# COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
# U.S. HOUSE OF REPRESENTATIVES

## *The Next Great Observatory: Assessing the James Webb Space Telescope*

Tuesday, December 6, 2011
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

**Introduction**

In 2001, the James Webb Space Telescope (JWST) was ranked as the highest priority large space mission in astronomy by the National Academies of Science in their decadal survey *Astronomy and Astrophysics in the New Millennium.* Originally estimated by the decadal committee to cost $1 billion and to be launched in 2007, JWST was dubbed as the next Great Observatory that will be three times more powerful than the Hubble Space Telescope in the infrared and eight times more powerful than the Spitzer Space Telescope.

However, after high-level scrutiny arising from years of program cost and schedule overruns, NASA recently developed a revised plan for JWST that – if fully funded – would enable completion and launch by October, 2018. The revised budget life cycle costs now total just over $8.8 billion.

The purpose of the hearing will be to receive testimony from NASA, academic and industry stakeholders on the progress and remaining challenges associated with completing JWST by the target launch date of October, 2018, and at a cost no greater than $8.85 billion.

**Witnesses**

**Mr. Rick Howard,** Program Director, James Webb Space Telescope, National Aeronautics and Space Administration

**Dr. Roger Blandford,** Professor of Physics, Stanford University and Former Chair, Committee for the Decadal Survey of Astronomy and Astrophysics**,** National Research Council

**Dr. Garth Illingworth,** Professor & Astronomer, UCO/Lick Observatory, University of California, Santa Cruz

**Mr. Jeffrey D. Grant,** Sector Vice President & General Manager, Space Systems Division, Northrop Grumman Aerospace Systems

**Overarching Questions**

- What confidence should Congress have in the new cost and schedule estimates for JWST?

- What are the chief technical and programmatic challenges facing JWST? Does the re-plan address systemic issues with the program and put it on a path for success?

- What attributes of JWST merited its selection as the top-priority large-scale mission in the decadal survey *Astronomy and Astrophysics in the New Millennium* released in 2001? Are those reasons still valid today? Does the fact that JWST has not been completed as envisioned in the previous decade affect the recommendations in the most recent decadal survey, *New Worlds, New Horizons in Astronomy and Astrophysics* released in 2010?

## Background

Previously known as the Next Generation Space Telescope (NGST), the James Webb Space Telescope (JWST) was planned as the follow-on space telescope, building on the successes of the Hubble Space Telescope. The main technical features of JWST include a 6.5 meter diameter mirror optimized for observations in the infrared using four specialized scientific instruments (detailed below). JWST is set to orbit nearly 1 million miles from Earth in the Earth-Sun Lagrange (L2) point. These features are expected to produce unparalleled scientific discovery, glimpsing back to the origins of the galaxies and providing insights into the early formation of stars and planets.

### *Program Timeline*

- June 1997 – *The Next Generation Space Telescope: Visiting a Time When Galaxies Were Young* report utilized initial feasibility studies to present a technological roadmap for the development of the next generation space telescope (NGST) in the next decade at a cost of $500 million and launch date of 2007.
- 2001 – Telescope identified by NAS as top-priority in Decadal Survey, *Astronomy and Astrophysics in the New Millennium;* estimated cost is $1 billion.
- Summer 2002 – Mission Definition Review completed and project moved out of Phase A (feasibility studies) into Phase B (definition studies); the cost was estimated to be $2.5 billion with a launch date of 2010; Northrop Grumman was awarded prime contractor.
- March 2005 – NASA identified further cost growth, increasing life-cycle cost estimate to $4.5 billion and a schedule slip of 2 years.
- April 2006 – Independent review teams concluded that JWST's scientific performance and technical content were sound, with concern centered on the program's early year funding constraints.
- July 2008 – Program confirmation review placed the baseline life-cycle cost at $5 billion with a launch date of June 2014.
- June 2010 – Senator Barbara Mikulski (D-MD), Chairwoman of the Senate Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies, requests an independent review of the program; NASA commissioned an Independent Comprehensive Review Panel (ICRP) led by John Casani, Special Assistant to the Director at the Jet Propulsion Laboratory.
- October 2010 – ICRP report delivered to NASA and to Congress; NASA notified Congress of increase to cost baseline of over 15 percent and delay to schedule baseline of over 6 months, triggering a 'Breach Report' (more below).
- September 2011 – JWST re-plan approved with new baseline of $8.8 billion total life cycle cost with launch readiness date of October 2018.

## Astronomy and Astrophysics Decadal Surveys

The 2001 Decadal Survey *Astronomy and Astrophysics in the New Millennium* identified the then-called Next Generation Space Telescope (NGST) as the top-priority for large-scale missions for the decade 2001-2010. Although the Hubble Space Telescope continues to provide excellent science, the NGST would be far more sensitive and be able to see light in the infrared that Hubble could not. Pursuing NGST was the next logical step in advancing scientific discovery and was believed to have sufficient technology readiness to make the telescope affordable. The decadal survey estimated NGST would cost $1 billion and be ready for launch in 2008.

Despite changes to the program in the ensuing decade – including revised cost and schedule baselines, as well as de-scoping the segmented mirrors from an 8 meter to 6.5 meter diameter – JWST was supposedly still on track (based on the revised cost and schedule) when it was time again for the National Academies to conduct the next decadal survey. Given assurances by NASA, the survey committee had little evidence to believe otherwise. Yet, even as doubts emerged, the committee presented its recommendations assuming JWST would be launched no later than the middle of the decade. *New Worlds, New Horizons in Astronomy and Astrophysics* (Astro2010) therefore moved forward under the assumption that JWST would be completed as planned and recommended pursuit of the next top-priority mission, the Wide-Field Infrared Survey Telescope (WFIRST). WFIRST would conduct exoplanet and dark energy research. It is now expected that WFIRST cannot begin development until after JWST is launched.

## Independent Comprehensive Review Panel (ICRP)

In a letter to NASA in June 2010, Senator Barbara Mikulski (D-MD), Chairwoman of the Senate Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies requested an independent review of the JWST program citing concerns about continued growth in cost and delay in schedule. The letter requested an independent panel review the root causes of the cost growth and schedule delay, to assess NASA's plans for completing development and testing of the telescope, to review possible changes to the telescope and to provide a minimum cost to launch. NASA subsequently commissioned an Independent Comprehensive Review Panel (ICRP) led by John Casani, Special Assistant to the Director at the Jet Propulsion Laboratory. A copy of the report can be found here: http://www.nasa.gov/pdf/499224main_JWST-ICRP_Report-FINAL.pdf

The ICRP report revealed poor budgeting and program management, not technical performance, as the root cause for JWST's woes. At the outset, it was determined that JWST did not have a proper budget baseline and that budgeted reserves were insufficient. They found that costs were managed on a year-to-year basis, which led to deferred work and corresponding increases to life cycle costs. The cost of deferring work further reduced reserves available in later years, resulting in a project life cycle cost that continued to spiral out of control. The ICRP, however, did not find the funds spent as wasted. Cutting-edge hardware had been delivered and tests were underway.

Specifically, the ICRP provided NASA with 22 recommendations as to how to get the program back on track and outlined what it thought to be a new cost-to-launch budget profile for a launch in 2014. In summary, the report states:

*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.*

- *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 the Goddard Space Flight Center (GSFC) to ensure that the Project is managed with a focus on the Life Cycle Cost and Launch Readiness Date, 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 Independent Cost Estimates (ICE) 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.*[1]

NASA agreed with all of the recommendations presented by the ICRP and made several changes even before completing its re-plan of the program. According to NASA, they have now:

- Elevated program visibility, reporting, performance assessment and cost control;
- Replaced all JWST senior management at both Goddard and Headquarters;
- Elevated JWST to a division level within Science Mission Directorate that reports directly to the NASA Associate Administrator on a weekly basis; and
- Used ICRP cost and schedule estimates as one of the inputs to develop the new baseline.

## Summary of JWST Breach Report and Re-Plan

Pursuant to Section 103 of the NASA Authorization Act of 2005 (PL 109-155), NASA is required to provide Congress with a new cost and schedule baseline for major programs that exceed costs by more than 15 percent or schedule by more than 6 months. NASA notified Congress on October 28, 2010 that the agency anticipated JWST would breach both its cost and schedule baselines and deferred its formal response until it could conduct a complete assessment.

In response to the ICRP report and as part of the required report to Congress, NASA delivered a *Cost and Schedule Analysis Report for the James Webb Space Telescope* (Breach Report) to Congress on October 21, 2011 which estimates the full life-cycle cost of the mission to now be $8.835 billion with a launch date of October 2018.

[1] JWST-ICRP Final Report, October 29, 2011, p. 9

Table 1:
JWST Life-Cycle Cost
As in Breach Report (October 2011) *

| Budget Authority ($millions) | Spent to Date | FY 2010 Actual | FY 2011 Enacted | FY 2012 | FY 2013 | FY 2014 | FY 2015 | FY 2016 | Budget to Complete | LCC Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Revised Profile | 2,552.30 | 461.4 | 515.3 | 527.6 | 627.6 | 659.1 | 646.6 | 621.6 | 2,223.60 | 8,835 |
| | | | | | | | | | | |
| PBR** FY12 | | | 471 | 375 | 375 | 375 | 375 | 375 | 2,346.00 | |
| | | | | | | | | | | |
| Delta to PBR | | | 44.3*** | 152.6 | 252.6 | 284.1 | 271.6 | 246.6 | 1,251.80 | |

* See Appendix 1 for a complete historical overview of budgeted costs for JWST
**Presidential Budget Request (PBR)
*** Congress approved an updated FY11 operating plan to reprogram the additional $44 million

According to NASA's report, the newly programmed JWST baseline:

- Represents a high confidence, realistic schedule with adequate reserves that launches JWST as soon as possible.
- Presents a funding profile that was adjusted to reduce risk and provide adequate early year reserves.
- Included a Joint Cost and Schedule Confidence Level (JCL) analysis consistent with an 80% confidence level; and
- Was reviewed by the JWST Standing Review Board (SRB) – NASA's independent external review board – with findings and recommendations factored into final plan.

As evident in Table 1 above, the new baseline will require approximately $1.2 billion in additional funding in FY12-FY16 (above the President's FY12 request). NASA is proposing that funds be redirected from within its budget so that half would come from the Science Mission Directorate (with the exception of Earth Science) and half from the Cross-Agency Support account. NASA and the Administration continue to discuss the budget adjustments with the final determination to be reflected in the budget request for fiscal year 2013. The fiscal year 2012 budget as passed by Congress on November 17, 2011 reflects the additional funds needed for JWST in FY12 by providing $529.6 million.

***Analysis of Alternatives***

As part of the required Breach Report, NASA asked the Aerospace Corporation to conduct an analysis of alternatives (AOA) to JWST to ensure that all possible options were given proper consideration. As summary, the AOA:

- Reviewed four categories of observatories (airborne, ground, space and variants to the JWST baseline) and assorted combinations thereof;
- Measured performance of alternatives against JWST Level 1 science requirements; and
- Distilled alternatives down to 12 potential options based on ability to meet the mission science requirements and technical feasibility to analyze in further detail

The results of the analysis concluded that the JWST baseline continues to be the best value. Specifically, the Aerospace Corporation found that none of the alternatives provide the equivalent Level 1 science requirements at a lower cost or at an earlier full operational capability date. Furthermore, while alternative designs might lower costs in one area or another, the science that must be given up to accommodate those designs rendered the alternative undesirable based on the science requirements determined by the National Academies Decadal Survey process. Furthermore, many of the 2011 decadal survey recommendations are predicated on the groundwork that is to be laid by JWST.

## Program Design Elements & Status

### *Sunshield*

A critical element of the telescope's design is a giant tennis-court sized sunshield that will block the mirrors and science instruments from light from the Sun, Moon and Earth as well as prevent radiation from the telescope's own heat-producing equipment. The sunshield will consist of five layers – none touching the other – of a heat-resistant material called silicon-coated Kapton. Each layer will be no thicker than ½ of a human hair.

In order to ensure a successful sunshield design and deployment, the sunshield has to undergo extensive testing. Currently a template membrane has been constructed and tested to validate that its shape holds under tension and to verify the folding/packing concept works on a full-scale mockup. Additionally, a 1/3 scale model was constructed to test deployment and undergo thermal testing in a cryogenic chamber. Construction on the final sunshield has not yet started.

### *Mirrors*

The purpose of the mirrors is to collect the light and channel it to the instruments. Because JWST is designed to detect the faintest of infrared light, billions of light years away, the mirrors must be precisely engineered. JWST's primary mirror is made up of 18 individual hexagonal segments that fold up inside the rocket; once deployed the mirrors will function as a single 6.5 meter (21.3 feet) diameter mirror – the largest ever to be deployed in space. All 18 mirrors have been manufactured, polished and coated and all but six have completed testing and are ready for final assembly. The final 6 will be tested at cryogenic temperatures with final adjustments made by the end of this calendar year.

### *Scientific Instruments*

The Integrated Science Instrument Module (ISIM) contains four science instruments and a guide camera. The ISIM and science instruments are 90% complete and are undergoing integration at the Goddard Spaceflight Center. The NIRSpec instrument was found to have quality issues which will delay its delivery. However, this delay is captured in the new re-plan and should not affect overall schedule.

- Mid-Infrared Instrument (MIRI) – provided by the European Consortium with the European Space Agency (ESA) and by the NASA Jet Propulsion Laboratory (JPL). MIRI has both a camera and a spectrograph that sees light in the mid-infrared allowing it to see newly forming stars and faintly visible comets as well as objects in the Kuiper Belt. MIRI's camera will provide wide-field, broadband imaging similar to those the public has come to expect from Hubble. The spectrograph will provide new physical details of the objects it will observe.

- Near-Infrared Camera (NIRCam) – provided by the University of Arizona is Webb's primary imager detecting light from the earlier stars and galaxies. NIRCam is equipped with coronagraphs that will allow astronomers to take pictures of very faint objects around a central bright object, like solar systems. NIRCam's coronagraphs work by blocking a brighter object's light, making it possible to view the dimmer object nearby - just like shielding the sun from your eyes with an upraised hand can allow you to focus on the view in front of you. With the coronagraphs, astronomers hope to determine the characteristics of planets orbiting nearby stars.
- Near-Infrared Spectrograph (NIRSpec) – provided by the European Space Agency (ESA), with components provided by NASA/GSFC. Used to disperse light from an object into a spectrum by which physical properties such as temperature, mass and chemical composition can be determined.
- Fine Guidance Sensor Tunable Filter Imager (FGS-TFI) – provided by the Canadian Space Agency. The Fine Guidance Sensor allows the telescope to point precisely while the Tunable Filter will be able to select and focus on extremely specific wavelengths of light. Most cameras can only see a certain wavelength, but FGS-TFI will be able to pick from a range. The FGS-TFI will be used to study just-forming planetary systems and dust disks that could become planets, the internal dynamics of galaxies, and the characteristics of elements and molecules in clouds of stellar gas.[2]

***Spacecraft Bus***

The spacecraft bus houses the electronics, attitude and thermal control, communications and propulsion systems. These systems are considered relatively "standard" given that all space telescopes and satellites require similar systems. For this reason, design of the bus only recently began final critical design review that is scheduled for late 2014.

***Assembly and Testing***

A majority of the hardware for JWST has been constructed. However, due to the nature of the telescope's orbit nearly 1 million miles from Earth and the requirement that it operate in temperatures approaching -400 degrees Fahrenheit, NASA has no "second chance" to make sure JWST performs as planned. The majority of the cost and time remaining to complete JWST will be in assembly and testing. Along the way, components must be tested to make sure they function individually, as a group, and as the complete telescope. In addition, hardware such as platforms and machinery must be specifically made to accommodate construction of the huge telescope.

Goddard Space Flight Center is in charge of assembling each of the science instruments into a larger unit, which will be subjected to both temperature and vibration testing. The mirrors will be mounted to their support structure and tested. The testing ensures that JWST can withstand the stress of launch and the extreme conditions in space.

Johnson Space Center will then test the entire assembly in a large 120-foot-tall vacuum chamber originally used for the Apollo program. The chamber is currently being modified to ensure testing at the proper cryogenic temperatures and should be ready for use by summer 2012. Once that test is complete, the sunshield and spacecraft bus will be added to the package and tested yet again before being readied for launch.[3]

[2] http://www.jwst.nasa.gov

[3] http://ngst.gsfc.nasa.gov/status.html

**Recent FY2012 Appropriation Activity**

On July 7th the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies reported an FY2012 appropriations bill that provided zero funds for JWST. As stated in the report:

> *The James Webb Space Telescope (JWST) Independent Comprehensive Review Panel revealed chronic and deeply rooted management problems in the JWST project. These issues led to the project cost being underestimated by as much as $1,400,000,000 relative to the most recent baseline, and the budget could continue to rise depending on the final launch date determination. Although JWST is a particularly serious example, significant cost overruns are commonplace at NASA, and the Committee believes that the underlying causes will never be fully addressed if the Congress does not establish clear consequences for failing to meet budget and schedule expectations. The Committee recommendation provides no funding for JWST in fiscal year 2012.*
>
> *The Committee believes that this step will ultimately benefit NASA by setting a cost discipline example for other projects and by relieving the enormous pressure that JWST was placing on NASA's ability to pursue other science missions.*

On September 15th, the Senate Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies reported an FY2012 appropriations bill providing a total of $530 million for JWST, a number reflected in the NASA re-plan but not officially requested by the Administration. Per the report:

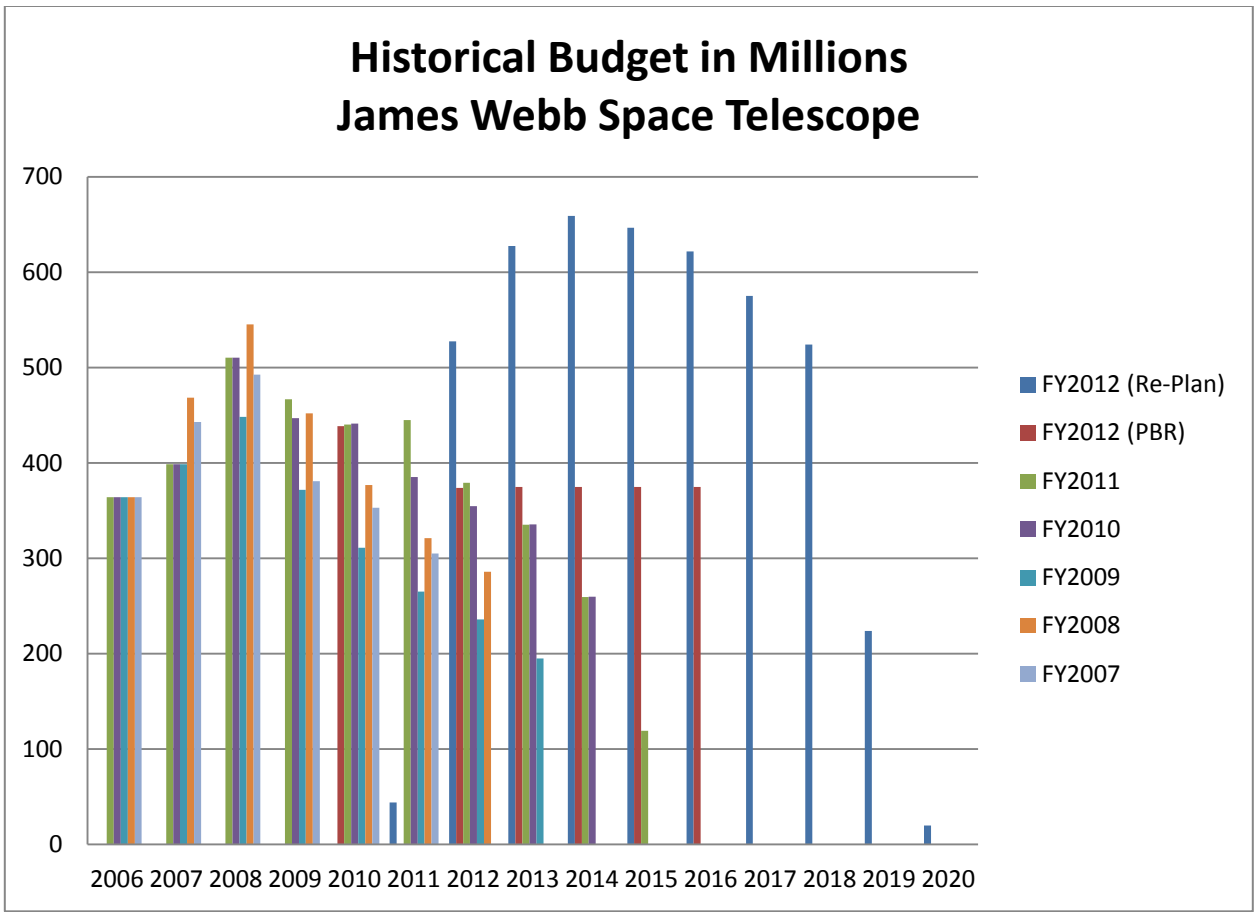
> *The Committee strongly supports completion of the James Webb Space Telescope [JWST]. JWST will be 100 times more powerful than the Hubble Space Telescope and is poised to rewrite the physics books. Last year, the Committee asked for an independent assessment of JWST. That assessment, led by Dr. John Casani, found that while JWST is technically sound, NASA has never requested adequate resources to fund its development. As with many other projects, budget optimism led to massive ongoing cost overruns because the project did not have adequate reserves or contingency to address the kinds of technical problems that are expected to arise in a complex, cutting edge project. Without funds, the only other way to deal with problems is to allow the schedule to slip. That slip, in turn, makes the project cost even more, when accounting for the technical costs as well as the cost of maintaining a pool of highly skilled technical labor through the completion of the project.*
>
> *In response to the Casani report, NASA has submitted a new baseline for JWST with an overall life cycle cost of $8,700,000,000. NASA has assured the Committee that this new baseline includes adequate reserves to achieve a 2018 launch without further cost overruns. The Committee intends to hold NASA and its contractors to that commitment, and the bill caps the overall development cost for JWST at $8,000,000,000.*

On November 17, the House and Senate agreed to final FY12 appropriations for NASA as part of a "mini-bus" that included funding for Agriculture, Commerce-Justice-Science (CJS), and Transportation-Housing and Urban Development (T-HUD). The bill ultimately yielded to the Senate version, providing JWST with the full amount needed as cited in the re-plan. However, very

specific language about how Congress expects NASA to manage the program was included in the conference report. It states:

> *James Webb Space Telescope (JWST).—According to the recent JWST budget replan, the program's lifecycle cost estimate is now$8,835,000,000 (with formulation and development costs totaling $8,000,000,000). This represents an increase of $1,208,000,000 over the previous lifecycle cost estimate, including an increase of $156,000,000 above the budget request for fiscal year 2012. In order to accommodate that increase in this agreement, the conferees received input from the administration and made reductions to the requested levels for Earth and planetary science, astrophysics and the agency's budget for institutional management. Although the amounts provided for these other science activities still constitute an increase over the fiscal year 2011 levels, the conferees note that keeping JWST on schedule from fiscal year 2013 through the planned launch in fiscal year 2018 will require NASA to identify another $1,052,000,000 over previous JWST estimates while simultaneously working to meet the deficit reduction requirements of the Budget Control Act of 2011 (P.L. 112–25). As a result, outyear work throughout the agency may need to be reconsidered. The conferees expect the administration to come forward with a realistic long-term budget plan that conforms to anticipated resources as part of its fiscal year 2013 budget request.*
>
> *To provide additional assurances that JWST's management and funding problems are under control, the conference agreement includes language strictly limiting JWST formulation and development costs to the current estimate of $8,000,000,000 and requiring any increase above that amount to be treated according to procedures established for projects in 30 percent breach of their lifecycle cost estimates.*
>
> *In addition, the conferees direct the GAO to continually assess the program and to report to the Committees on Appropriations on key issues relating to program and risk management; achievement of cost and schedule goals; and program technical status. For its first report, the conferees direct the Comptroller General to assess: (1) the risks and technological challenges faced by JWST; (2) the adequacy of NASA's revised JWST cost estimate based on GAO's cost assessment best practices; and (3) the extent to which NASA has provided adequate resources for and is performing oversight of the JWST project to better ensure mission success. The first report should be provided to the Committees no later than December 1, 2012, with reports continuing on an annual basis thereafter. Periodic updates should also be provided to the Committees upon request or whenever a significant new finding has been made. NASA is directed to cooperate fully and to provide timely access to analyses, data, applications, databases, portals, reviews, milestone decision meetings, and contractor and agency personnel.*

## APPENDIX 1[4]




The chart above depicts total costs to go for each year as outlined in each fiscal year budget request. The chart does not reflect actual expenditures, which through fiscal year 2011 totaled $3.536 million.

[4] Chart derived from data obtained from: http://www.govbudgets.com/project/Science/James_Webb_Space_Telescope/James_Webb_Space_Telescope/James_Webb_Space_Telescope_(JWST)/