted NASA management to change the baseline launch date from June 2013 to June 2014 and to add extra reserves in the out years.

Unaware of how badly understated the JWST Budget[2] was, NASA management thought there was a 70% probability of launching in June 2014 at a total lifecycle cost of nearly $5 billion with the Confirmation budget profile. In fact, the Project had no chance of meeting either the schedule or the budget profile.

Another contributing factor was that in balancing the overall astrophysics program, the Astrophysics Division did not allocate the full funding amount needed to execute the Project. This might have required shifting resources from other programs within the Division. If this was not within its budgeting authority, the Division should have gone on record to the SMD and Agency management that its portfolio was not executable. Instead, the Division accepted the Project's continuing practice of deferring work and accepted the consequence of continued cost and schedule growth.

Still another contributory factor was the lack of effective oversight by GSFC of what the Project presented at Confirmation and at the subsequent program budget submissions. The direct cause for this was the interpretation of the NASA governance policy on roles, responsibilities, and accountabilities regarding the Center in project management and execution, due either to ambiguity in the NASA governance policy or to lack of effective communication between HQ and the Centers on this important issue. In either case, immediate corrective action is required.

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[1] The term "threats" as used in this report refers to items of work that arise during development and are not included in the Project work plan and for which there is no allocated budget.

[2] At the Confirmation Review, the phrase "JWST Budget" was used to indicate the budget developed by the JWST Project and presented as the basis for Confirmation. For clarity, the phrase "Project Budget" is used throughout this report to refer to that budget.

The flaw in the Project Budget should have been revealed as part of the Confirmation process. The fact that it was not reflects the lack of an effective cost and programmatic analysis capability at HQ. This too requires immediate corrective action. It is critical to the successful completion of JWST to establish credible program and cost control capabilities at the GSFC Project office and to establish a robust independent analytical capability at both GSFC and HQ.

Project Management

The Project reported a "red" assessment on cost in 7 of 9 quarterly reporting periods following Confirmation. The implication of these warnings—that the Project had no chance of meeting the planned budget and launch schedule—was interpreted by NASA leadership as a cost-control issue on the part of the contractor and not as a fundamentally broken estimate. Unaware of this, NASA worked with OMB and Congress to add funds piecemeal to the JWST Project on a year-to-year basis to help the Project, but these actions did not fix the Project in terms of providing the budget allocation to meet the agreed to life cycle cost and defined launch date. Again, the lack of an operational and effective cost and programmatic analysis capability at HQ was a contributing factor. Such a capability is required as a forcing function to define for senior NASA leadership what the current Project status is and what resources would be required to execute the Project.

The JWST Project Office at GSFC should be restructured to ensure that the Project is now managed with a focus appropriate to the Implementation Phase. Particular focus needs to be given to managing the project to the Life Cycle Cost (LCC) and Launch Readiness Date (LRD), and to developing robust I&T plans, consistent with delivering an Observatory that will meet its science requirements. The flawed practice by the Project of not adequately accounting for threats in the budgeting process needs immediate correction.

Essential to fixing these problems is moving the JWST management and accountability from the Astrophysics Division to a new organizational entity at HQ that would have responsibility only for the management and execution of JWST.

Minimum Cost-to-Launch

The earliest launch date possible—and hence the minimum cost to complete—is September 2015 and would require an additional ~$250 million above the current FY 2011 President's Budget profile in both 2011 and 2012. In addition, the critical management change noted above, along with the restructuring of the JWST Project office, supplemented by additional changes outlined in the report, must go "hand-in-hand" with additional funding.

In the time available, it was not possible to do an independent estimate of the cost-to-complete. As such, the Panel approached the question from several different points of view as described later in this report, leading to a judgment that the total LCC will be in the range of $6.2 billion to $6.8 billion. The Panel adopted an LCC of $6.5 billion on which to base its profile. Going forward, a bottoms-up estimate validated by an independent analysis and at least two independent cost estimates (ICEs) is required. Although not explicitly accounted for in the Panel numbers, there may be a number of low probability threats whose occurrence could cause an additional year delay in launch and a correspondingly higher cost.

In providing these assessments and recommendations, the Panel is fully aware of the problem in adjusting budgets at this late date—especially in the face of the nation's fiscal challenges. Nevertheless, despite management and budget shortcomings, the JWST Project has invested funds wisely in advancing the necessary technologies and reducing technical risk such that the funds invested to date have not been wasted. The management approach, however, needs to change to focus on overall life cycle cost and a well-defined launch date.

3. Overview

ICRP Task

In a June 29, 2010, letter to NASA Administrator Charles Bolden (see Appendix E), Senator Barbara Mikulski, Chair of the Senate Subcommittee on Commerce, Justice, and Science, expressed concern about JWST cost growth and schedule delays and asked that a panel be charged to conduct an independent and comprehensive review of JWST and to carefully examine four areas:

1. The technical, management, and budgetary root causes of cost growth and schedule delay.
2. Current plans to complete development, with particular attention to the integration and test program and management structure.
3. Changes that could reduce cost and schedule or diminish the risk of future cost increases without compromising Observatory performance.
4. The minimum cost to launch JWST, along with the associated launch date and budget profile, including adequate reserves.

In response, the NASA Associate Administrator convened the Independent Comprehensive Review Panel (ICRP) and charged it with providing a response to Senator Mikulski.

The ICRP was asked to pursue its task with an emphasis on reviewing existing data from an independent, integrated perspective and on providing recommendations based on inputs from existing teams, as well as from information gained as a result of investigations of areas the Panel believed required further evaluation.

Biographies of the Panel members and support staff appear in Appendix B.

ICRP Schedule

The Panel performed its activities through several weeks of investigation, followed by deliberations and generation of the final report. The schedule of activities was as follows:

- Panel kickoff: August 23, 2010
- Investigation: August 24–September 19
    - Fact-finding interviews with key Project personnel, stakeholders, and subject matter experts
    - Analysis of data received to date and relevant prior studies
    - Independent technical and programmatic assessments as defined by the Panel
- Final Panel deliberations and initial report generation: September 20–October 1
- Revision, editing, and production of draft report: October 2–21
- Briefing to NASA HQ, including limited release of draft report: October 22
- Revision, editing, and production of final report: October 22–29

A detailed schedule showing specific meetings and activities appears in Appendix C.

Methodology

The ICRP proceeded through a fact-finding–investigation process and deliberations, addressing the causes for past cost and schedule growth and the four areas identified above as follows:

- Review of prior studies and Project data that address causes of the cost and schedule growth, including integration and test, management structure, and budgetary issues;
- Technical and programmatic review of the Project's existing data, including plans for future activities;
- Interviews with key Project personnel and relevant stakeholders;
- Evaluation of the cost and schedule estimate at complete for the current plan;
- Independent technical and programmatic assessments of the current plan tasked to the Panel's support staff; and
- Development of the "minimum cost-to-launch" option for JWST, incorporating inputs from several different sources.

The Aerospace Corporation (Aerospace) supported the ICRP with independent technical and programmatic analysis as needed to meet the objectives listed above. Administrative functions for the Panel were handled by the Executive Secretary, also from Aerospace.

4. Areas of Concern

In her letter to the Administrator, Senator Mikulski singled out four areas for careful consideration. This section provides a summary of the Panel's observations regarding those areas, while Section 5 contains detailed findings, assessments, and recommendations on the specific issues uncovered.

4.1 Root Causes

The root causes for the recent cost and schedule growth in JWST can be traced to what occurred at the Confirmation Review in July 2008 and to the execution of the Project following Confirmation.

Two fundamental mistakes were made at the time of Confirmation. First, the Project Budget presented for Confirmation was not based upon a current, bottoms-up estimate of projected costs. Furthermore, it did not reflect the threats against the budget that existed at the time. Consequently, the budget approved at Confirmation understated the real requirements. Second, the Agency Program Management Council (APMC) did not fully recognize the inadequacy of the Project Budget, although they did add contingency (reserves) to cover unanticipated problems that were likely to occur on such a complex project. However, there were two issues with the Confirmation budget decision: the reserves added to the Project Budget were inadequate, and the reserves were skewed to the out years so that inadequate reserves were provided in the years needed.

NASA policy generally sets budgets for development projects at a 70% confidence level. A project budgeted at 70% confidence has a 70% chance at being completed at or below its budget. In addition to a 70% confidence budget, which implies approximately 20% reserves, the GSFC standard for development projects requires 25% in unencumbered reserves in each budget year to address the unanticipated problems that occur in complex space system development projects. For JWST, the Agency reserves were established against an unreasonably low budget, and much of the reserves were allocated to the out years, not in the near-term years needed to avoid deferring work. For a project as challenging as JWST, in a portfolio without substantial flexibility, an 80% confidence budget would more likely represent a most probable cost, including maintaining 25% reserves in each year to deal with unanticipated problems. The constraints of the operating plan precluded budgeting for adequate reserves in FY 2009 and FY 2010, but the overall reserves were too low due to the incorrectly developed Project baseline cost estimate.

After Confirmation, the Project failed to change its management approach to be consistent with the accepted practice of managing a project to a required LCC and LRD, as agreed to at Confirmation. Prior to Confirmation, the Project managed to stay within its yearly budget allocation by deferring planned work in the budget year to a later year as a cost-control measure. This was not an effective LCC control measure since costs were not contained; rather they were simply postponed and funded out of a subsequent year's allocation at a higher cost (typically 2–3 times higher), due to inefficiencies visited upon other dependent tasks. The yearly budget allocation was determined primarily by affordability considerations, and not by an LCC commitment or a firm launch date. An approach of working to a budget cap with little reserves is acceptable during the preliminary design and risk reduction phase of a program, since it is rarely possible to estimate the LCC of highly complex, technology-driven projects before completing a preliminary design. In fact, the cardinal objective prior to Confirmation should be to retire project risk by developing technology to the point where the cost-to-complete can be reasonably estimated and an integrated project can be developed as a precondition for approval to proceed beyond Confirmation. The JWST Project did just that.

The management approach leading up to Confirmation was to plan work for every available dollar during each fiscal year. Rather than set aside reserve money to maintain scheduled work plans, the Project chose to defer lower priority work to future years. In this way, the Project was able to plan more work in each year, albeit at the risk of having to defer some of that work. The corollary effect of this was to increase the life cycle cost due to the inefficiencies incurred with deferring work and also to prolong the duration of the Formulation Phase. While effective albeit not ideal during the technology development phase before Confirmation, this management paradigm was not well-suited to sound post-Confirmation execution, where the commitment is to complete the development based on the expectation of a reasonably bounded LCC and a firm launch date. The commitment by the Project to manage the Program to the cost and schedule implied to Congress, OMB, and HQ senior management at the time of Confirmation was not carried out.

Rather than change its management paradigm after Confirmation, the Project continued the practice of deferring work into future years to stay within annual budget commitments. Management at both the Astrophysics Division and the Agency level were aware of this practice and tacitly condoned it. This is not consistent with managing a project to cost and schedule.

Senior management at GSFC, the Science Missions Directorate (SMD), and the Agency should have recognized the major impact to the LCC and LRD commitment that would result from the practice of deferring work to future years. The implication of this should have been clear from the regular monthly reporting, but prompt and effective remedial action was lacking. There are three reasons why this occurred:

1. The independent program analysis function within the Agency did not adequately penetrate the LCC and LRD implications of the Project Budget submissions, which led to an under-budgeted project that had to defer work each year with adverse effects.
2. Inadequate programmatic oversight within the Agency allowed generally poor cost management and reporting practices by the Project to go unchallenged during Program execution.
3. The JWST Project was not managed in a way appropriate for the Implementation Phase.

4.2 Current Plans to Complete Development

Overall, the JWST Project's hardware development program is progressing well, with the majority of flight hardware manufacturing and testing yet to be completed, but apparently on track with many of the challenging technology developments reasonably in hand, owing to significant accomplishments in the Formulation Phase. However, major uncertainties remain in the integration and test program, as noted by the Test Assessment Team (TAT) in their report of August 2010.

The TAT identified a significant number of opportunities to adjust the remaining cryogenic/optical testing at GSFC and JSC that would improve the overall technical and programmatic risk to the mission. This would be accomplished by reducing the planned timeline and allowing for the earliest possible detection of critical problems, such as those that might require opening the test chamber and implementing a second, corrective cryogenic test cycle.

The TAT concluded that testing at GSFC can be reduced from 14 to 10 months and that testing at JSC could be reduced from 167 to 90 days. Although there would be a small but acceptable reduction in prelaunch predictability of performance, there would be no predictable loss of science capability.

However, a significant—and not easily quantifiable—risk remains that problems will be found that either directly threaten mission success and/or do not allow an adequate characterization of the risk to mission success. The Program needs to establish appropriate reserves to address such problems. To date this has not been the case; the schedule and test plan activities seem to be continually evolving. This is because the Project, responding to crises and problems, and without adequate reserves, was in a continual re-planning mode.

The issue of the integration and test program structure and management was treated in detail in the TAT Report and will not be repeated here in full. However, key problems identified by the TAT included gaps in the test plans and the lack of an effective and cost-efficient test program. The Panel endorses the recommendations in the TAT Report as necessary corrective actions to contain future JWST cost and schedule erosion.

4.3 Changes to Diminish Risk of Future Cost Increases

Based on the issues present in the current plans to complete, the Panel has identified changes to address the root cause issues discussed in the report, plus ones that could be implemented to diminish the risk of future cost increases and delays in the launch date. These are summarized below. Further discussion and the full set of recommendations appear in Sections 5 and 6.

- Move the JWST management and accountability from the Astrophysics Division to a new organizational entity at HQ having responsibility only for the management and execution of JWST.
- Restructure the JWST Project Office at GSFC to ensure that the Project is managed with a focus on the LCC and LRD, as well as on meeting science requirements appropriate to the Implementation Phase.
- Assign management and execution responsibility for the JWST Project to the GSFC Director, with accountability to the Science Mission Directorate Associate Administrator at HQ.
- Establish the Office of Independent Program and Cost Evaluation (IPCE) as the recognized Agency estimating capability, responsible for validating the most probable cost and schedule estimates developed by projects and for developing ICEs for major milestone reviews.
- Develop a new JWST baseline cost and schedule plan-to-complete that incorporates adequate contingency and schedule reserve in each year. Include a realistic allowance for all threats in the yearly budget submission. Budget at 80% confidence, and require 25% reserves in each year through launch. Commission a new ICE, reconcile the new plan with it, and update the plan appropriately.

4.4 Minimum Cost-to-Launch

The minimum cost-to-launch JWST will be achieved by launching at the earliest possible date, consistent with safely completing the work needed to assure a successful mission. The earliest achievable launch date, previously thought to be June 2014, now appears to be September 2015, largely driven by inadequate reserves that have led to the Project deferring work and accumulating delays since the Confirmation Review in 2008.

This report discusses several different techniques used to estimate the required funding profile, including adequate reserves, to support the September 2015 launch date. The two primary estimates came from a request to the GSFC Director for an estimate for the minimum cost-to-launch and a corresponding launch date, and from an adjustment by the Panel to the Mission Critical Design Review (MCDR) baseline budget to include the known threats and liens and to add reserves by individual Project element as judged appropriate by the Panel. These two estimates were cross-checked against a historical cost growth curve and a complexity assessment model, both developed by Aerospace. Given all these inputs, and projecting a continuing Project Cost Performance Index (CPI) of 0.8, the Panel developed a budget profile for the minimum cost-to-launch, including completion of commissioning six months later, as shown in Table 4.1 below. Further details, including a graphical representation, appear in Appendix A.

	LRD	FY11, $M	FY12, $M	FY13, $M	FY14, $M	FY15, $M	FY16, $M	FY11–16, $B	LCC $B
ICRP Assessment	9/15	710	640	530	450	420	180	2.9	6.5

Table 4.1 ICRP assessment of the minimum cost-to-launch for a September 2015 LRD.

This assessment indicates that the LCC for JWST will be approximately $6.5 billion. To put this in context, the Hubble cost-to-launch was $4.7 billion in FY 2010 dollars; the cost through SM-1 in 1993, when Hubble's mirror problem was fixed, was $5.8 billion.

As described in the TAT Report, the Project can avoid some cost (and further cost growth) by simply accepting greater uncertainty in the accuracy to which flight performance can be predicted before launch. This does not imply any erosion in confidence that acceptable performance will be achieved.

To meet this schedule (launch in September 2015; end of six-month commissioning in February 2016)—and to meet the goal of "minimum-cost-to-launch"—would require an additional ~$1.4 billion over the current life cycle cost estimate in the FY 2011 President's Budget from FY 2011 through the first half of FY 2016, including an additional ~$250 million in both FY 2011 and FY 2012. The level of the near-term increases needed to fund the lowest cost approach to launch, particularly in FY 2011, is a challenge to the Agency, OMB, and Congress. Yet this is what is needed to put JWST on a recovery path when complemented by appropriate management and structural changes in the Project. If such funds are not available, particularly in FY 2011, the launch date will slip into 2016 (and probably even later), and the overall cost will likely grow by amounts that exceed the additional funds required in FY 2011 and FY 2012. The derivation of these totals and the rationale for these amounts are more fully discussed in Appendix A.

It was not possible to develop an independent and more in-depth estimate in the time available. Given that a bottoms-up cost estimate has not been done since the contract was awarded, a bottoms-up estimate is needed for the entire the JWST Project. The estimate should be validated by an independent analysis of the basis of estimates and the underlying assumptions and at least two ICEs. Although not explicitly accounted for in these numbers, there are a number of recognized low probability, high-consequence threats that, should they occur, could cause an additional year delay in launch and a correspondingly higher cost.

5. Findings, Assessments, and Recommendations

This section contains the ICRP Findings, Assessments, and Recommendations. In the context of this section—

- Findings are meant to be statements of fact, i.e., objective statements without opinion and without prejudice.
- Assessments are subjective and represent opinions of the Panel about what the Findings could imply as adverse consequences to the Program, and are intended to lay the basis and rationale for the Recommendations.
- Recommendations are subjective and represent opinions of the Panel as to how NASA might deal with the consequences of the Findings.

The ICRP took reasonable care to validate the Findings as factual through dialog with the interviewees, and in some cases by asking the principals themselves to do a validation. However, the ICRP is solely responsible for the Assessments and Recommendations, the validity of which are based on the experience and knowledge of the Panel.

The root causes for recent cost growth and schedule delay are traceable to the Project baseline established at the Confirmation Review and to the Project's implementation practices following Confirmation. The Project was hampered by earlier poor decisions and funding problems and went into the Confirmation Review carrying some burden of those past problems. Nonetheless, the Confirmation Review is when the Project should have been put on an executable plan to launch, with the appropriate management and oversight structure and the needed budget profile. Therefore, the ICRP focused on the assessment of cost and schedule growth and root cause following Confirmation.

5.1 Baseline Funding

The Project Budget baseline adopted at the July 2008 Confirmation Review was flawed. Not only was the budget inadequate to envelope the scope of the Program, but the allocated reserves proved to be insufficient given that the Project Budget was far too low and the reserves were skewed to the out years.

Findings

- The Project Budget presented for Confirmation contained no allowance for known threats.
- The Project Budget presented for Confirmation was incorporated into the FY 2010 President's Budget Request.
- It is NASA policy (NPR 7120.5D) to budget space system development programs to a 70% confidence level.
- The GSFC policy for reserves (GPR 7120.7) is at least 25% per year at Confirmation.

Assessment

NASA did not establish an adequate cost and schedule baseline at the Confirmation Review milestone. The Project Budget was inadequate because the Project did not include an allowance for threats that were known at the time nor did it account for the prior year earned value performance of the major contractors or the Center. Furthermore, the Project did not do a full bottoms-up cost estimate in preparation for the Preliminary Design Review (PDR), the Non-Advocate Review (NAR), or the Confirmation Review.

Figure 5.1 shows the Project Budget (Phases A–E) and Confirmation Review baseline. The difference between the two was identified as Contingency and is equal to the amount available for reserves. The highly unusual cost profile that peaked at PDR was explained on the basis that some major elements of the Project were already past their PDRs. While the Confirmation Review did provide reserve funds, they were really too low, given the low Project Budget request. This led to the Confirmation Baseline being "broken" from the start, since the available contingency was not adequate to cover the threats and liens that were known at the time, but which were not included in the Project Budget.

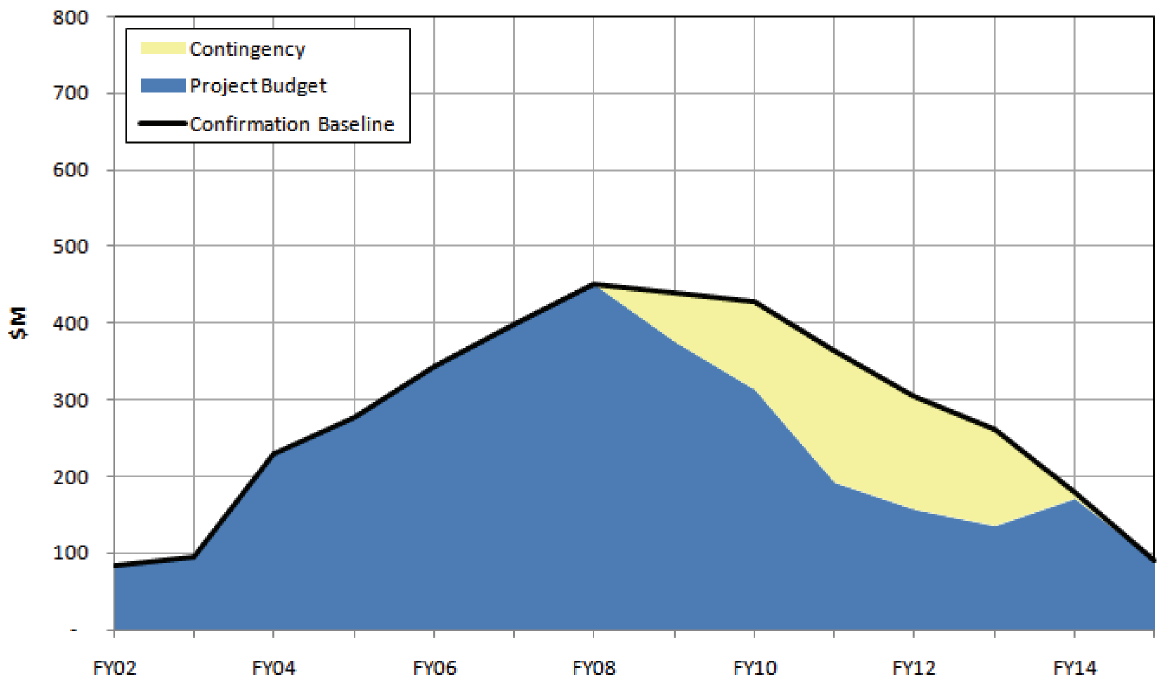

Figure 5.1 Plot of the Confirmation Review baseline budget (Phases A–E) and the available contingency.

The phasing of reserves accepted at the Confirmation Review was low in the near term. The Baseline Funding profile established at Confirmation (the black line in Figure 5.1) put the majority of the reserves in the out years.

The resulting percentage Contingency, shown in Table 5.1, appears unnecessarily large except in FY 2009, apparently reflecting recognition by the APMC of the questionable Project Budget roll-off profile. Recognizing the implication of the roll-off, the APMC assigned an action to re-examine the Project Plan and determined the need to provide additional funding in the next budget cycle.

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Confirmation Baseline	439	429	365	304	260
Project Budget, $M	376	313	191	156	135
Contingency against Project Budget, $M	63	116	174	148	125
Contingency as % of Project Budget	*17%*	*37%*	*91%*	*95%*	*93%*

Table 5.1 Contingency established at Confirmation.

As shown in Figure 5.1, the Project Budget showed that peak funding would occur in the same year as the Project PDR and that Project costs would go down by 16% in FY 2009 and 58% in FY 2011. Historically, the cost profiles of projects continue to increase after PDR. Based on the technical status of the Project, the prior deferral of spacecraft development, and the complexity of the integration and testing phase, this was a highly suspect budget profile.

To develop a sense of the effect of including an allowance for threats and reserves, the Panel adjusted the Project Budget by incorporating the dollarized value of the threats that were on the Project books at the time and 25% reserves. The result is shown in Figure 5.2. The figure clearly shows that a funding shortfall would exist in FY 2008, FY 2009, and FY 2010. For reference, and as a point of comparison, the 70% confidence IPAO ICE is also shown.

Table 5.2 shows that $340 million is the cumulative difference from FY 2008 to launch between the Confirmation Baseline and the Adjusted Project Budget. The cumulative difference between the Confirmation Baseline and the ICE is $640 million.

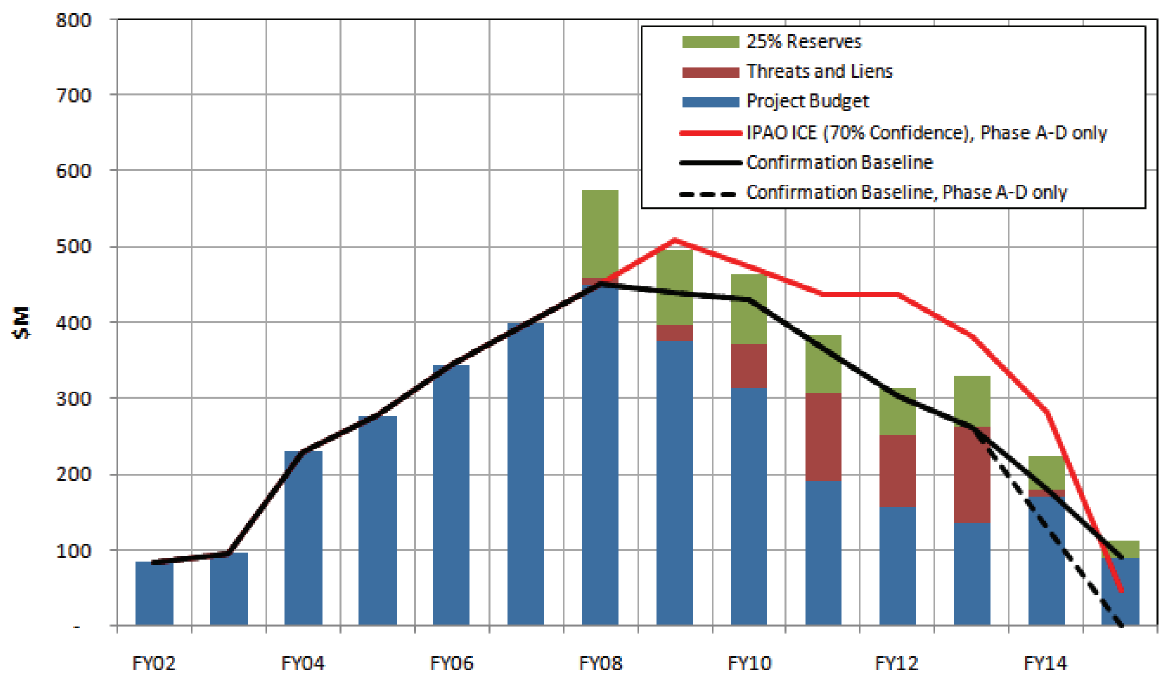

Figure 5.2 The Adjusted Project Budget (Phases A–E) and the IPAO ICE.

	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Total[2]
Difference between the Adjusted Project Budget[1] and the Confirmation Baseline, $M	123	57	34	18	8	69	32	–	341
Difference between IPAO ICE (Phase A–D only) and the Confirmation Baseline (Phase A–D only), $M	–	70	45	73	134	121	153	47	643

Table 5.2 Funding differences from the Confirmation Baseline.

[1] Adjusted Project Budget = Project Budget (Phase A–D), plus threats and liens known at the time and 25% reserves per year.
[2] Due to rounding, totals may not match sum of components.

Finally, Figure 5.3 shows that the Project Budget offered at Confirmation was nothing more than a reflection of the FY 2009 President's Budget Request (developed in the 2007–2008 timeframe and publicly released in February 2008) suggesting that budget profile was certainly not reflective of a current budget estimate or current cost plan.

Also shown is the FY 2010 President's Budget Request reflecting two things:

- First, a major increase in FY 2008 to accommodate the actual cost incurred by the Project in FY 2008 (nearly $70 million more than that projected at Confirmation), once again illustrating that the Project Budget presented at Confirmation was not based on current cost plan.
- Second, a one-year shift in the internal LRD from June 2013, which was the basis of the Project Budget, to June 2014, as recommended by the SRB and accepted by HQ.

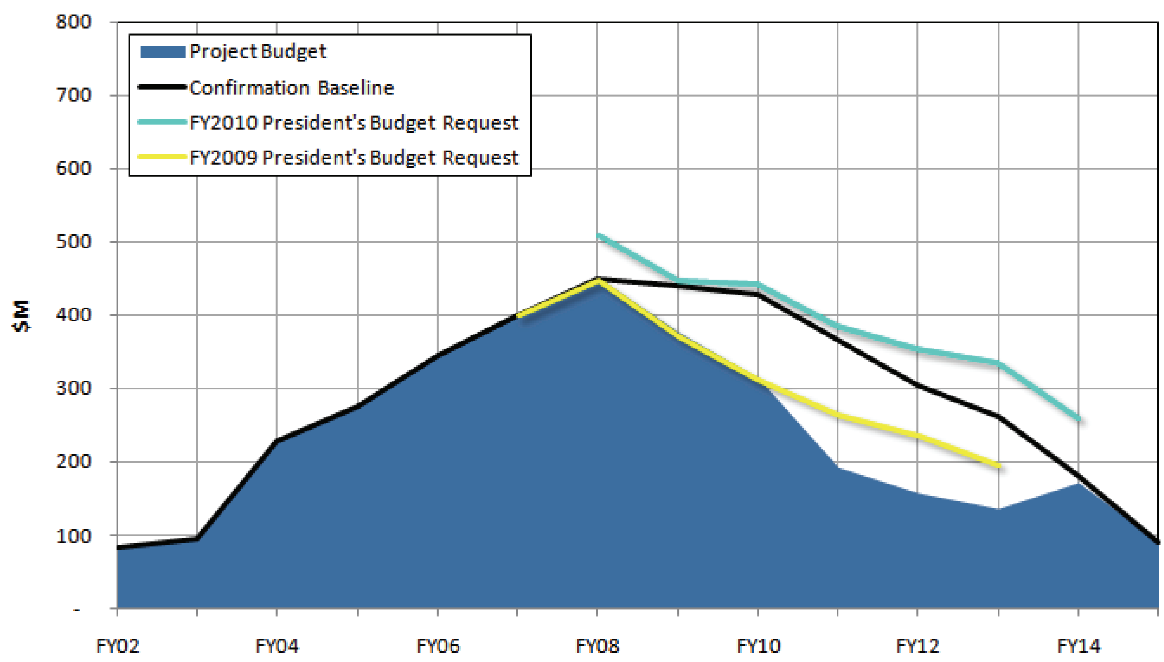

Figure 5.3 Confirmation Baseline (black) and the President's Budget Requests for FY 2009 (yellow) and FY 2010 (blue).

Recommendations

1. Develop a new baseline cost and schedule plan-to-complete that incorporates adequate contingency and schedule reserve in each year.
2. Include a realistic allowance for all threats in the yearly budget submission.
3. Budget at 80% confidence, and require 25% reserves in each year through launch.
4. Commission a new ICE, reconcile the new plan with it, and update the plan appropriately.

5.2 Independent Analysis Capability

As described above, the Project Budget was fundamentally flawed, but HQ also lacked a robust independent cost and program analysis capability and accepted the Project Budget as a true reflection of the estimated cost-to-go, i.e., containing an appropriate allowance for all known threats and liens.

Independent analysis capability within the Agency plays a crucial role in checking project budget plans. Historically, the Agency had such a capability that reported to the Administrator, but that function has not existed for over a decade.

Findings

- The SRB provided the independent assessment to the APMC at the JWST Confirmation Review.
- The IPAO provides support to the SRB in the form of ICEs and other logistical support.
- The approved Confirmation Baseline budget was significantly less than the IPAO ICE.
- The JWST SRB is a non-consensus body.
- The JWST SRB chair is not a NASA employee.

Assessment

A cardinal purpose of the Confirmation Review process used by NASA is to establish a programmatic and technical baseline defining the Implementation Phase for a mission. As discussed above, significant flaws existed in the Confirmation baseline for JWST. While there are ways this could have been recognized at the time, the independent cost and programmatic function of the Agency was not sufficiently capable to reveal the fundamental flaw in the baseline cost.

The IPAO is the professional cost-estimating capability within NASA and is located at Langley Research Center; it is organizationally part of IPCE. The IPAO provides support to the SRB, including the preparation of ICEs, but the SRB has complete discretion regarding if and how to use that support. The ICE, prepared in support of the SRB, was $0.5 billion more than the SRB recommended and more than the APMC ultimately approved.

IPCE should be accountable for the quality and completeness of IPAO products, and should be the organization specifically responsible for using those products in fulfilling its fiduciary responsibility to the Agency. Clearly, this did not happen in the case of JWST.

The SRB provides a mechanism for conducting independent reviews at regular milestones, and the APMC relies on the SRB to provide an independent assessment of the readiness of a project to proceed to implementation. The JWST SRB is a non-consensus body, and its recommendations are at the sole decision of its Chair, who is a non-Government person. The JWST SRB serves with integrity and commitment, but it performs an advisory function only and does not have an accountable fiduciary responsibility to the Agency as does the IPCE.

Recommendation

5. Establish IPCE as the recognized Agency estimating capability, responsible for validating the most probable cost and schedule estimates.
6. Hold IPCE accountable for developing ICEs for major milestone reviews, reporting directly to the Agency PMC and not simply acting as a support organization to the SRB.

5.3 Project Management

A different project management paradigm is required during the Implementation Phase (after Confirmation) than before. Deferring work from one year to the next as a technique for staying within the yearly funding cap necessarily increases the run out cost and incurs schedule slip, and thus contravenes the Agency's commitment to the LCC and LRD made at Confirmation.

Project management requires the identification and reporting of threats and liens and an ongoing assessment of the adequacy of available reserves to cover them plus an allowance for the yet to be recognized ones.

Findings

- Since Confirmation, the Project has continued its practice of deferring work in order to stay within its yearly funding cap.
- The Spacecraft Element schedule has been continuously delayed relative to the rest of the Observatory.
- JWST Project does not use likelihood of occurrence to determine an expected value for ISIM threats, whereas the prime contractor tracks likelihood as well as consequence.

Assessment

Deferred Work

Managing costs on a year-to-year basis led to deferred work and life cycle cost increases. Inadequate reserves in the period immediately following Confirmation resulted in a non-executable Project. Without the reserves needed to fund the exigencies normally experienced in the course of development, the Project simply continued the practice of deferring some of the work planned in the current year to a future year. Due to the inefficiencies created when deferring already planned work, this led to escalating increases in the life cycle cost of JWST and continued erosion of the schedule.

Experience shows that deferred work potentially doubles or triples costs, due to the impact of the deferrals on other work. This leads to a cascading effect wherein the cost of delayed activities further reduces the limited real reserves available to the project in later years, creating an escalating spiral for project life cycle cost. As the JWST Project was underfunded from Confirmation, the result has been a substantial impact to life cycle cost and schedule.

The practice of not reflecting known threats and liens, along with inadequate reserves, can be seen in the Project's budget submissions at the Confirmation Review in 2008, during the POP09 budget cycle, and at the Program Budget proposal at the time of the MCDR in April 2010 (see Figures 5.4 through 5.6).

Figure 5.4 shows the Confirmation Baseline (black line) and the Project Budget approved at Confirmation (blue bars). The difference between the two is the contingency, which was considered adequate to cover the needed reserves as discussed above (also see Figure 5.1). When the threats and liens, known at the time of Confirmation (red segments), and 25% contingency (green segments), are added to the budget, the reason for deferring work becomes apparent.

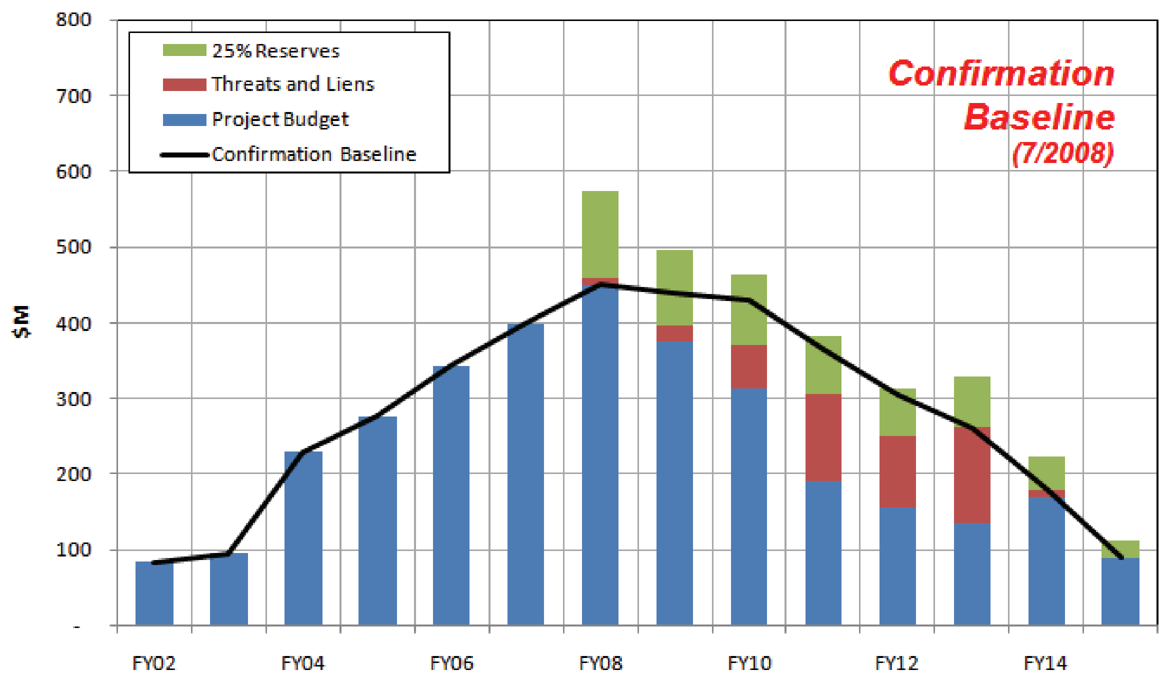

Figure 5.4 Confirmation Baseline (black) compared to the Project Budget adjusted for threats and liens plus reserves.

Figure 5.5 shows the Project budget proposal developed in spring 2009. The figure shows the actual for FY 2008, an increase of almost $70 million from the Project Baseline. Additional funds were added in FY 2008 to cover the FY 2008 actual, but by then it was too late to avoid deferment of $50 million to $70 million of work planned in FY 2008 to FY 2009, affirming the need for the 25% reserves amount suggested in the Confirmation Baseline. Had 25% reserves been available throughout FY 2008, it is unlikely that the Project would have had to defer any of the planned work to 2009. Note the increase in the budget plan for FY 2009 from the Confirmation Baseline to the POP09 budget; also note also that the threats have grown in that year as well.

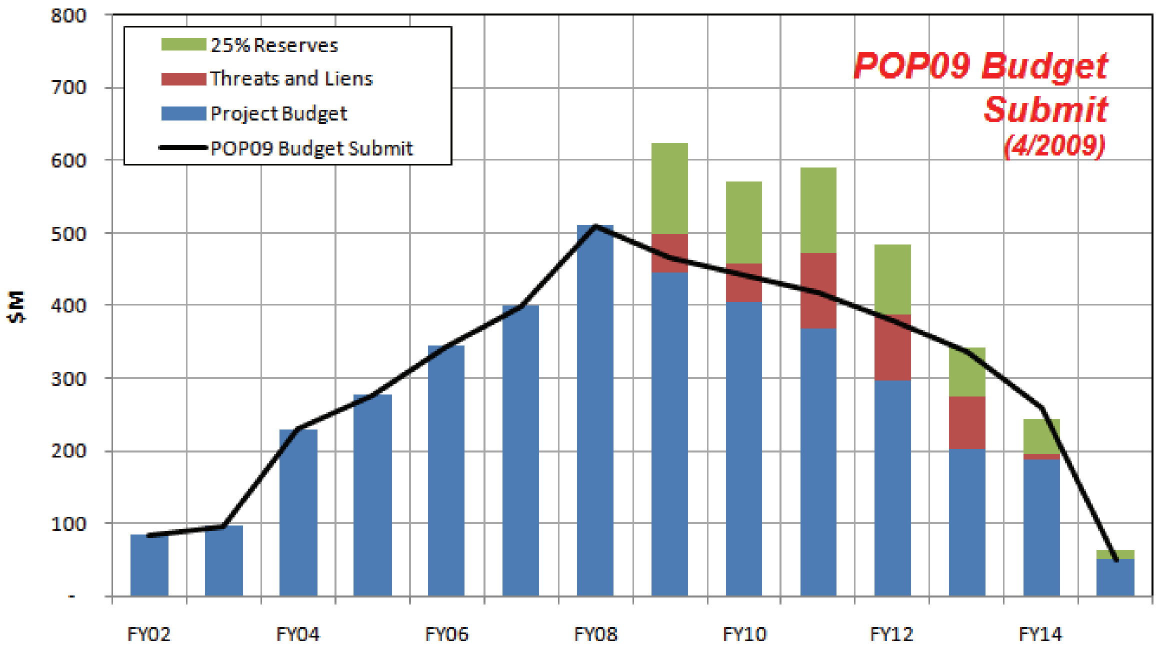

Figure 5.5 POP09 Budget Submit (black) compared to the Project FY 2009 Budget adjusted for updated threats and liens plus reserves.

The cascading effect of deferred work can be seen in Figure 5.6. An effective cost and program analysis function at the Agency level would have alerted executive management to this impending crisis. More properly, this should have been recognized by Center management before the Project was allowed to proceed on this basis. This can be attributed to the combination of the Center's expectation that program execution, and hence oversight, was the province of the SMD Program Office—and to the fact that the Center lacked the capability to do its own independent (of the Project) cost and program analysis.

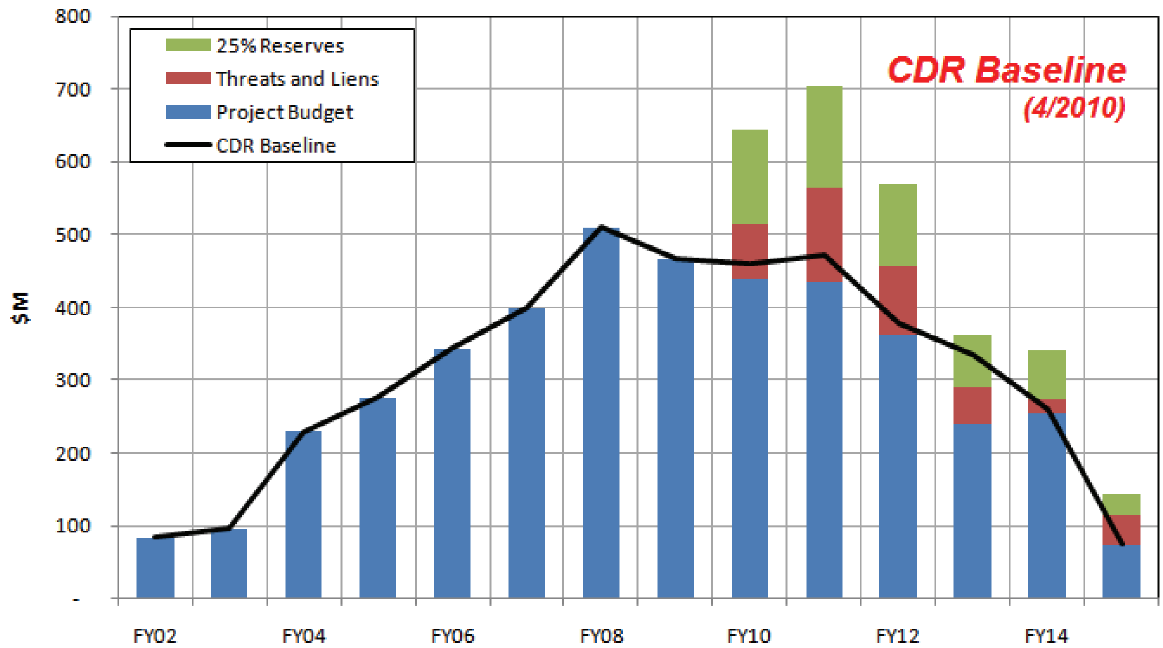

Figure 5.6 CDR Baseline (FY 2012 Interim Budget Submit) (black) compared to the MCDR Project Budget (April 2010) adjusted for updated threats and liens plus reserves.

It is clear from these observations that reserves on the order of 25% per year on the cost-to-go are required to allow Project work to proceed on schedule, to ensure that the cost remains within the LCC commitment, and to conform to the requirements of GSFC GPR 7105.7.

Threats and Liens

Differing definitions of threats, liens, and encumbrances have led to confusion. Threats and liens are tracked at both GSFC and NGAS (which includes those from subcontractors such as Ball Aerospace), but they are not included in the Project Budget until formalized and are not clearly communicated to SMD. This is illustrated by the $90 million "surprise," wherein SMD claims that NGAS submitted a large overrun shortly after the Confirmation Review in 2008. In fact, this "surprise" was the result of known threats for which the Project had asked the contractor to submit a formal proposal. Had the threats been included in the Project estimate, only the difference between the contractor's proposed cost and the Project's "should cost" estimate would have been a surprise. It is also noteworthy that the different groups track threats differently: NGAS uses likelihood estimates to determine an expected value (EV) of the dollarized threats, whereas GSFC management does not use EV to evaluate threats. Nonetheless, tracking threats more openly would lead to improved understanding of the risks to the budget, regardless of how the threats are characterized or their cost likelihood is reported.

The convoluted process for transitioning from threat to lien to encumbrance and the reporting of those items makes it easy to misunderstand the financial position of the JWST Project. The Project defines a threat as a problem that might produce a funding or schedule impact. Using judgment, a dollarized consequence is assigned to each threat and the threat is tracked via standard risk mitigation processes. When it is determined that a threat it has a 100% likelihood of occurrence, meaning it cannot be mitigated, it becomes a lien. At that point, it is used to encumber the budget, meaning that funds can be expended against it. While the process appears reasonable, there is lack of clarity regarding when the different transition points occur and how well the likelihood is evaluated, particularly since the JWST Project does not consider likelihood assessment in tracking its own ISIM-generated threats.

Project Implementation

Formulation and Implementation phases require different management approaches. Over $1.5 billion was spent over 6+ years on the Phase A/B effort, an unusually high investment for the Formulation Phase of a project. The Project has clearly done an excellent job in developing and maturing several key technologies. Significant funds were spent early and appropriately in order to get these challenging technologies to Technology Readiness Level (TRL) 6. This reflects a respect for lessons learned on numerous other Department of Defense (DoD) and NASA projects (Hubble is cited as an example where this was not done). However, even after reaching TRL 6, significant further engineering is needed to build and qualify the flight hardware.

While there has been a significant retirement of risk, JWST is still a high-risk project with substantial work remaining. The Implementation Phase (C/D) of a project typically has different areas of focus than that of the earlier Formulation Phase. Phase A/B activities may require different types of personnel to focus on interfaces, I&T, ground systems, mass margins, and related areas, which reviews of the I&T plan (such as the TAT Report) can help inform. The recent management change at NGAS, wherein a new JWST Project manager with I&T experience replaced a predecessor who had worked on the Project from its outset, is an appropriate example of how a different approach is needed in Phase C/D of a project.

Slipping the schedule of the JWST spacecraft element has increased risk. The CDR for the spacecraft is still months away and little work has been done because of the focus on other areas. The rationale for delaying the spacecraft CDR appears to have been to address the more challenging technology areas of the mission early to retire risk and avoid major cost and schedule impacts, but is really just another example of deferring work to fit within an over-constrained budget profile. This had the unintended consequence of placing the burden of interface accommodation largely on the spacecraft. It is thus likely that thermal, mechanical, and dynamics issues will need to be “absorbed” by the spacecraft, which could create significant cost and schedule impacts to the spacecraft element going forward.

Recommendations

7. Restructure the JWST Project Office at GSFC to ensure that the Project is managed with a focus on the LCC and LRD, as well as on meeting science requirements appropriate to the Implementation Phase.
8. Fund all existing deferred work in FY 2011 to get the Project back on track.
9. Implement a threats and liens system that is consistently applied across all elements of the Project.
10. Assess and track the likelihood of threats at the GSFC management level to more clearly delineate the process for transitioning from threats to liens.

11. Manage and assess contingency in terms of its adequacy to cover unknown and as yet unrecognized threats using the industry standard process of assessing the dollarized EV of existing threats.
12. Accelerate the spacecraft element schedule to more closely bring development into alignment with other Project elements.

5.4 Program Management

The five-year budget plans for projects are the responsibility of the Directorate and the relevant Division at NASA HQ. Those entities have a responsibility for ensuring that the budgets they develop for OMB and Congress are based on executable plans, especially for major projects.

Findings

- The Astrophysics Division's overriding management objective is to provide the most balanced science program across the Division within the resources provided to it.
- The budget for JWST in FY 2010 amounts to approximately 40% of the Astrophysics Division budget.
- Substantial decreases in the Astrophysics budget over time have put significant pressure on all programs in the portfolio.

Assessment

The Astrophysics Division Director appropriately noted his responsibility to manage his program to balance the overall science within the Astrophysics Program, i.e., to best meet the needs and interests of the broad science community given the funding available to the Division. However, when the Division undertakes a flagship project of the scale of JWST, it takes on an added responsibility to ensure that the project is delivered on schedule and within budget. The Division is now accountable for meeting NASA commitments to the Administration and Congress to execute the projects assigned to it within the resources and the timeline promised. This is particularly important for very large and expensive missions like JWST, where any problems can rapidly become very costly to address. In effect, a commitment to begin funding a flagship mission such as JWST requires an understanding by all stakeholders that the Project must have priority in available funding.

In balancing the overall astrophysics program, the Division did not allocate the full funding amount needed to execute the JWST Project, arguably because that might have required shifting resources from other programs within the Division. If that were not allowed within its budgeting authority, the Division should have gone on record to the SMD and Agency management that its portfolio was not executable. Instead, it accepted the Project's continuing practice of deferring work and accepted the consequence of continued cost and schedule growth.

The fact that JWST comprises some 40% of the Astrophysics Division annual budget creates challenges in funding the Project adequately while balancing the science programs across the Division. The proper course of action would have been either to reprogram funds from other activities in the Division or to insist on a re-baseline action. The Astrophysics Division and SMD did neither.

There is a need for adequate funding of flagship science missions without decimating the portfolio. The yearly funding requirements for large flagship projects can exceed the full cost of a typical small science mission. Funding the Project with 25% reserves per year could mean that the start of new or smaller missions might need to be delayed. In the peak funding years, this can amount to $100 million or more per year, enough to support a small mission. While the Astrophysics Division Director is under pressure to balance the science priorities with programmatic commitments, flagship missions must be funded with the full level of reserves needed to fulfill the Agency commitments to Congress and the Administration.

The JWST Program reports to NASA HQ rated the Project "red" on cost in 7 of 9 quarterly reporting periods following Confirmation. Senior management at HQ, already aware that the reserves in FY 2009 were low, reacted by adding resources in FY 2009 and taking action to add additional funding in the next operating plan submission. However, the amounts envisioned were substantially less than needed, being premised on the flawed budget plan. Funding added in 2009 and in early 2010, while viewed as a fix at the time, was simply insufficient given the size of the budget mismatch and the rate at which the Project was both accruing threats and converting them into liens. By the time new funds were available, the converted threats used all the new funds. Meanwhile, additional threats and problems had arisen, necessitating additional new funds.

An ongoing cost and program analysis capability independent of the Project at the Agency level is required to properly inform senior management and executive leadership and to prevent decision making that is based on flawed budget and execution information.

Recommendation

13. Move the JWST management and accountability from the Astrophysics Division to a new organizational entity at HQ having responsibility only for the management and execution of JWST.

5.5 Governance and Accountability

Projects of the scale of JWST are complex, with many interfaces within the Agency. Clear lines of accountability are required to ensure that projects are executed consistent with the budgetary and performance expectations of the Agency, OMB, and Congress.

Findings

- The NASA policy on governance (NPD 1000.01a) states that "Programs and projects are executed at the NASA Centers under the direction of the Mission Directorate Associate Administrators. The Center Director has specifically delegated Technical Authority responsibilities related to projects."
- Since the Confirmation Review, the Project has been rated "red" on cost for 7 of 9 quarterly assessment rating periods.

Assessment

Corrective action taken by executive officials in response to the "red" reports was not sufficient to correct the problems. The inadequacy of reserves in the early years was recognized at the time of Confirmation, but not the flaws in the cost baseline. "Red" conditions showed up in the cost reports within weeks after Confirmation, but these were taken as expected given the recognized reserve weakness. However, the inadequacy of the Project Budget, called for much larger funding than management anticipated. Funding was added on several occasions to assist the Project, in the belief that it would address the underlying problem. While this did help in reducing the amount of deferred work, it was quickly consumed to solve immediate issues resulting from previously inadequate reserves. Hence, none of these funding additions resulted in fixing the Project, i.e. establishing an executable cost baseline with adequate reserves in each year of Project implementation. Projects having the complexity of JWST require 25% reserves in each year of execution to solve the problems as they emerge in order to maintain schedule.

NASA governance policy is not consistent with accountability for project execution. As written, the NASA policy directive, NPD 1000.01a, does not hold Center Directors accountable for execution of projects managed at their Centers. Center management provides institutional, technical, and other capabilities to support the project. NASA Headquarters has the program management authorities and accountability. Yet Centers have the full range of space flight project development capabilities needed for effective project implementation, which HQ does not. There is a need to make Center management, under the leadership of the Center Director, fully accountable for project implementation within agreed to cost, schedule, and performance guidelines and to document this intent in the policy directive.

Lack of clear lines of authority and accountability has contributed to a lack of executive leadership in resolving the broken JWST life cycle cost baseline. The flawed budget should have been discovered as part of the Center's execution responsibility, but the interpretation of the Agency governance policy on the Center role in this regard is ambiguous and not uniformly interpreted within the Agency.

Ongoing, regular independent assessment and oversight processes at the Agency are missing. The Project is required to report its status on both monthly and quarterly cycles to successive levels of Center, Directorate, and Agency management. However, none of these receiving organizations has analysts charged with conducting an independent analysis of Project inputs. This results in a situation of "over reporting and under reviewing." Instead, the Agency relies on a system of independent and outside review by consultants external to the Agency (such as the SRB) to advise senior management. Such mechanisms can be effective to support milestone decisions, but do not provide for the day-to-day oversight required to help keep large, complex projects from getting into trouble in the first place. A functional organization accountable for ongoing project assessment, budget execution performance, and defense of project budget requirements to Congress and the OMB no longer exists within NASA. It became clear during the Panel's interview process that some individuals within the Agency believe that this function is provided by the SRB. Clearly this is an inadequate interpretation of what is needed for oversight and one that demonstrates the recognized lack of an in-house capability.

Recommendations

14. Revise the wording of the Agency's Center responsibilities document, NPD 1000.01a, to correctly and unambiguously reflect clear lines of authority, accountability, and responsibility for program execution.
15. Assign management and execution responsibility for the JWST Project to the GSFC Director, with accountability to the Science Mission Directorate Associate Administrator at HQ.
16. Ensure that the Project Office, the Center, and the Agency are each held directly responsible for conducting in-depth analysis and projections of monthly JWST Project cost and schedule performance.

6. Other Considerations

In her letter to NASA, Senator Mikulski requested an analysis of the root causes of the escalating costs and schedule erosion. The senator also asked for a comprehensive review to assess how to complete development of JWST within budget and on schedule. The preceding sections of the report spoke to the four key areas noted in the letter, including root causes, and offered recommendations to address the root causes for JWST cost growth and schedule delay. This section completes the Panel's response to the request for a comprehensive review by addressing other areas where improvement would enhance the probability of completing JWST within budget and on schedule. While these may not have contributed directly to the budget issues previously discussed, they represent opportunities for improvement that may help avoid future cost growth.

6.1 Communications

Findings

- Communication problems have arisen between the GSFC JWST Project and both NASA HQ (SMD) and NGAS.
- When the Project expenditure rate is over $1 million per day, delays in executive decisions can lead to cost impacts.
- The JWST Project Manager reports to the vice president of Civil and Military Systems, four levels down from the chief executive officer (CEO) of Northrop Grumman.

Assessment

Communication issues are present between the JWST Project and SMD management. The lack of effective communication between the Project Manager and both SMD and the Astrophysics Division leadership was apparent during the Panel's fact-finding interviews. There was a contrast between the view of the SMD and the Astrophysics Division—who claimed they had been responsive to Project needs and had given the Project all that was requested when requested—while Project management asserted that they had never been funded adequately and had little or no reserves to deal with the inevitable issues that arise in a project like JWST.

Issues exist in effective communication between NASA management and NGAS. The opinion that NGAS was largely to blame for the problems that the JWST Project has experienced appeared to be widespread throughout NASA. Yet in percentage terms, the overruns at GSFC on ISIM and the GSFC-managed instruments are comparable to those at NGAS. Furthermore, the importance of the threats list in the NGAS presentations at the NASA–NGAS monthly status reviews (MSRs) seems not to have been recognized by Project management. The message routinely communicated to HQ appeared to be that "the Project was in trouble and that NGAS is out of control." However, NGAS financial performance to date is typical of NASA projects. Based on NASA–NGAS monthly status review data and the fact-finding interviews, this opinion was not substantiated. In fact, NGAS had received award fees from GSFC that reflected a qualitative overall evaluation of "Very Good." This misunderstanding is an artifact of the poor communication within NASA and the Project team.

In the 15 award fee periods since Program start, NGAS has received award fees from GSFC that reflected a qualitative overall evaluation of "Very Good" and a cost performance of "Good." Since the Confirmation Review, the NGAS award fees for cost have been reduced to

"Poor/Satisfactory" to reflect NASA's concern about NGAS cost performance. Since the cost portion of award fee is only 25% of overall award fee (12.5% of total fee), the recent low grades on cost have had limited impact. Part of the miscommunication between NASA and NGAS is likely due to the relatively low NGAS incentive for cost control and the relatively high value placed by NASA on controlling JWST costs and balancing the Agency budget.

JWST Project reporting is at too low a level at the prime contractor. NASA is concerned about the performance of NGAS, which has experienced significant growth during the Project. There was no evidence that the JWST Project at NGAS received inappropriate attention from NGAS management, but in light of the importance of this project to NASA, the challenges that remain, and the NASA concern about NGAS, it would be prudent to have the Project report directly to the Space Systems Division at NGAS to assure top management focus on this important project. A commitment from the President of NGAS to actively participate in JWST internal reviews would also be appropriate.

There seems to be good communication at the working level with continuous meetings and teleconferences. However, it was not apparent that high-level, regularly scheduled meetings of the type that gives JWST sufficient priority are occurring in the various organizations. These meetings are needed to anticipate and address problems before they become serious. Executive Project meetings—for example, wherein the NASA Project team would present status to senior executives of the major implementing organizations on cost and schedule, threats, liens, contract risk management, and personnel and priority issues—have proven to be an effective tool for keeping communications open and for removing roadblocks to effective implementation. Only top-level executives can establish priorities within organizations, but they must have knowledge of the issues.

The Project does not maintain onsite residents at NGAS facilities and vice versa. A resident GSFC manager at NGAS could help to avoid surprises and would further the concept of a team effort. It is normal practice for the contracting agency to have resident managers at the plant site of the prime contractor. GSFC has done this on other projects. Given that the NGAS contract represents nearly half the JSWT budget, this is an important oversight. Not only would resident GSFC representatives help provide a path for improved communication, the involvement of GSFC personnel in NGAS activities would help to strengthen the partnership.

Recommendations

17. Improve communications between the JWST Project and both GSFC management and NASA HQ SMD.
18. Assign at least one senior GSFC project person to be resident at NGAS throughout the Project. Consider having an NGAS manager resident at GSFC.
19. Conduct monthly or bi-monthly JWST Executive Project meetings, attended by the NASA Associate Administrator and the President of NGAS.

6.2 Potential Risk in Integration and Test Phase

Finding

- The Test Assessment Team (TAT) performed an independent review of the integration and test phase of JWST in August 2010.

Assessment

The integration and test (I&T) phase of a project is used to integrate and qualify the systems for flight. During I&T, many system components are tested in relevant environments to qualify the systems for flight. However, for a system of the size and complexity of JWST, the typical "Test as You Fly" (TAYF) approach can be only partially implemented based on the combination of physical size and thermal requirements.

The TAT Report offered a focused, independent assessment of JWST I&T. The TAT identified several areas in the Project's I&T that could be changed to mitigate risk and potentially increase the schedule margin to allow for an additional thermal vacuum cycle if needed.

Recommendation

20. Implement the TAT Report recommendations to substantially reduce the scheduled test time by running complementary testing off the critical path and by more effective sequencing of certain critical cryogenic and optical test segments.

6.3 System Engineering

Finding

- The Project plans to transfer responsibility for system engineering from NGAS to GSFC for the remainder of the Project.

Assessment

A highly capable, experienced system engineering group is fundamental to project success. A decision on system engineering is a decision on accountability. In a project of this complexity and visibility, it is appropriate for the Government to be accountable. It is crucial, however, that the transfer of responsibility be executed properly. The transfer of system engineering ownership from NGAS to GSFC will require a modification to the contract and a change in the award–incentive fee structure. This should be given a high priority and negotiations completed expeditiously if the necessary conditions for this to be successful are met. A central requirement is that the system engineering team for a project of this cost and complexity be highly experienced and capable, include strong, experienced leadership, and include the active involvement of NGAS. This should not be viewed as a budget-reduction step, as it will likely be budget neutral or could even cost more. The quality of both technical and management system engineering personnel is crucial to the GSFC implementation of this decision. It might be useful to convene an implementation review by the GSFC Director, consistent with governance changes, to assure all essential elements of success are in place, including the following areas: overall implementation approach, verification and validation approach, experience and talent of the system engineering staff, decision-making process and dispute resolution, and clear lines of authority and accountability.

Recommendation

21. Establish a plan that provides the required level of experience and that involves the appropriate NGAS personnel before changing the system engineering accountability.

6.4 Project Scientist and Science Team

Finding

- JWST has a Project Scientist and science team on staff to assist in the decision-making process regarding science activities and requirements.

Assessment

The science team plays an important role in NASA science projects. Experience with large science projects has shown that science teams such as the JWST Project science team play a unique role in the project. The science team is in a good position to provide inputs to difficult trades involving Observatory performance, but its role should be broader than that. As representatives of the ultimate customer of the Observatory, the Project science team can utilize its awareness of the technical, cost, and schedule issues to

- Assist in interfaces with the Science Mission Directorate and the operations center (STScI);
- Utilize its understanding of the science performance and the technical challenges to help identify potential problems and then recommend remedial actions; and
- Provide an independent voice that identifies potential problems that could impact the completion and effective implementation of the Project.

Typically, the Project Scientist and many key members of the science team are intimately involved in helping to solve key technical issues. Because of their unique roles, they are often in the best position to provide inputs to difficult trades involving observatory scientific performance.

The science team on JWST, however, seems not to have played a significant role in these matters. In the numerous presentations and discussions across all elements of the JWST Project, the science team was not identified as either a contributor to or initiator of any recommendations. This apparent lack of input suggests that the Project science team has adopted a “hands-off” approach that is unfortunate in a project of this magnitude and importance.

Recommendation

22. Strengthen the role and the independent voice of the science team in the Project.

7. Afterword

The James Webb Space Telescope (JWST) is one of the most complex spacecraft ever developed by NASA. The JWST Project has made excellent progress in developing the difficult technologies required for its successful operation, and no technical constraints to successful completion have been identified. JWST is more complex, and significantly more capable, than the Hubble Space Telescope that it will follow in the NASA suite of Great Observatories. While Hubble operates in low Earth orbit only 560 km from Earth, and uses a single 2.4-meter diameter primary mirror, JWST will operate at 1.5 million km from Earth with a telescope designed to function at temperatures colder than liquid nitrogen, using an 18-segment primary mirror that is 6.5 meters in diameter.

NASA's Great Observatories—Hubble, Chandra, and Spitzer—have demonstrated the technological prowess of NASA and its industrial partners over the last two decades. Each of these projects was at the cutting edge of technology and faced substantial challenges, but nevertheless achieved striking levels of success. Each mission team overcame numerous problems and each Observatory provided major scientific discoveries that attracted national and international attention. Hubble became a household name as a result of its scientific discoveries and its stunning images of the beauty and complexity of the Universe. The Great Observatories demonstrated to the world that the United States had the technological base and management expertise to execute such major projects and implement uniquely powerful space observatories. Even now, no other nation can execute missions of such complexity.

JWST continues this tradition of high-risk, high-return ventures that address some of the greatest scientific questions of the time. It is astonishing to realize that JWST will have the ability to look back 13.5 billion years through 98% of all time to when the Universe was young and see the first galaxies as they form. The abilities of JWST far exceed those of Hubble and it is highly likely to go beyond Hubble's now legendary accomplishment of generating more discoveries than any other science mission.

This report raises significant concerns about the way in which the JWST Project has been planned and managed and how its budgets were established. The ICRP did not find that the funds used by JWST over the last 7–8 years were wasted. On the contrary, a substantial amount of cutting-edge hardware has been delivered and is now being tested as part of the first steps toward the overall integration and test of the Observatory. The JWST Project does face serious difficulties, however, largely stemming from the lack of a well-defined plan for completion and because a series of decisions have led to substantial underfunding. The Project must find the path to a successful launch with a realistic budget and executable schedule.

JWST will play a key role in understanding how and when the first galaxies were born, characterizing the planets that are now being discovered around nearby stars, in providing further insights into the nature of the dark energy and dark matter, and into how stars and planetary systems are born. There is no easy path to understanding such complex scientific questions. To do these things at the level needed to advance scientific understanding requires a complex telescope with truly unique capabilities. JWST is that telescope.

Appendix A: Minimum Cost-to-Launch

The minimum cost-to-launch JWST will be achieved by launching at the earliest possible date, consistent with safely completing the work needed to assure a successful mission. This is consistent with the experience of those within NASA and contractors who have been involved with large space flight projects.

The current Phases A–E LCC established at the MCDR in April 2010 is $5.1 billion, the cost through launch plus commissioning, followed by five years of operations, assuming launch in June 2014. Recent progress shows that this is now not practical. With the work remaining, JWST likely cannot be launched earlier than September 2015 and will require a total LCC in excess of $6 billion. To put this in context, Hubble cost-to-launch was $4.7 billion, in FY 2010 dollars, and the cost through SM-1 in 1993 when Hubble's mirror problem was fixed was $5.8 billion.

Approaches

Several approaches were used to arrive at the yearly funding profile with reserves that would support the 2015 launch date. While the estimates provide insight into addressing the minimum cost of launching JWST, there is significant uncertainty as to the actual cost. The major components were as follows:

- First, the ICRP asked the GSFC Director to assemble a team and provide the Panel with a best estimate drawing on the full resources and experience of the Center. The team, which included the JWST Project, including the prime contractor, provided the estimate referenced below as the "Center Estimate."
- Second, the ICRP evaluated the Project Budget developed for the JWST MCDR in March 2010. The Panel used their experience to modify the MCDR baseline to adjust for deferred work, to include threats and liens, and to distribute reserve percentage by element, according the Panel's judgment of the risk by element. This estimate is referenced below as the "Adjusted Estimate."
- Third, the ICRP used a historical growth analysis based on a set of 20 SMD missions. This is discussed below under "Historical Cost Growth."
- Fourth, a complexity analysis by Aerospace indicated that the cost of JWST was "in-family" with missions of similar complexity; this was also used as a cross-check on the results. This is discussed below under "Complexity Index."

The threats included in the first two estimates include the known and anticipated threats, which can be considered tactical in nature. In a sense, the resulting estimate-to-complete can be viewed as a nominal minimum estimate. However, as with any project, there are the potential strategic risks that represent significant albeit less likely threats to the launch date. The impacts of these items are discussed below under "Strategic Threat Assessment."

None of these approaches constitutes a full bottoms-up cost estimate or a full ICE, which should be done as part of building a credible new baseline for JWST.

An additional factor that framed the development of a minimum cost-to-launch assessment was the date for implementing this profile. The 2011 fiscal year began on October 1, 2010. To be more consistent with the time scales for possible Agency and congressional action, the Panel's analysis was based upon implementing the recommended budget changes on January 1, 2011.

Center Estimate

The Center estimate is based on the estimate done by the JWST Project, with NGAS input and evaluation by the GSFC management team. This reflects the first of the "minimum cost-to-launch" estimates. The resulting likely launch date is September 2015. Current liens are included, as are high-probability threats from NGAS and 25% reserves in each year. The total cost-to-launch including commissioning would now be $5.4 billion, an increase of $0.9 billion over the current Project plan cost-to-complete. The cost for the five years of operations would remain unchanged from prior budget submissions; the LCC would now be $6.0 billion, including $0.03 billion for JSC chamber modifications, which are on a separate line in the NASA budget.

The adopted schedule (LRD of September 2015) includes some consideration of the savings envisaged by the TAT Report and also reflects a conservative approach to providing schedule contingency in the Program. The schedule contingency is particularly important since the spacecraft CDR has not yet been held, some key I&T activities for NIRCam and ISIM remain, and a full assessment of the I&T program at JSC also needs to be completed. This schedule contingency is also included in the cost estimate.

The cost-to-launch and associated LRD provide an informed baseline estimate that provides one answer to the Panel's charge. This Project estimate does not represent a full bottoms-up estimate, however, so there is significant uncertainty associated with final number in the Center Estimate (Table A.1). Nonetheless, this new LRD and LCC are substantially more feasible than the most recent baseline plan available at the time of the Panel investigation, the MCDR baseline.

	LRD	FY11	FY12	FY13	FY14	FY15	FY16	FY11–16, $B	LCC $B
Center Estimate	9/15	633	586	455	293	262	141[2]	2.4[2]	6.0
Adjusted Estimate	9/15	774	564	357	357	319	127[2]	2.5[2]	6.2
ICRP Assessment	9/15	710	640	530	450	420	180[2]	2.9[2]	6.5
FY 2011 President's Request[1]	6/14[1]	445	379	335	259	52[1]	—	1.5[1]	5.1

Table A.1 Minimum cost-to-launch estimates and the FY 2011 President's Budget Request.

Notes

- Yearly cost is shown in $M with contingency for LRD September 2015, including commissioning.
- Through FY 2010, JWST has spent $3.0 billion.
- LCC includes Phase E (science operations) of $0.59B, which starts at launch + six months (at completion of commissioning); does not include JSC chamber modifications of $26.5 million in FY 2011 as this is carried in a different account line in the NASA budget.
- [1] Not a credible LRD (June 2014 cannot be met with this budget). FY 2015 includes only commissioning costs.
- [2] Cost including six-month commissioning period.

Adjusted Estimate

The ICRP generated an adjusted minimum cost-to-launch estimate; this estimate was again based on the MCDR baseline, but updated to include adequate reserves based on the Panel's experiences. The MCDR baseline exhibited insufficient reserves and did not fully account for the likely conversion of many existing threats into liens. The Panel adjusted the MCDR Project estimate as follows:

- Added an appropriate level of reserves throughout the remaining years to launch (allocated to the JWST Project and NGAS).
- Changed LRD to September 2015.
- Included the threats and liens on the Project Threat List, i.e., current as of the MCDR.
- Added in the Panel's estimate of current deferred work into FY 2011.

This process led to a minimum total cost-to-launch of $5.6 billion and a LCC of $6.2 billion (where the current Phase E mission operations estimate of $0.59 billion is retained, as adopted at the MCDR; see the Adjusted Estimate in Table A.1). Since the point of departure for this estimate is the MCDR baseline, this is not considered an independent cost estimate—although it does provide a sanity check on the Center estimate for minimum cost-to-launch. Again, to put this in context, HST, which was a much less complex mission, had a total cost-to-launch of approximately $5 billion in current dollars. Hubble's LCC was approximately double this because of servicing costs over 20 years.

Historical Growth Analysis

One cross-check was to use historical cost growth data from twenty past SMD missions to assess the potential cost of JWST. The results of the analysis, using historical cost growth data from CDR to launch, are shown in Figure A.1. The mission CDR for JWST was held in spring 2010, but several elements were at different levels of maturity at that time. A key caveat is that the historical data are for smaller, lower-cost missions than JWST, with shorter schedules, although there are indications that the cost growth is somewhat independent of project size. Cognizant of these concerns, the data suggest a cost around $6.5 billion–6.8 billion LCC, with a large uncertainty, for an optimal budget profile. As discussed previously, constraining the Project funding to a specific level below that needed in any year would drive the LCC higher and lead to launch delays.

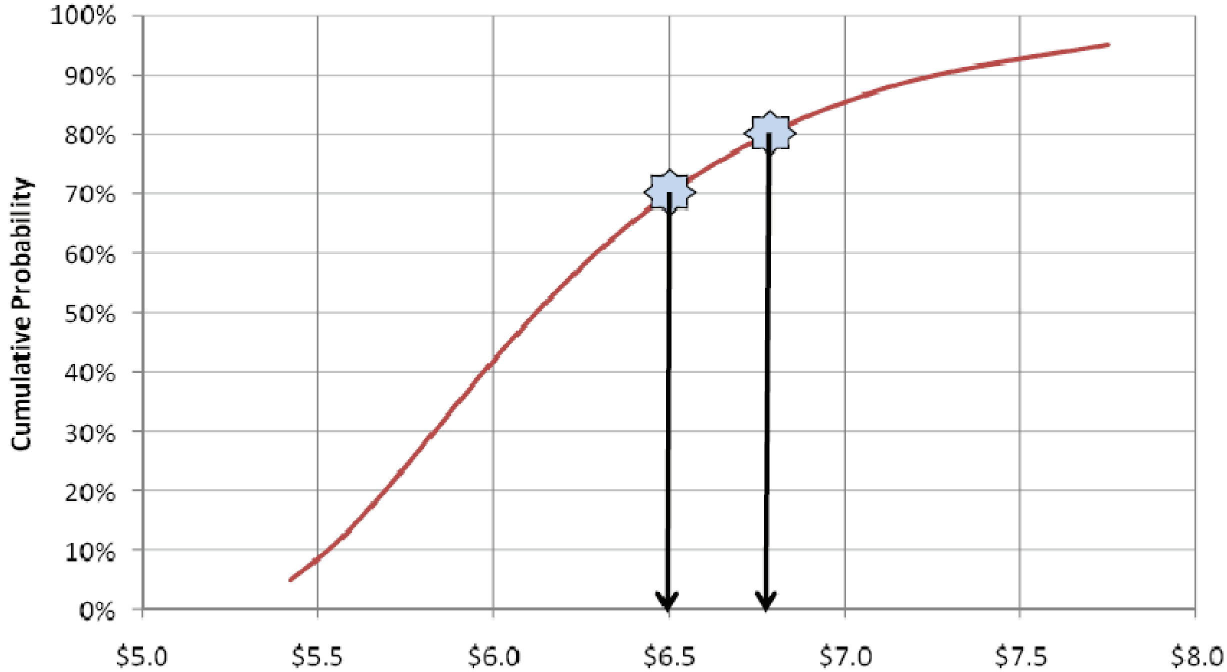

Figure A.1 Estimated total mission cost (RY$B) based on historical cost growth data; not an ICE.

Complexity Index

Aerospace maintains a Complexity Based Risk Assessment (CoBRA) model that can be used to assess the reasonableness of cost and schedule of a mission based on its "complexity index," which is essentially a representation of the technical and programmatic characteristics of a mission. JWST is considered to be one of the most complex science missions carried out to date and therefore falls at the high end of the range, greater than 90%, on the complexity index. JWST is consistent with being "in family" for an LCC around $6 billion–$7 billion (see Figure A.2). Like the historical growth analysis above, this should be considered a cross-check on the potential mission cost rather than an independent cost estimate.

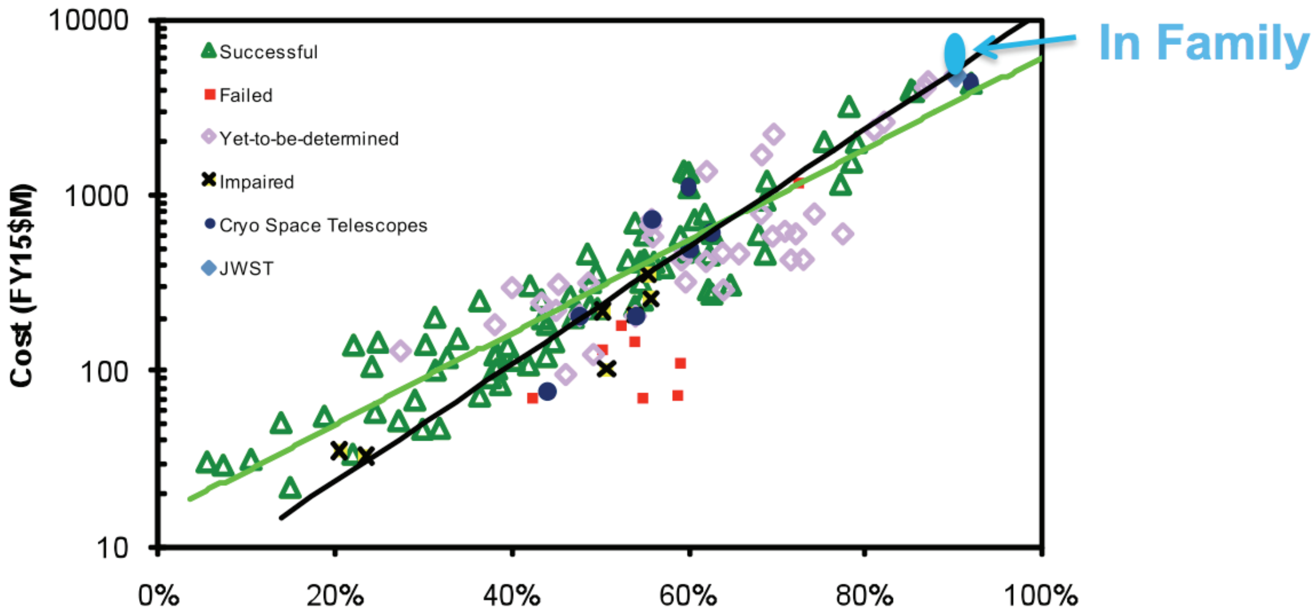

Figure A.2 Cost vs. complexity index for various missions.

ICRP Assessment

The ICRP Assessment is that the total LCC is likely to be in the range of $6.2 billion to $6.8 billion, i.e., about $6.5 billion. This assessment is a considered judgment number, accounting for a number of subjective factors, e.g.,

- The Center Estimate and the Adjusted Estimate result in an LCC around $6 billion–$6.2 billion.
- A CPI adjustment to the above range of $6.5 billion–$7.3 billion: NGAS has consistently performed at a CPI of about 0.8, and although NASA does not require Centers to use EVM on internally managed project work, the cost growth for the JWST internally managed work (~55%) was similar to the NGAS growth (~45%)
- S-curve resulting from historical cost growth data in the 70%–80 % range.
- An allowance for some of the strategic threats discussed earlier.
- Past experience that the Project, absent a full bottoms-up estimate, has tended to underestimate costs.

Given these factors, the ICRP adopted a profile with less funding in FY 2011 to match the January 1, 2011, date, relative to the Panel's Adjusted Estimate that used full-year funding in FY 2011 and more in FY 2012 and the out years. See Figure A.3.

To get the JWST Project "back on track" in an efficient and cost-effective way toward realizing a minimum cost-to-launch budget requires significant additional funding in FY 2011 and FY 2012 (approximately $250M in each year). This would enable the Project to recover from inadequate reserves and past management and oversight decisions that have resulted in deferral of key work. These estimates lead to a cost-to-launch (FY 2011 through launch plus commissioning) of approximately $2.9 billion. Note that if no additional funds can be found in FY 2011, further delays in the launch date and significantly increased costs will occur. The most efficient approach is to increase the Project's FY 2011 funding.

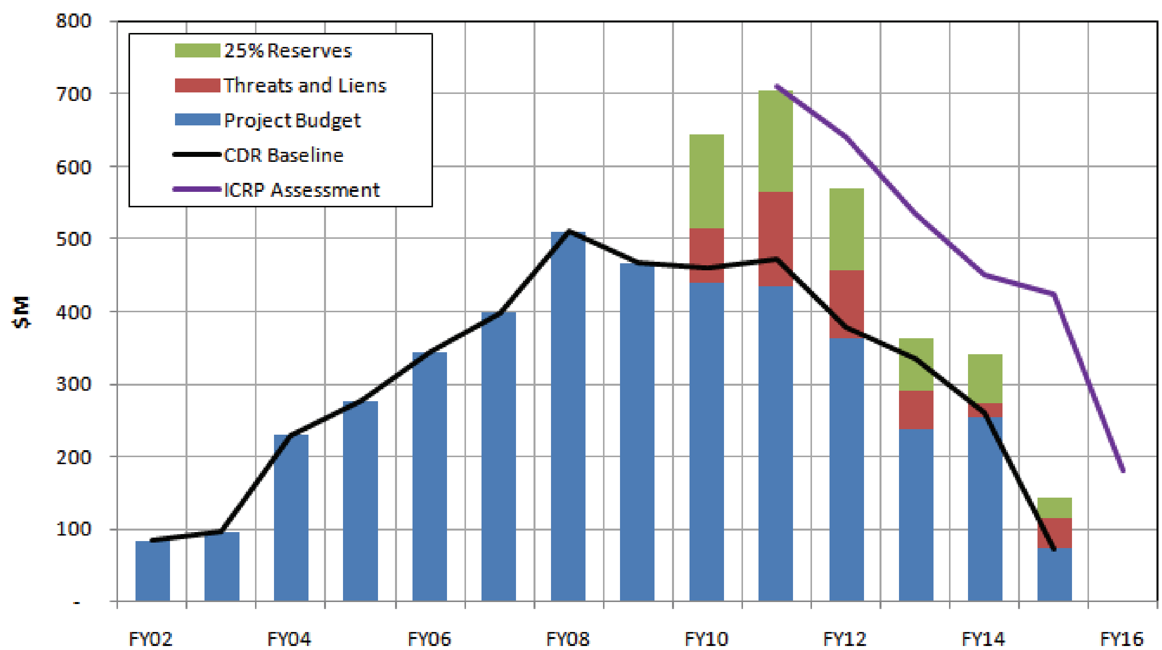

Figure A.3 ICRP assessment for minimum cost-to-launch.

Additional Considerations

Strategic Threat Assessment

A further check on risks to the schedule was carried out by Aerospace to consider threats to the schedule that arise from low-likelihood, high-consequence problems (e.g., a structural failure in testing, having to break vacuum at JSC more than planned, or a damaged sunshield). While these events may be unlikely (i.e., the probability of occurrence is typically far lower than 50%), the impact on the schedule could be on the order of months, not weeks, and therefore lead to significant cost impacts if they fall on the critical path. These major risks were called “strategic threats” to differentiate them from the more tactical and smaller items typically carried in the Project threat lists.

Aerospace evaluated the information available from the JWST Project and NGAS to derive an initial list of potential strategic threats, including the likelihood and consequence of these risks if realized. Aerospace also had several meetings with the NGAS Integrated Product Team (IPT) leads to further refine this list. Of the potential strategic threats evaluated by Aerospace, those that were likely to result in Project schedule slips (i.e., they were likely to fall on the critical path) were evaluated statistically to assess the potential schedule impact. This process also incorporated some “opportunities,” as per the TAT Report, for example, but those were in the minority.

The initial Aerospace analysis indicated a potential schedule slip that could exceed a year. The possibility of a year slip is not clear given the limited time for analysis, but for each year slip, the associated cost is likely to be around $300 million—based on the burn rate of the JWST Project in 2014–2015 and beyond. This cost and schedule risk will apply to any of the cost estimates under discussion. The likelihood of some of these strategic threats occurring is significant, so while the September 2015 LRD is a good working baseline for the minimum cost-to-launch budget, the potential for a slip of a year or more should be recognized and further assessed.

Improved Cost Estimates

The minimum cost-to-launch estimates discussed above should be considered a lower bound starting point in part because of the lack of a credible cost baseline in the JWST Project. As noted elsewhere in this report, the JWST Project has not performed a full bottoms-up cost estimate with their prime contractor since 2002 when the initial contract was negotiated. In addition, the ICEs done in 2008 for the Confirmation Review have not been updated. This was surprising, especially given the budget issues that have arisen over the last two years.

The Agency and Project seem to be “flying blind” without a full bottoms-up cost assessment, validated by an independent analysis, and an up-to-date ICE. In fact, it might be valuable to conduct two ICEs in parallel, as was done prior to the Confirmation Review in 2008, one within NASA similar to the 2008 IPAO estimate, and one external to NASA (leveraging previous analyses to provide continuity with the 2008 work). The reconciliation of the bottoms-up Project estimate with the ICEs will again provide valuable insights.

Doing a bottoms-up cost estimate and new ICEs will take time, but this should be done in parallel with the transition of the JWST Project to a funding profile consistent with the 80% confidence level and an LRD in September 2015. Any additional funds applied in FY 2011 will help get the JWST Project off the cycle of crisis management, help mitigate the inevitable costly deferrals associated with decisions made in that mode, and move the Project onto a path that has a credible and achievable launch date.

Minimum Cost-to-Launch vs. Capped Yearly Funding

Adopting a minimum cost-to-launch budget is desirable, although it has one quite challenging aspect: the high level of funding required in FY 2011. However, the Astrophysics Division alternative of capping the funding in each year will lead to a significantly higher total cost and a substantial launch delay. During the fact-finding investigation period, the JWST Project told the Panel that a yearly cost-capped budget profile would delay the LRD to the 2017–2018 timeframe or later. Furthermore, the cost-capped approach is not an efficient use of resources and is not ideal if there is no clearly defined LRD. While the near-term budget increments needed for the minimum cost-to-launch are challenging for those dealing with funding in the Executive Branch and within Congress, the minimum cost approach discussed here has significant merit in addition to cost savings: it commits the Project to a defined schedule that allows forward planning for future science missions, allows ramp-up on JWST on a timescale during which Hubble will most likely lose capability, and provides a stable baseline for Project management to efficiently execute to cost and schedule.

Appendix B: Biographies

Members

John Casani (Panel Chair)

John Casani is currently Special Assistant to the Director at the Jet Propulsion Laboratory. The majority of his career has been in systems engineering and project management. He has been a leader in the development and management of spacecraft systems. Casani was Project Manager for three major space missions at JPL: Voyager, Galileo, and Cassini. He held senior project positions in many of the early space programs, including Explorer, Pioneer, Ranger, and Mariner. He is the recipient of the National Academy of Engineering Founders Award and the National Aerospace Museum Lifetime Achievement Award. He is an Honorary Fellow of the AIAA and a member of the International Astronautics Academy. He has received several NASA awards, including the Distinguished Service Medal, the Exceptional Achievement Medal, and the Medal for Outstanding Leadership. He received the AIAA Space System Award and the von Karman Lectureship, the National Space Club Astronauts Engineer Award, and the AAS Space Flight Award. Casani has a BSEE and an Honorary Doctor of Science degree from the University of Pennsylvania and an honorary degree in Aerospace Engineering from the University of Rome.

William F. Ballhaus, Jr.

William F. Ballhaus, Jr., is the retired president and chief executive officer of The Aerospace Corporation, an independent, nonprofit organization dedicated to the objective application of science and technology toward the solution of critical issues in the nation's space program. Ballhaus joined Aerospace as president in 2000 after an 11-year career with Lockheed Martin Corporation. At Lockheed Martin, Ballhaus served as corporate officer and vice president, engineering and technology, where he was responsible for advancing the company's scientific and engineering capabilities and for overseeing research and engineering functions. Prior to his tenure with Lockheed Martin, Ballhaus served as president of two Martin Marietta businesses, Aero and Naval Systems (1993–1994) and Civil Space and Communications (1990–1993). Before joining Martin Marietta, Ballhaus served as the director of the NASA Ames Research Center (1984–1989). He also served as the acting associate administrator for aeronautics and space technology at NASA Headquarters (1988–1989).

Ballhaus serves on the boards of directors of Draper Laboratory and of OSI Systems. He is also a member of the National Academy of Engineering and completed two three-year terms as a member of the NAE Council in 2007. Currently, Ballhaus serves as chair of the Space Foundation. He is an honorary fellow of the AIAA and served as its president in 1988–1989. He is a fellow of the Royal Aeronautical Society and the American Astronautical Society and is a member of the International Academy of Astronautics. He serves on the Jet Propulsion Laboratory Advisory Council and served on the Defense Science Board (2001–2009) and the Air Force Scientific Advisory Board (1994–2001; co-chair, 1996–1999). He also served as a member of the National Oceanic and Atmospheric Administration Science Advisory Board. Ballhaus is a graduate of the University of California, Berkeley, where he earned a PhD in engineering and BS and MS degrees in mechanical engineering.

Ballhaus has received a number of awards, including Presidential Ranks of Distinguished Executive and Meritorious Executive, both conferred by President Ronald Reagan; the NASA Distinguished Service Medal; National Intelligence Medallion from the Director of National Intelligence; the National Reconnaissance Office Gold Medal; Air Force Exceptional Civilian

Service Medal; Air Force Association's Gen. Bernard A. Schriever Award for Space Leadership; National Defense Industrial Association's (NDIA) Peter B. Teets Award for championing the advancement of national-security space; NDIA Bob Hope Distinguished Citizen Award; Distinguished Engineering Alumnus Award from UC Berkeley; AIAA's Lawrence Sperry Award; AIAA Von Karman Lectureship; Arthur S. Flemming Award from the Washington, D.C., Junior Chamber of Commerce; Distinguished Executive Service Award from the Senior Executives Association; and Election to the NASA–Ames Hall of Fame.

Steven Dorfman
Steven Dorfman is the retired Vice Chairman of Hughes Electronics. During his time at Hughes he served as chief executive officer of Hughes Space and Communications Company, the world's leading builder of communication satellites and a provider of Space Systems for the NASA, NRO, Navy and Air Force; Hughes Communications, a leading owner and operator of communication satellites; and Hughes Telecommunications and Space, a unit responsible for the above businesses plus the international development of DirecTV. While CEO of Hughes Communications, Dorfman was responsible for the development of the Galaxy System, the leading North American satellite service provider, subsequently merged with Intelsat; the JCSAT system for Japan, in partnership with Mitsui and Itochu; the initiation of the direct to home business at Hughes which ultimately became DirecTV; and several other satellite businesses.

After retiring from Hughes, Dorfman was the Hunsaker Visiting Professor at MIT, the Chairman of ProtoStar, Ltd. and a member of the President's Information Technology Advisory Committee. Dorfman has served on the Boards of Hughes, Raytheon, PanAmSat, American Mobile Satellite, Galaxy Latin America, JCSAT, DirecTV, Galaxy Institute, ProtoStar and HRL Laboratories. He has been a Trustee of the Boys and Girls Club and the Devereux Foundation. He is currently a member of the National Academy of Engineering (NAE), the Tennenbaum Capital Advisory Board, the Thoroughbred Owners of California, and is a Senior Fellow of the California Council for Science and Technology. He has served on advisory committees for NASA, FCC, USIA, Department of Transportation, Air Force, USC School of Engineering, Hughes Network Systems, Boeing Satellite Systems, JPL, Ames Research Center and the National Research Council. Among Dorfman's awards are the Distinguished Public Service Award, NASA's highest award, for his work on Pioneer Venus; the Society of Satellite Professionals Hall of Fame; and Via Satellite's Satellite Executive of the Year for 1995.

David Gallagher
David Gallagher is currently Deputy Director for Astronomy and Physics at the Jet Propulsion Laboratory (JPL). In his most recent assignment, Gallagher was manager of the Advanced Optical Systems Program Office at JPL. Prior to this assignment, he was the Project Manager for the Space Interferometry Mission. He also managed the Spitzer Space Telescope Project, the Starlight Project, PMIRR Instrument, and Drop Physics Module re-flight. He also served as the Integration and Test Manager for the WF/PC-2 Instrument, which corrected the spherical aberration for the Hubble Space Telescope. Gallagher received a BS in Electrical Engineering from Purdue University in 1982. After working for IBM for several years, he started and ran a software consulting firm until he joined JPL in 1989.

Garth Illingworth
Garth Illingworth is an Astronomer/Professor at the University of California Observatories (UCO)/Lick Observatory and the University of California, Santa Cruz. His research focus is on the formation of the first galaxies and their evolution in the first 1–2 billion years (see "firstgalaxies.org"). He is principal investigator of a major Hubble Space Telescope (HST) imaging Program using the new WFC3/IR camera that is a precursor to the surveys to be done

with JWST for galaxies in the first 500 million years. Illingworth has been involved with major space and ground projects starting with HST (as Deputy Director at STScI in the 1980s), the initial conceptual development of NGST (JWST) in the late 1980s and early 1990s, construction of the ground-based Keck telescopes in the 1990s as chair of the Keck SSC which had oversight of instrument development for Keck, Deputy PI on the HST Advanced Camera, and also as current chair of the 30-meter TMT Project SAC. Illingworth was the Chair of the scientific organizing committee for the first NGST science meeting "The Next Generation Space Telescope" held in 1989 at STScI, and one of three developers at STScI in the late 1980s of the initial passively-cooled large (8-16 m) UV-Optical-IR telescope concept for NGST. He has also been widely involved in science policy issues and chaired the "O/IR in Space" panel of the 1990 Decadal Survey, and, for five years until mid 2008, the Congressionally mandated FACA committee that advised NSF, NASA, DOE, and Congress (the Astronomy and Astrophysics Advisory Committee). Illingworth chaired the European Southern Observatory Visiting Committee in 2010, and is currently chairing the JSTAC, the James Webb Space Telescope Advisory Council, that advises STScI on future JWST science operations.

John Klineberg

John Klineberg was CEO of Swales Aerospace, a space systems and engineering services company in Beltsville, MD, from December 2005 until May 2006. Before he retired at the end of 2003, he was president of Space Systems/Loral, a major provider of commercial communications satellite systems and services, and vice president of Loral Space & Communications, of which SS/L is a wholly owned subsidiary. Before becoming president in 1999, Klineberg was SS/L's executive vice president for Globalstar programs, where he led the successful development, production and deployment in orbit of the Globalstar satellite constellation for providing a new generation of cellular telephone services. Before joining Loral in 1995, Klineberg spent 25 years with the National Aeronautics and Space Administration (NASA) in a variety of management and technical positions. He was the director of the Goddard Space Flight Center; director of the Lewis (now Glenn) Research Center; deputy director of the Lewis Research Center; deputy associate administrator for Aeronautics and Space Technology at NASA Headquarters, and a research scientist at the Ames Research Center. Before beginning his career at NASA, he conducted fundamental studies in fluid dynamics at the California Institute of Technology and was an engineer at the Douglas Aircraft Company in California and at the Grumman Aircraft Company in New York.

Klineberg has received many awards for his outstanding service to NASA and his significant contributions to the fields of aeronautics and space systems, including the NASA Distinguished Service Medal; the NASA Outstanding Leadership Medal; the NASA Goddard Award of Merit; the U.S. Government rank of Distinguished Executive; the U.S. Government rank of Meritorious Executive; the AIAA Barry M. Goldwater Education Award; and the Engineer of the Year Award from the University of Maryland. Among his other activities, he is a member of the U.S. Air Force Scientific Advisory Board; an advisor to NASA; a frequent member of National Research Council review committees; a member of the International Astronautical Federation; a fellow of the American Astronautical Society; and a fellow of the American Institute of Aeronautics and Astronautics. He earned his BS degree in engineering from Princeton University, his MS degree in aeronautics from the California Institute of Technology (Caltech), and his PhD in aeronautics and political science from Caltech.

David Schurr

David Schurr is currently the Deputy Director of the Joint Agency Satellite Division, a new Division in NASA's Science Mission Directorate established to manage all reimbursable operational satellite and instrument development for NOAA and the USGS. Prior to this assignment, Schurr was the NASA Comptroller, responsible for development and execution of the Agency budget and advocacy for NASA programs with Congress and the Office of the President. He started his career at Johnson Space Center, working as a Payload Officer in the Space Shuttle Mission Control, responsible for Department of Defense and interplanetary satellite missions. Prior to moving to NASA Headquarters, he was a Program manager within the International Space Station Program Office, managing development of Japanese and Italian modules, and the deputy business manager for the International Space Station. Schurr holds a BS degree in aerospace engineering from the University of Notre Dame and Master's degrees in process control and business administration from the University of Houston.

Support Staff

Rosalind Lewis (Analytical Support Lead)

Rosalind (Roz) Lewis is the Principal Director of the Acquisition Analysis and Planning Subdivision at The Aerospace Corporation. In this position, Lewis manages four departments that support a variety of Program offices, corporate initiatives, and external civil and commercial customers in the areas of cross Program studies and anomaly data collection; programmatic analysis and modeling to include cost, schedule and risk analysis; and system engineering, acquisition strategy and Program execution support. Lewis joined The Aerospace Corporation in 1987 as a Member of the Technical Staff in the Computer Science Laboratory, where she developed software tools for experiment mission planning, upgraded a network resource scheduling system, and studied fault tolerant computing methodologies. As a Senior Project Engineer in a Program office, she led a multidisciplinary effort to develop and deploy a digital imagery dissemination system. She was promoted to Senior Project Leader in the Air Force Satellite Control Network (AFSCN) where she studied the impact of GPS-aided satellite navigation on the AFSCN and supported systems engineering and integration activities for cross segment initiatives. In 1999, she joined the RAND Corporation as a Senior Engineer, where she conducted and participated in studies regarding the acquisition, development and use of space systems, including GPS and Galileo. Other studies and analysis concerned the development and applications of information and communication technologies in government and consumer environments. Lewis holds a BS degree from USC in Computer Science, a MS degree from Polytechnic University in Computer Science, and a MS degree from USC in Systems Architecture and Engineering.

Marcus Lobbia (Executive Secretary)

Marcus Lobbia is a Manager–Engineering in the Space Architecture Department, Systems Engineering Division of The Aerospace Corporation (Aerospace), where he has been active in the development and application of various analysis models and tools for both NASA and the Air Force. He has experience in a variety of disciplines, including conceptual design, trajectory modeling, aerodynamics, cost analysis, and system architecture development. He recently spent over two years on site at NASA Headquarters, where he served as the Aerospace interface for the Office of Program Analysis and Evaluation (since renamed the Office of Independent Program and Cost Evaluation). Among recent activities, he has led the Aerospace team developing the Sand Chart Tool affordability assessment capability for the last several years, was one of the primary analysts supporting the 2009 Review of U.S. Human Space Flight Plans Committee, and assisted NASA in assessing workforce impacts related to the Fiscal Year 2011 President's budget Request. Lobbia holds a BS degree in Aerospace Engineering from the University of California, San Diego, and MS and PhD degrees in Aeronautics and Astronautics Engineering from the University of Tokyo, Japan.

Appendix C: ICRP Schedule

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	
22 *August*	23 Kickoff telecon	24	25 Review documents and data	26	27	28
29	30 Fact-finding/interviews with JWST Project, SRB, TAT, SMD Astrophysics (hosted at Aerospace Corporation in LA)	31	1 *September* Review documents and data	2	3 Internal telecon	4
5	6 Labor Day; Write draft findings, assessments, recommendations	7	8 Internal telecon	9 Telecon interview with Lockheed (NIRCam)	10	11
12	13 Fact-finding/ interviews with NGAS in LA	14 Morning fact-finding/interview with Ball (in LA)	15 Fact-finding/interviews with GSFC management, staff and others (hosted at GSFC)	16	17	18 Write draft report
19	20 Write draft report	21 Internal meeting, follow-up fact-finding/interviews (hosted at Aerospace Corporation in LA)	22	23	24 Internal telecon; Prepare presentation charts	25
26	27 Internal telecon; Prepare presentation charts	28 Preliminary Presentation at NASA HQ	29 Edit/update draft report	30	1 *October* **Draft Report (not for distribution; Panel use only)**	2
3	4	5	6 Internal telecon; Write final report	7	8 Internal telecon	9
10	11	12 Internal telecon	13 Write/edit/update final report	14 Internal telecon	15	16
17	18 Edit/update final report	19 Internal telecon	20 Internal telecon; Prepare charts for HQ briefing	21	22 Final Presentation at NASA HQ	23
24	25 Internal telecon	26 Final revisions to final report	27 Internal telecon	28	29 **Deliver Final Report**	30

Appendix D: ICRP Interviews

Name	Affiliation
August 30–31 (held at The Aerospace Corporation in El Segundo, CA)	
Phil Sabelhaus	NASA
Rick King	NASA
Robyn O'Mara	NASA
Charlie Calhoon	SGT, Inc.
Jean Olivier*	retired (NASA)
Steve Scott	NASA
Hamilton Fernandez	NASA
Bill Taylor	retired (NASA)
Ken Sizemore	retired (NASA)
Jon Morse*	NASA
Geoff Yoder*	NASA
Matt Mountain*	Space Telescope Science Institute
Kathy Flanagan*	Space Telescope Science Institute
Alan Dressler	Observatories of the Carnegie Institution
Georg Siebes	Jet Propulsion Laboratory
Jerry Nelson	University of California, Santa Cruz
September 8 (teleconference)	
Eric H. Smith*	Lockheed Martin Corporation
Marcia Rieke*	The University of Arizona
September 13 (held at Northrop Grumman in Redondo Beach, CA)	
Scott Willoughby	Northrop Grumman Corporation
Robert Burke	Northrop Grumman Corporation
Dave DiCarlo	Northrop Grumman Corporation
Mike Herriage	Northrop Grumman Corporation
James Wehner	Northrop Grumman Corporation
Jon Arenberg	Northrop Grumman Corporation
Mike Hirsch	Northrop Grumman Corporation
Stacy Sooks	Northrop Grumman Corporation
Tom Reoch	Northrop Grumman Corporation
September 14 (held at The Aerospace Corporation in El Segundo, CA)	
Mark Bergeland	Ball Aerospace & Technologies Corp
Paul Lightsey	Ball Aerospace & Technologies Corp
Brad Shogrin	Ball Aerospace & Technologies Corp
Alison Barto	Ball Aerospace & Technologies Corp

Name	Affiliation
September 15-16 (held at Goddard Space Flight Center in Greenbelt, MD)	
Rob Strain	NASA
Rick Obenschain	NASA
Orlando Figueroa	NASA
George Morrow	NASA
Mike Hawes	NASA
Trish Pengra	NASA
James Ortiz*	NASA
Ed Weiler	NASA
Eric P. Smith	NASA
Anne Kinney	NASA
Ken Ledbetter	NASA
Rick Howard	NASA
John Mather	NASA
John Decker	NASA
John Durning	NASA
Matt Mountain	Space Telescope Science Institute
Kathy Flanagan	Space Telescope Science Institute
Phil Sabelhaus	NASA
Paul Geithner	NASA
Dan Blackwood	NASA
Mike Menzel	NASA
Lee Feinberg	NASA
Julie Baker	NASA
Christine Steeley	NASA
Robyn O'Mara	NASA
Chris Scolese	NASA
September 16 (held at JPL Office in Washington, DC)	
Jean Toal Eisen	Senate Subcommittee on Commerce, Justice, Science and Related Agencies Appropriations
September 22 (teleconference)	
Amy Kaminski*	NASA (on detail from Office of Management and Budget)
Rob Strain*	NASA
September 28 (held at NASA Headquarters in Washington, DC)	
Chris Scolese	NASA
Mary D. Kerwin	NASA
September 28 (held at the New Executive Office Building in Washington, DC)	
Brian Dewhurst	Office of Management and Budget (on detail from NASA)
Celinda Marsh	Office of Management and Budget
Paul Shawcross	Office of Management and Budget
Kimberly Briggman	Office of Science and Technology Policy

Appendix E: Sen. Mikulski Letter to NASA

BARBARA A. MIKULSKI
MARYLAND

SUITE 503
HART SENATE OFFICE BUILDING
WASHINGTON, DC 20510–2003
(202) 224–4654
TDD: (202) 224–5223

United States Senate
WASHINGTON, DC 20510–2003

June 29, 2010

Lt. General Charles Bolden (Ret.)
Administrator
National Aeronautics and Space Administration
300 E Street, SW
Washington, DC

Dear Mr. Administrator:

The James Webb Space Telescope (JWST) will be the most scientifically powerful telescope NASA has ever built – 100 times more powerful than the Hubble which has already rewritten our textbooks. Congress has provided all of the funding requested for the JWST. Yet ongoing cost overruns and inadequate phasing of reserves have required an additional $95 million in fiscal year (FY) 2009 and another $20 million in FY 2010.

I am deeply troubled by the escalating costs for the JWST. The report the agency provided in response to my Subcommittee on Commerce, Justice, Science and Related Agencies Appropriations provided little comfort that the problems are behind us. Simply put, NASA must manage the cost and schedule of its large scale programs to the highest standard.

I request that you immediately initiate an independent and comprehensive review of JWST, led by experts from outside of NASA. I recommend this review be overseen by your immediate office and that you appoint individuals with the depth and range of experience to assess how to complete development of JWST within budget and on schedule. The members of the panel should be familiar with NASA management processes for large projects, as well as the Centers, contractors, and science involved in this project.

The panel should examine carefully four areas:

1. The technical, management and budgetary root causes of cost growth and schedule delay

2. Current plans to complete development, with particular attention to the integration and testing program and management structure

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3. Changes that could reduce cost and schedule or diminish the risk of future cost increases without compromising Observatory performance

4. The minimum cost to launch JWST, along with the associated launch date and budget profile, including adequate reserves

Our goal should be to launch JWST as early as possible, with the lowest overall cost. This panel's input will be critical to our consideration of NASA's FY 2011 appropriations. I expect that this panel will begin work within the next 30 days and offer their recommendations to you and to the Committee in a timely manner.

Thank you for your personal attention to this matter to guarantee both an independent assessment and an appropriate response from NASA. Please contact Jean Toal Eisen of my staff if you have any questions about this request.

Sincerely,

Barbara A. Mikulski
Chairwoman
Subcommittee on Commerce, Justice, Science
and Related Agencies
Committee on Appropriations

Appendix F: Acronyms

APA	Allowance for Program Adjustment
APMC	Agency Program Management Control
ATP	Authority to Proceed
CDR	Critical Design Review
CE	Cost Estimate
CFO	Chief Financial Officer
CPI	(Project) Cost Performance Index
DoD	Department of Defense
EAC	Estimated Cost at Complete
EV	Expected Value
FACA	Federal Advisory Committee Act
GSFC	Goddard Space Flight Center
HST	Hubble Space Telescope
I&T	Integration and Test
ICE	Independent Cost Estimate
ICAN	Independent Cost Assessment Node
ICRP	Independent Comprehensive Review Panel
IPAO	Independent Program Assessment Office
IPCE	Office of Independent Program and Cost Evaluation
ISIM	Integrated Science Instrument Module
JPL	Jet Propulsion Laboratory (Pasadena, California)
JWST	James Webb Space Telescope
LCC	Life Cycle Cost
LRD	Launch Readiness Date
MCDR	Mission Critical Design Review
NAR	Non-Advocate Review
NASA	National Aeronautics and Space Administration
NGAS	Northrop Grumman Aerospace Systems
NIR	Near-Infrared
NIRCam	Near-Infrared Camera
NPD	NASA Policy Directive
OMB	Office of Management and Budget
OTE	Optical Telescope Element

PA&E	Program Assessment and Evaluation
PDR	Preliminary Design Review
PMC	Program Management Council
POP	Project Operations Plan
PPBE	Preliminary Project Budget Estimate
SMD	Science Missions Directorate
SRB	Standing Review Board
TAT	Test Assessment Team
TAYF	Test as you Fly
TFI	Tunable Filter Imager