Testimony
of
Dr. Berrien Moore III
Executive Director
Climate Central
Princeton, New Jersey

Opportunities and Challenges for NASA Science Programs
before the
Subcommittee on Space and Aeronautics
of the House Committee on Science and Technology

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Madam Chairman and members of the Subcommittee, thank you for the opportunity to appear today on behalf of Space Studies Board (SSB) of the National Research Council (NRC), chaired by Dr. Charles Kennel. Dr. Kennel is also a member of the blue-ribbon Review of U.S. Human Space Flight Plans Committee. Dr. Kennel regrets that he could not be here to provide testimony today. I will try to cover most of the same key priorities, issues, challenges and opportunities for NASA's science programs that Dr. Kennel would have presented for you. Although I also serve on the SSB with Dr. Kennel, my views are my own and do not represent an official position of the NRC.

With your permission, I will submit my written testimony for the record and recap briefly my views for you here this morning.

NASA's science programs have been called the agency's "crown jewel" and with good reason. They represent less than a quarter of NASA's annual budget and only three percent of the annual federal Research and Development (R&D) investment. For this relatively small investment, in recent years, NASA's science programs have provided: critical insights into global climate change and the management of Earth's resources; helped us understand and anticipate the impact of solar storms on our technological infrastructure; changed our views about the potential habitability of other worlds in our solar system and beyond; and revolutionized our understanding of the major constituents of energy and matter in our universe and its eventual fate. In a word, NASA's science programs have enriched our lives, strengthened our societies, and expanded our horizons.

As you consider NASA authorization legislation for the coming years, it is important to keep in mind the potential opportunities that lie in front of the agency's science programs. On the increasing strength of Earth science, we know can state that global warming is "unequivocal,"[1] but this simply sets the challenge. We need now to develop the capability to monitor and thereby manage greenhouse gas emissions through the this century and beyond, and concurrently, we need the capability to project with a quantitative understanding of the uncertainties the impact of climate change to at least the regional level, and thereby, provide essential information to help decision makers mitigate the varying impacts of climate change on local environments and populations.

In solar and space physics, joint observations from multiple spacecraft orbiting in the wake of the Earth may allow predictive models of space plasma and particle interactions to begin to unravel the physics of "magnetic reconnection" and thereby advance our understanding across a range of spatial scales and topics from fusion reactors to black holes. In planetary science, we will have an opportunity to follow-up on the discovery of liquid water environments on Mars and the moons of the outer planets and search for organic compounds and other past or present evidence of potentially life-bearing environments beyond Earth. In astrophysics, we will have an opportunity to follow up on

[1] "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Fourth Assessment Report (Working Group One) of the intergovernmental Panel on Climate Change.

the discovery over the past decade of more than 300 planets outside our solar system and hence expand the search for planets 'more like' our own Earth. There is also an opportunity in astronomy for NASA to cooperate with the physics community to build upon discoveries about the accelerating expansion of our universe and associated energy "creation" and thereby establish the necessary extended observational platforms to understand the nature of the now-termed "dark energy", which apparently dominates the energy budget of the universe and drives its expansion. And in life and microgravity sciences, the International Space Station (ISS) could provide U.S. researchers with their first permanent microgravity research platform.

These are each unique opportunities during our lifetimes for the United States to demonstrate technical leadership, advance the state of scientific knowledge for humanity's benefit, and leave important legacies for future generations. In stating this, I clearly recognize the significantly challenging economic environment, and I am well aware of the out-year budget constraints and recent "Guidelines."[2] The times call for careful setting of priorities; I present this testimony in the knowledge of this necessity.

When considering authorization legislation for the agency, it is also important to keep in mind how NASA's science programs can be employed as a tool to address national priorities outside the scientific enterprise. For example, in foreign affairs, NASA's science programs have a long history of international cooperation with partners in Europe, Japan, Russia, and Canada. With a number of new space powers emerging around the globe, NASA's science activities provide an opportunity to engage countries like China and India in peaceful, scientific pursuits that could encourage transparency in their space programs. Because they are a demanding consumer of new technologies, NASA's science programs also help address economic competitiveness by driving new developments in critical technologies like instrumentation, autonomy, communications, and data management. And the exciting discoveries made in NASA's science programs are particularly inspirational to youth and easily shared with the internet and smart phone generation, a potentially important source of new engineers and scientists for our economy. In past legislation, Congress has recognized the value of sharing the adventure of space research via new virtual methods and should continue to do so.

To realize these opportunities, a number of critical issues must be addressed and challenges met. Arguably the largest issue is restoring or at least maintaining the balance of funding between NASA's science and human space flight activities. Several years ago, over $3 billion was eliminated from the Science Mission Directorate budget to help pay for return to flight, Space Shuttle retirement, and the Constellation Program. This eliminated the projected growth in NASA's Science Mission Directorate and exacerbated what had already been dangerous downward trends in portions of the science portfolio. For example, after accounting for structural changes in how NASA

[2] OFFICE OF MANAGEMENT AND BUDGET; June 11, 2009; MEMORANDUM FOR THE HEADS OF DEPARTMENTS AND AGENCIES: Planning for the President's Fiscal Year 2011 Budget and Performance Plans

categorized its budget, the 2007 National Research Council Earth science and applications from space "decadal survey"[3] documented that support for the overall effort for Earth observations and the associated science in NASA was reduced by more than 30-percent between 2000 and 2006 (see discussion below).

Across the Agency, reductions in science support led to the deferment of multiple missions, painful program restructurings, dramatic reductions in research grants, and the elimination of many technology investments. A recent report by the Congressional Budget Office warns that estimates of the cost of NASA's Constellation Program through the first manned lunar landing have risen from $57 billion to $92 billion, and may reach $110 billion. Although the Review of U.S. Human Space Flight Plans Committee is tasked with developing an affordable and sustainable human space flight program that fits within the current budget profile for NASA's human exploration activities, it is a very difficult task and does not guarantee that NASA's human space flight programs will not encounter unanticipated problems and future cost growth. To ensure the productivity of NASA's science programs, it is important that any future growth in human space flight costs not impact the already flat science budget. In the past, budgetary "firewalls" have been erected to protect other parts of the NASA budget from cost growth in human space flight programs, and Congress may want to consider such measures in the future. In doing so, Congress may need to ensure that such firewalls are actually honored.

A related issue is the question of ISS utilization and NASA funding for microgravity research. While a number of the long-promised ISS research facilities are available or will become available in the next year, the number of US investigators currently in a position to exploit the potential of these facilities is very limited. The NASA programs that supported the development of investigations to use these facilities were either cancelled or severely cut in the middle of this decade. From 2004 to 2008, the number of life and microgravity science investigators supported by NASA fell from 769 to 230, a 70-percent drop overall with physical sciences research dropping by 90-percent. Many of the small number of US-sponsored ISS investigations that remain were preserved by congressional intervention. Although Congress has designated the ISS as a national research laboratory to encourage its utilization by other federal R&D agencies, Congress should keep in mind that NASA's role, which has declined significantly, in supporting the life and microgravity sciences community to make effective use of ISS remains central and limited. As a consequence, the former research community has largely dissipated, and there are many questions about how high quality research can, or will be, solicited and supported during the window of opportunity we are now entering for ISS utilization.

Turning to the other science-related studies, per Congressional request, the NRC is currently undertaking three decadal surveys – in astronomy and astrophysics, planetary science, and biological and physical science in space. Upon completion, these surveys will have reached community consensus on research priorities that can inform NASA's planning processes and congressional and White House decision makers. Each of these

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[3] National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond (2007),* http://www.nap.edu/catalog.php?record_id=11820#toc.

surveys incorporates inputs from hundreds of researchers. I strongly encourage members of Congress to closely review these decadal survey reports when they are released, invite their leadership to brief you and your staffs, and reflect their priorities in your legislation wherever possible.

Within NASA's Science Mission Directorate, Earth science is arguably one of its most critical functions and a source of some of NASA's greatest contribution to the nation. It is also an area where a Decadal Survey had profound impact. As one of the co-leaders of the Earth Science Decadal Survey,[4] I applaud Congress's subsequent increased support for NASA's Earth science program. This support was and is needed.

As noted earlier, despite the wealth of information that NASA's Earth observation research has supplied on understanding climate change, much more is needed. The challenge is growing and will not go away; climate change is not a *problem de jour*. Recognizing the need for increased information, the 2009 Recovery Act was targeted to accelerate implementation of the Earth science decadal missions. I believe that NASA used this money primarily to pay for cost overruns and delays in the existing program, (e.g., LDCM, GPM, and Glory), which could be argued indirectly accelerates (or rather does not further delay) the decadal missions. It could also argue that it rewards poor management.

The Earth science budget in the President's FY 2010 request is a marked improvement over the early budgets. However, it remains inadequate, particularly in the out-years and well below the recommended profile from the Decadal Survey. The following Figure highlights the difficulty (see also Attachment One).

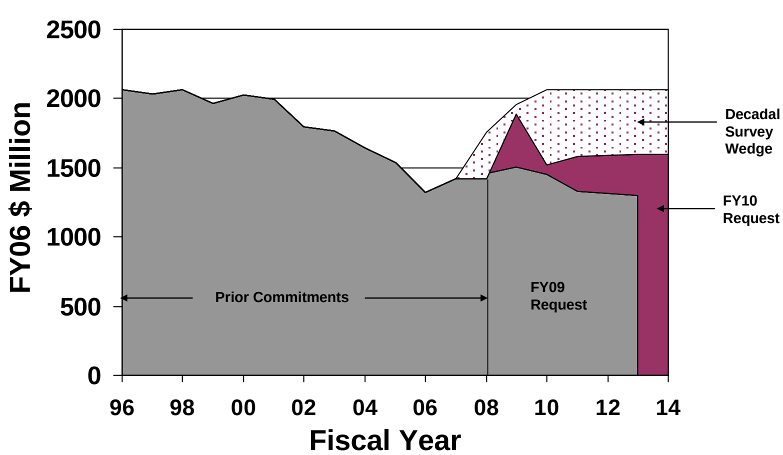

Figure 1. Comparison between the President's FY10 NASA request and the NRC decadal survey recommendation. The spike seen in 2009 is from the Recovery Act.

On the current path only four (SMAP, ICESat-II, DESDynl and CLARREO) of 15 missions recommended by the NRC's Earth Science decadal survey will be launched

[4] Ibid.

before 2020. This mission backlog, which I believe the nation can ill afford, has been exacerbated by the recent loss of the Orbiting Carbon Observatory mission and continuing delays in NPP. Where funding can be added to the NASA science budget, Congress should consider accelerating the remaining missions from the Earth science decadal survey. Congress may also want to consider encouraging NASA to explore more rapid means of obtaining key measurements from space by utilizing smaller spacecraft wherever possible.

Finally, I note that Congressional add-ons can add further stress to the budget:

- An additional $9 million was marked to refurbish the DSCOVR spacecraft's earth science instruments, even though DSCOVR did not rise to the very high bar set by the decadal survey. (The survey did note that the space environment sensors on DSCOVR would fulfill the pressing need for an operational replacement of the instruments on the aging ACE spacecraft)>

- Last year Congress directed NASA to spend $10 million to initiate development of the TIRS instrument. The FY10 budget indicates the LDCM project is now carrying "between $150-175M" to accommodate TIRS. Although very desirable, the cost for TIRS comes at the expense of the recommended program.

- In a separate area, I question the logic in this cost environment of spending whay may eventually amount to $50 million to undertake the feasibility of the Constellation architecture facilitating service missions to future observatory-class science spacecraft.

In closing my extended discussion on Earth science, let me note that there are major strategic issues in Earth science and the associated observations which remain open as we consider how best to provide the needed information to respond wisely to climate change. In the decadal survey, we recommended that:

- The Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, and NPOESS programs.[5]

The need for this *overall* Earth observing plan remains.

Returning to the many cross-cutting issues that affect NASA science programs broadly, one of the most critical is mission cost growth. I touched upon the issue of cost growth in my Earth science discussion above, but it is hardly an issue for Earth science alone; it is an issue that has plagued many of NASA's programs for a long time. It is important to note the obvious: the problems induced by cost growth can become acute within a flat

[5] I note that Congress is seeking a similar report (See Attachment One—Congressional Record.

budget environment. To pay for cost growth on one mission, the funding for other missions is often deferred, leading to schedule slippage and potential gaps in the overall research enterprise. For example, a recent NRC mid-decade review of NASA's solar and space physics programs found that very little of the recommended priorities from the prior decadal survey will be realized during the decade in question – threatening the status of the survey's integrated research strategy – partly because cost growth on some missions has delayed their launch as well as the development of other missions. The effect can be and usually is cascading.

There are numerous different explanations for why cost growth occurs, and the pathologies are different for each mission. Some causes, such overly ambitious science measurements and technology assumptions, are self-inflicted. NASA's Science Mission Directorate is taking some steps to correct these issues. One of the long-standing axioms of program management is that it is necessary to spend a significant amount of money on a program in the early concept stages in order to better understand the technology and engineering requirements and tradeoffs.[6] NASA is now doing this for some of its missions. NASA and the NRC are also requiring independent cost estimates — as opposed to estimates produced by a mission's advocates – in the current round of decadal surveys to improve the overall planning process and help to keep mission proposals honest. The NRC is also starting a congressionally-mandated study of the causes of mission cost growth and possible ways to remediate it that may inform future cost management strategies.

However, it is important to also point out that some causes of cost growth originate outside NASA. The engineering development of each mission has a most efficient path to follow, and stable, adequate funding is critical to keeping that efficient path in place. If Congress and the White House do not provide stable, adequate funding levels, the schedule for mission developments are often stretched out, leading to increased mission costs. As discussed above, this has occurred in the Earth science program; the NRC mid-decade review of NASA's solar and space physics programs also found that instability in the funding for NASA's Solar-Terrestrial Probes Program was a key cause of mission cost growth. The budget resources that the White House and Congress provide to NASA must match not only mission objectives, but also how, where, and by whom a mission will be developed and carried out.

An issue related to cost growth is the balance between different sizes of missions. The NRC's decadal surveys universally recommend a mix of small, medium, and large missions in each research area. This allows a field to pursue difficult, long-term, but highly rewarding research goals that usually require missions costing a billion dollars or more, while still infusing the field with new data from regular missions costing hundreds or even tens of millions of dollars. Unfortunately, cost growth on large missions can reduce or eliminate opportunities for frequent, innovative, and risk-taking research by eliminating small mission opportunities, such as NASA's Discovery, Mars Scout, Explorer, and suborbital programs. This problem is especially acute where a single large

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[6] In the Earth Science Decadal Survey, we explicitly called for extended and early Phase A studies to provide early understanding of the technology readiness issues.

mission development, like the James Webb Space Telescope in astrophysics or the Mars Science Laboratory in the Mars Exploration Program, dominates spending for a particular field or program.

Congress should be vigilant about mission balance in NASA's science programs, encourage NASA to take proactive steps to avert cost growth on large missions as early as possible, protect funding for smaller mission opportunities where possible, and restore funding for smaller mission opportunities when they are temporarily reduced. The NRC is currently undertaking two studies, on suborbital and mission-enabling activities, that will provide additional advice on those NASA programs that provide smaller, more frequent research opportunities.

Another cross-cutting issue that has emerged in several recent NRC reports is the importance of investments in technology development independent of science flight missions. NASA had such programs in the past, but they were largely eliminated due to other budget demands. My colleague, Ray Colladay, has covered this issue in detail in his testimony, but its importance to NASA's science programs should be noted. There are numerous technologies that are essential to accomplishing the goals established by the decadal surveys that are currently at relatively low technology readiness levels. Attempts to develop these technologies within flight mission development projects increase the chances that the missions will go dramatically over budget. In addition, it limits the ability of these technologies to be adapted to a broader set of missions. NASA managers are often reluctant to create separate technology development programs because of concern that they become unfocused and also because they are easy targets for budget cuts when flight programs overrun. However, there is no reason that a well-run and tightly focused technology development program will not work. Congress should encourage NASA to make necessary technology investments in advance of mission development starts and protect those investments when they are well-managed and productive.

An issue that has repeatedly appeared in NRC reports on NASA's science programs is the shrinking availability and affordability of launch vehicles. This problem is most acute for medium-sized science payloads that have relied in the past on the workhorse Delta II launch vehicle. As the Air Force moves the Global Positioning System (GPS) to Evolved Expendable Launch Vehicles (EELVs), there may not be enough business to maintain the Delta II line in an operational or affordable state. NASA is encouraging the development of potentially affordable alternatives to the Delta II through its Commercial Orbital Transportation Systems (COTS) program, and these efforts should receive Congress's support. If these efforts do not come to fruition, NASA will either have to make potentially unacceptable technical compromises to fit medium-sized missions on smaller launch vehicles, or pay unnecessary and much higher costs to launch medium-sized missions on larger launch vehicles.

Finally, NASA is both a research and advanced technology development agency. As such, it must continue to have multi-year budget authority (subject to the availability of funds). This is essential.

Like any cutting-edge, highly technical endeavor, NASA’s science programs face a number of issues, from both within and without, that must be addressed in a forthright manner to maintain the high productivity of the U.S. civil space program’s “crown jewel”. I hope my testimony provides you with useful advice on some of the important steps that can be taken to meet these challenges. Given the remarkable advances in NASA’s science programs over the past decade, the relatively small investment required, and the opportunities we anticipate in the coming decade, such steps are well worth the effort.

This completes my prepared remarks and I am happy to answer any questions the subcommittee may have. Thank you.

Attachment One

Issues in Earth Science

The Decadal Survey Committee concluded that the recommended NASA program could be accomplished by restoring the Earth science budget in real terms to where it was in the late 1990s. To track progress since release of the decadal survey, we've continued to update the budget figure shown in the report's Chapter 2. This graph shows - in constant year (2006) dollars – how the NASA Earth science budget has fared over time. It corrects for inflation and accounting changes that have been made over the years, such as the switch to full-cost accounting and the latest change to separately account for so-called "cross-cutting programs" (which fund center operations). This has been done because it puts the budget request in context, and this is needed to compare budgets from different years in an apples-to-apples fashion. The gray portion shows the previously enacted budgets and the FY09 request; the President's FY10 request is shown in purple and includes the $325M that Congress directed to Earth science in the Recovery. Even with this one-time significant infusion of funds, the program is falling short of what the Decadal Survey Committee recommended. The gap between the recommended funding level and out-year projections is both large and persistent. The NASA Earth science program requires an on-going commitment of funding at a higher level if it is to make needed progress on the decadal survey. The program is doing what it can with the resources it has been given – however it has not been given enough to accomplish all that is expected of it.

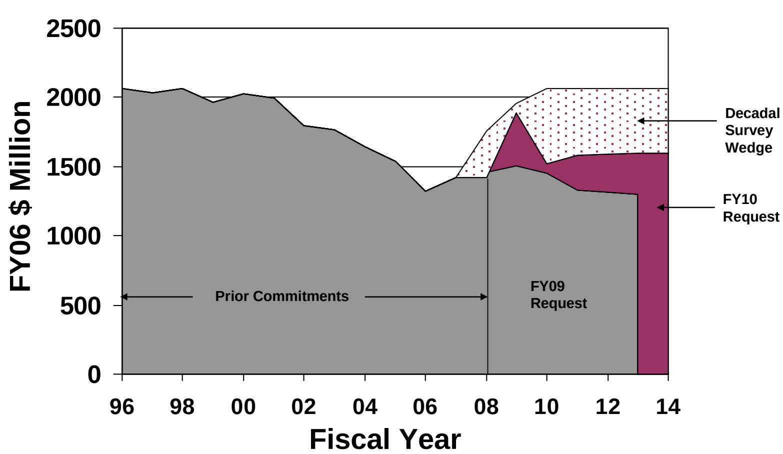

Figure 1. Comparison between the President's FY10 NASA request and the NRC decadal survey recommendation. The spike seen in 2009 is from the Recovery Act.

On accelerating decadal survey missions

The latest budget has the first decadal survey mission (SMAP) launching in late 2013 or early 2014, with a second (ICESat-II) launching in late 2014 or early 2015. In contrast, the decadal survey had recommended launching four missions by 2013. It is my understanding that CLARREO is to be launched in 2019 (12 years after the release of the Decadal Survey). So, what happened? Put simply, the needed budget increase did not happen and existing programs overran. To remain within the allocated profile, NASA stretched out the program.

The Stimulus monies, even though it states an objective of accelerating decadal survey missions, does not seem to be having the intended effect, unless one argues that it prevented further delays. Tracking NASA's weekly reports on its recovery act website, it does not appear any activity has occurred related to the decadal survey missions; indeed the FY10 budget indicates SMAP and ICESat-II will likely slip rather than accelerate. Perhaps there is more detail in the operations plan that NASA has been preparing, but this is not yet public.

Thoughts on Cost Growth & Schedule Slips

As noted in my testimony, schedule slips and cost growth go hand-in-hand. Changes or increases in scope also tend to be associated with both cost growth and schedule slips. Simply put, the NASA Earth Science program cannot afford any of the above. As mentioned earlier, the program does not have enough funding to accomplish all that is expected of it in a reasonable time frame. When existing missions grow beyond their allocated budgets, the situation becomes that much worse.

Glory’s cost grew between the FY09 and FY10 requests as its launch was delayed from March 2009 to January 2010. This brings its development cost estimate to $296M, compared with $259M back in 2008. In terms of lifecycle cost, in the last two years it has grown ~$90M.

NPP’s launch was delayed again from June 2010 until January 2011 due largely to the late delivery of the VIIRS instrument--the mission was originally supposed to launch in late April 2008. So, instead of NASA Earth science program costs for NPP decreasing as the mission transitions into operations, they are increasing to cover the extended development phase. The change between the baselines development estimate (from 2008) to that reported in the FY10 budget is greater than $130M.

GPM and LDCM are also slipping to the right. What is more troubling is that these two missions are still in formulation. Each of these missions, when you add up the appropriations lines projected through 2014 is at least on the order of $850M (each). It is important to note that some of the cost growth for LDCM comes from unfunded and costly Congressional mandates.

Cost growth in the existing program and early decadal missions greatly imperils the *decadal vision*, which requires multiple measurements covering all aspects of the Earth system. Allowing individual missions to grow in scope at the expense of the program means important missions and measurements will be lost or deferred and intended synergies will be lost. In the decadal survey, we explicitly recommended a firm triage: missions that grow significantly in budget need to be parked in the breakdown lane until they can be placed through descopes or other strong management actions on a more reasoned and restrictive budget profile. If this is not done, the existing program or early decadal missions will block the realization of the overall program.

References/Screenshots from the NASA budget sections of relevance for NASA budget below for Glory, NPP, GPM, and LDCM

Mission Directorate:	Science
Theme:	Earth Science
Program:	Earth Systematic Missions
Project In Development:	Glory Mission

FY 2010 Budget Request

Budget Authority ($ millions)	Prior	FY 2008 Actual	FY 2009 Enacted	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	BTC	LCC TOTAL
FY 2010 President's Budget Request	**218.5**	**82.3**	**50.7**	**27.1**	**10.1**	**4.4**	**1.9**	**0.0**	**0.0**	**395.0**
Formulation	70.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.8
Development / Implementation	147.7	82.3	50.7	15.4	0.0	0.0	0.0	0.0	0.0	296.1
Operations / Close-out	0.0	0.0	0.0	11.7	10.1	4.4	1.9	0.0	0.0	28.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 2009 President's Budget Request	**219.2**	**35.2**	**29.7**	**9.1**	**9.8**	**2.7**	**0.0**	**--**	**0.0**	**305.7**
Formulation	70.8	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	70.8
Development / Implementation	148.4	35.2	25.1	0.0	0.0	0.0	0.0	--	0.0	208.7
Operations / Close-out	0.0	0.0	4.6	9.1	9.8	2.7	0.0	--	0.0	26.2
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0
Changes from FY 2009 Request	**-0.8**	**47.1**	**21.0**	**18.0**	**0.3**	**1.7**	**1.9**	**--**	**0.0**	**89.2**
Formulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0
Development / Implementation	-0.7	47.1	25.6	15.4	0.0	0.0	0.0	--	0.0	87.4
Operations / Close-out	0.0	0.0	-4.6	2.6	0.3	1.7	1.9	--	0.0	1.9
Other	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	-0.1

Explanation of Project Changes

Cost growth since the FY 2009 Budget is related to the launch delay from March 2009 to January 2010. The reasons for the launch delay, and associated cost growth, were addressed in NASA's Glory Project Cost and Schedule Analysis Report (CSAR) to Congress, as required by Section 103(d)(2) of the NASA Authorization Act of 2005.

Mission Directorate:	Science
Theme:	Earth Science
Program:	Earth Systematic Missions
Project In Development:	Glory Mission

Development Cost and Schedule Summary

The base year development cost estimate below is consistent with the revised baseline reported in the Glory Project Cost and Schedule Analysis Report (CSAR) to Congress. At that time, the launch date was estimated to be June 2009. Cost growth since that time is due to the additional delay until November 2009. The Project is making good progress towards the new launch date.

Project	Base Year	Base Year Develop-ment Cost Estimate ($M)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Date	Current Year Milestone Date	Milestone Change (months)
Glory Mission	2008	259.1	2009	296.1	14	Launch Readiness	6/15/2009	1/23/2010	7

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Delta
Total:	**259.1**	**296.1**	**37.0**
Aircraft/Spacecraft	31.7	37.5	5.8
Payloads	117.4	138.6	21.2
Systems I&T	3.2	3.8	0.6
Launch Vehicle/Services	55.4	55.4	0.0
Ground Systems	0.9	1.1	0.2
Science/Technology	10.3	12.2	1.9
Other Direct Project Cost	40.2	47.5	7.3

Mission Directorate:	Science
Theme:	Earth Science
Program:	Earth Systematic Missions
Project In Development:	NPOESS Preparatory Project (NPP)

FY 2010 Budget Request

Budget Authority ($ millions)	Prior	FY 2008 Actual	FY 2009 Enacted	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	BTC	LCC TOTAL
FY 2010 President's Budget Request	**542.9**	**46.1**	**57.1**	**112.8**	**33.8**	**5.3**	**5.2**	**5.1**	**6.0**	**814.3**
Formulation	47.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.7
Development / Implementation	495.2	46.1	57.1	112.8	28.8	0.0	0.0	0.0	0.0	740.0
Operations / Close-out	0.0	0.0	0.0	0.0	5.0	5.3	5.2	5.1	6.0	26.6
Other	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
FY 2009 President's Budget Request	**554.5**	**70.0**	**94.4**	**46.3**	**8.6**	**8.9**	**9.2**	**--**	**11.4**	**803.3**
Formulation	47.7	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	47.7
Development / Implementation	506.8	70.0	94.4	46.3	0.0	0.0	0.0	--	0.0	717.5
Operations / Close-out	0.0	0.0	0.0	0.0	8.6	8.9	9.2	--	11.4	38.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0
Changes from FY 2009 Request	**-11.6**	**-23.9**	**-37.3**	**66.5**	**25.2**	**-3.6**	**-4.0**	**--**	**-5.5**	**11.0**
Formulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	--
Development / Implementation	-11.6	-23.9	-37.3	66.5	28.8	0.0	0.0	--	0.0	22.5
Operations / Close-out	0.0	0.0	0.0	0.0	-3.6	-3.6	-4.0	--	-5.4	-11.5
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	-0.1	0.0

Note: The FY 2010 LCC number in the table above is overstated by $14.9M due to the difference in the FY09 enacted bill and the April 2009 initial operating plan. Assuming approval of the initial operating plan, the estimated NPP lifecycle cost will be $799.4M, and the estimated Development cost will be $725.1M.

Explanation of Project Changes

The changes to the NPP budget are due to the launch delay from June 2010 until January 2011, primarily caused by late delivery of the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument.

Development Cost and Schedule Summary

The VIIRS sensor delivery from NASA's NPOESS partners continues to impact the NPP project. Ongoing issues with the VIIRS sensor development has caused the NPP launch to slip again. The revised NPP launch date is now January 2011 due to the late sensor delivery.

Project	Base Year	Base Year Develop-ment Cost Estimate ($M)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Date	Current Year Milestone Date	Milestone Change (months)
NPOESS Preparatory Project (NPP)	2006	592.9	2008	725.1	22	Launch Readiness	4/30/2008	1/31/2011	33

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Delta
Total:	**592.9**	**725.1**	**132.2**
Aircraft/Spacecraft	160.0	164.3	4.3
Payloads	194.2	162.3	-31.9
Launch Vehicle/Services	72.9	93.3	20.4
Ground Systems	48.2	49.4	1.2
Other Direct Project Cost	117.6	224.3	106.7
Science/Technology	0.0	31.5	31.5

Mission Directorate: Science
Theme: Earth Science
Program: Earth Systematic Missions
Project In Formulation: Global Precipitation Measurement (GPM)

FY 2010 Budget Request

Budget Authority ($ millions)	FY 2008 Actual	FY 2009 Enacted	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
FY 2010 President's Budget Request	**74.4**	**157.8**	**159.5**	**127.6**	**137.5**	**111.2**	**80.4**
FY 2009 President's Budget Request	**74.4**	**125.8**	**161.7**	**129.8**	**140.0**	**113.3**	--
Total Change from 2009 President's Budget Request	**0.0**	**32.0**	**-2.2**	**-2.2**	**-2.5**	**-2.1**	--

Estimated Project Schedule

GPM entered formulation in July 2002. Milestone dates beyond the formulation phase are preliminary estimates pending completion of formulation.

Milestone Name	Formulation Agreement Estimate	FY 2009 PB Request	FY 2010 PB Request
Development			
KDP-C	Dec 2003		May 2009
Core Observatory launch readiness date (LRD)	Nov 2010	Jun 2013	Jul 2013
Low-Inclination Observatory launch readiness date (LRD)		Jun 2014	Nov 2014

Mission Directorate: Science
Theme: Earth Science
Program: Earth Systematic Missions
Project In Formulation: Landsat Data Continuity Mission (LDCM)

FY 2010 Budget Request

Budget Authority ($ millions)	FY 2008 Actual	FY 2009 Enacted	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
FY 2010 President's Budget Request	**127.3**	**200.9**	**120.6**	**137.4**	**165.0**	**90.0**	**15.0**
FY 2009 President's Budget Request	**133.0**	**139.4**	**127.1**	**96.0**	**11.3**	**2.7**	**--**
Total Change from 2009 President's Budget Request	**-5.7**	**61.6**	**-6.5**	**41.3**	**153.7**	**87.3**	**--**

Starting in FY2009, NASA will develop a Thermal Infrared Sensor (TIRS) instrument, to be flown on LDCM or (potentially) some other spacecraft. A decision as to which spacecraft will carry TIRS will be made by summer of 2009. Meanwhile, funding for TIRS (approximately $150-175M) is now carried within the LDCM budget.

Estimated Project Schedule

In FY 2008, the LDCM Project awarded the LDCM spacecraft contract to General Dynamics and the Mission Operations Element (MOE) system development contract (in coordination with the USGS) to the Hammers Corporation, completing the mission complement.

In FY 2009, the LDCM Project will complete the spacecraft and MOE PDR, and the mission PDR. The OLI will undergo critical design and fabrication in FY 2009 and 2010. System integration and test will begin in FY 2011. Observatory integration and testing, as well as environmental testing, will take place in FY 2011, and launch vehicle integration will begin at the start of FY 2012.

Milestone Name	Formulation Agreement Estimate	FY 2009 PB Request	FY 2010 PB Request
Development			
Formulation			
Award OLI contract	June 2007	June 2007	July 2007
Confirmation Review	Jan 2008	Jan 2008	Dec 2009
Critical Design Review (CDR)	Feb 2009	Feb 2009	Apr 2010
PSR	May 2011	May 2011	Jun 2012
Launch	Jan 2011	Jan 2011	Dec 2012

From the congressional record
Note: Zoomed-in version below

SCIENCE

The bill provides $4,503,019,000 for science, an increase of $61,500,000 over the budget request. The amount provided reflects an unallocated adjustment of $70,898,000 and reflects unobligated balances carried into fiscal year 2009 from fiscal year 2008. NASA shall within 30 days of enactment of this Act provide to the House and Senate Committees on Appropriations its proposed distribution of the unallocated adjustment. In doing so, NASA shall identify offsets that do not result in delays or cancellations of missions in development or the cancellation of any selected projects, and shall not identify as offsets any increases provided above the request expressly provided by Congress.

Earth science.—NASA's Earth science portfolio shall have a continuous mixture of small-, medium-, and observatory class Earth science missions that guarantee regular and recurring flight opportunities for the Earth science communities.

Earth decadal survey missions.—A total of $150,000,000 is provided for Earth decadal survey missions. Funds are provided to support on-going activities of the ICESat II and SMAP missions. In addition, funds are provided to accelerate and achieve a level of system development more consistent with the National Academy of Sciences' recommendations. The bill provides funds to accelerate the ICESat II mission so that it will be ready to launch in 2013 concurrently with the SMAP mission, consistent with the National Academy of Sciences' recommendations.

Landsat data continuity mission (LDCM).—Funding of $10,000,000 is provided to initiate development of a thermal infra-red sensor (TSIS). NASA is directed to identify the earliest and least expensive development approach and flight opportunity for TSIS. NASA shall report its findings to the House and Senate Committees on Appropriations not later than March 2, 2009.

NASA is further directed to develop, in cooperation with the Office of Science and Technology Policy (OSTP) and the U.S. Geological Survey (USGS), a plan for a follow-on mission to LDCM consistent with the recommendations of the National Science and Technology Council's report, A Plan for A U.S. National Land Imaging Program. This plan is due to the House and Senate Committees on Appropriations no later than August 31, 2009.

Earth science applications program.—The bill provides $10,000,000 over the budget request for Earth science applications under the Research Opportunities in Space and Earth Sciences (ROSES) program, which shall be available to support new competitively-selected projects under subsection A.28, Earth Science For Decision Making: Gulf of Mexico Region, to be selected during fiscal year 2009.

Deep Space Climate Observatory (DSCOVR). The bill provides $9,000,000 for NASA to refurbish and ensure flight and operational readiness of DSCOVR earth science instruments.

Servicing Opportunities for Science Missions. Recognizing the historic successes NASA has achieved through the servicing of the Hubble Space Telescope, the National Research Council's recent report Launching Science: Science Opportunities Provided by NASA's Constellation System recommends that "NASA should study the benefits of designing spacecraft intended to operate around Earth or the Moon, or at the libration points for human and robotic servicing." This recommendation parallels the guidance provided by section 502 of the NASA Authorization Act of 2008 (P.L. 110–422), which recommends that provision be made for servicing of future scientific spacecraft to the extent practicable. Therefore, it will be critical that the Constellation program demonstrate unique capabilities to maintain synergies between free-flying scientific spacecraft and human spaceflight endeavors. Accordingly, the bill provides $20,000,000 for NASA to undertake an assessment of the feasibility of using the Constellation architecture to service existing and future observatory-class scientific spacecraft, fully utilizing the unique, core expertise and competencies for in-space servicing developed by the Goddard Space Flight Center and its private sector partners for the Hubble Space Telescope. NASA shall provide to the House and Senate Committees on Appropriations a plan for expenditure of this funding no later than 30 days after enactment of this Act.

Lunar landers.—The bill provides, as requested, $10,000,000 for the selected lunar lander.

Mars exploration.—NASA shall continue to engage the Mars community to define missions for the next decade that will lead to a Mars sample return in the 2020s. NASA is encouraged to define a budget profile for the Mars exploration program to support a lander mission and follow-on missions through 2020; consider augmenting technology to be demonstrated as part of the 2013 Scout; and support the small, competitively-selected missions such as Mars Scouts.

Mars science laboratory (MSL).—The bill provides the budget request of $223,331,000 for MSL. Over the past several months, NASA, with the concurrence of the House and Senate Committees on Appropriations, has taken reprogramming actions to address continuing project cost increases and to maintain a launch schedule in 2009; however, slower-than-expected progress, combined with late completion and deliveries of hardware, has contributed to deterioration in schedule performance. As a result, NASA has informed the House and Senate Committees on Appropriations on December 4, 2008, of its decision to delay a 2009 launch. The relative orbital location of Mars and Earth dictates that the next launch opportunity is 2011. However, in order to support a 2011 launch, NASA will need to identify additional resources in the range of $400,000,000. NASA is directed to provide to the House and Senate Committees on Appropriations not later than February 2, 2009, the impact on the project's baseline development cost estimate consistent with reporting requirements of section 103 of the NASA Authorization Act of 2005 (Public Law 109–155); and proposed resource allocations necessary to meet a 2011 launch. A reallocation of this magnitude can be expected to have significant impacts on other projects, and accordingly, NASA is directed to consult with the space science community to ensure its views are taken into consideration in any decision regarding future funding for MSL.

Outer planets.—NASA plans to conduct an outer planet flagship mission in cooperation with the European community, which a launch as soon as practicable. A more detailed plan and projected launch date shall be part of the fiscal year 2010 budget. The bill includes $101,089,000 for the outer planets program, as requested.

Hubble Space Telescope.—The bill provides the full requirement of $207,697,000 for the operations and upcoming servicing of the Hubble Space Telescope.

Astrophysics exoplanet exploration, other missions and data analysis.—An increase of $20,000,000 is provided to continue NASA's efforts in assessing lower cost versions of the Space Interferometry Mission (SIM) and in completing the detailed formulation phase of a "SIM-Lite" mission that would meet the requirements laid out in the most recent decadal surveys for an astrophysics mission.

Radiation Belt Storm Probes.—The bill provides the full budget request of $154,442,000 to continue this mission for launch in 2012.

Solar Probe.—The bill includes $18,000,000 for the Solar Probe mission, the highest priority recommendation of the National Academies' heliophysics decadal report. NASA is directed to work to achieve a launch no later than 2015.

Magnetospheric Multiscale Mission.—The bill includes the budget request of $94,582,000 for the Magnetospheric Multiscale Mission. NASA is directed to undertake no action to de-scope or reduce the project's scientific instruments or capacity.

Wallops Flight Facility (WFF).—The WFF is an important national asset that can be better utilized by focusing on emerging technologies that meet national needs and NASA priorities. The bill therefore provides programmatic increases of: $5,000,000 for advanced technology development of small satellites and unmanned aerial systems (UAS) that have the potential of lowering the costs of space and Earth science missions consistent with the goals of venture class missions recommended by the National Academies' Earth science decadal report; and $14,000,000 to improve launch pad infrastructure. NASA is directed to prepare a five-year action plan, including a proposed funding forecast, that identifies specific program and advanced technology development work that will utilize and expand the Wallops Flight Facility's role in the development of small satellites and unmanned aerial systems to meet critical earth science and other space system needs. This plan is due to the House and Senate Committees on Appropriations by June 1, 2009.

Ocean vector wind study.—NASA, working with NOAA and within the funds provided, shall study satellite and non-satellite alternatives for generating SeaWinds-like ocean wind data.

AERONAUTICS

The bill provides $500,000,000 for aeronautics research. The research and development activities undertaken with the augmentation shall not be based on the determination that the investment in an activity would result in a useable or useful product based only on one year's funding. Accordingly, the Aeronautics Research Mission Directorate is directed to provide to the Committees on Appropriations of the House and Senate in NASA's initial fiscal year 2009 operating plan a proposed expenditure analysis of the congressional augmentation to ensure that this investment of funds is devoted to long-term, multi-year research and development activities to support NextGen technology needs and solutions and "green" aircraft.

EXPLORATION

The bill provides $3,505,469,000 for exploration for fiscal year 2009, $5,000,000 over the budget request. The amount provided includes an unallocated adjustment of $18,000,000. NASA shall within 30 days of enactment of this Act provide to the House and Senate Committees on Appropriations its proposed distribution of the unallocated adjustment. In doing so, NASA shall identify offsets that do not result in delays or cancellations of missions in development or the cancellation of any selected projects, and shall not identify as offsets any increases provided above the request expressly provided by Congress.

Constellation systems.—The bill includes the budget request of $1,018,515,000 for Ares and $1,101,436,000 for Orion.

Constellation systems program, heavy lift cargo vehicle.—The bill includes $23,000,000 above the request for Ares V design requirements definition and research and development for a systems requirement review.

Earth decadal survey missions.—A total of $150,000,000 is provided for Earth decadal survey missions. Funds are provided to support on-going activities of the ICESat II and SMAP missions. In addition, funds are provided to accelerate and achieve a level of system development more consistent with the National Academy of Sciences' recommendations. The bill provides funds to accelerate the ICESat II mission so that it will be ready to launch in 2013 concurrently with the SMAP mission, consistent with the National Academy of Sciences' recommendations.

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