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Submitted to the
Committee on Appropriations
United States House of Representatives
Subcommittee on Commerce, Justice, Science and Related Agencies

on
The President's Fiscal Year 2013 Budget Request for NASA
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On behalf of the Association of Universities for Research in Astronomy (AURA), we are submitting comments on the fiscal year 2013 request for the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF). AURA is a not for profit consortium of 41 universities dedicated to the advancement of astronomy. AURA operates world-class astronomical observatories including the Space Telescope Science Institute, the National Optical Astronomy Observatory, the National Solar Observatory, the Gemini Observatory, and the Large Synoptic Survey Telescope. We first make general remarks about the relevance of astronomy to the nation, and then address the NASA and NSF requests.

Importance of Astronomy to the United States

We are often asked, "What puts *astronomy* in the must-have category as opposed to the nice-to-have category? Why are NASA and its space telescopes, and NSF and its ground-based facilities, of such national importance in these fiscally constrained times?" There are many answers to this question. One answer focuses on technology. Our national objectives include scientific and engineering leadership, an educated workforce, high technology capabilities and leadership, and jobs that create other jobs. Advances in astronomy, especially for a high-technology space mission like the James Webb Space Telescope (JWST), absolutely require major advances in technology and innovation in engineering as well as new hardware and new testing capabilities in our national aerospace industry groups. Likewise, the Large Synoptic Survey Telescope (LSST) pushes technology boundaries for data volume transfer and cyber-infrastructure at the National Science Foundation. This space- and astronomy-related technology is uniquely American, thus it leads to "home grown" solutions, i.e., to new small businesses and high-tech jobs. High-tech businesses and their related jobs have a high multiplicative factor, that is, they result in other jobs, many local. Such businesses also use what they learn on a program like JWST to improve and expand their business and to provide products for other science projects, or for unrelated areas where a new market may open up as a result of their expanded capability.

Beyond enhancing our crucial high-technology industrial base, NASA's science endeavors operate out in the open, unlike many of the US's advanced technology undertakings. The inspirational value of a space mission like JWST or a telescope like LSST can be profound, as has already been demonstrated by the Hubble Space Telescope. Educators and others on the front line of science, technology, engineering and mathematical (STEM) development include results from astronomy's premier flagship Hubble as a key tool in their arsenal. Every science teacher striving to engage and excite a class can point to an image taken by the Hubble Space Telescope and say, "only the United States can do this." Each year, Hubble's education programs reach over 500,000 pre-service and in-service teachers in the US and over six million school children use Hubble material in their curricula. JWST, like Hubble before it, will continue to demonstrate US leadership in these STEM fields that are so crucial to our country's future.

In yet another answer, we highlight the special appeal of astronomy, and how this appeal fundamentally affects us as a nation (this is distinct from the educational aspects in the previous paragraph). Almost everyone who has stood outside on a dark night and seen the stars has wondered, curious about what is up there and whether we are alone. It lies deep within our nature as human beings to wonder about our origins, and about our place in this vast cosmos. As the Hubble Space Telescope has demonstrated with its amazing pictures, people everywhere connect directly to the remarkable science from such telescopes, in large part to satisfy this innate curiosity and to continually refuel this sense of wonder.

For us in the US, it has been a matter of national pride that as the world's most powerful country we can, and should be, working at the forefront of scientific exploration in some areas. Being able to explore the universe in ways that no other country can is good for our national soul. Invariably as a country develops and its people move beyond day-to-day survival, there develops a sense that the nation must reach out and explore with its newly found capabilities. China and India and Brazil are all now embarking on the path of scientific exploration that the United States been on for many decades. Our nation will always face difficulties of one kind of another, but our quest for knowledge and understanding is something that needs to be continued if we are not to cede leadership to others.

National Aeronautics and Space Administration

We would like to thank the House Appropriations Committee for your past support for NASA and in particular for the James Webb Space Telescope (JWST). As the successor to the Hubble Space Telescope and NASA's top science priority, James Webb Space Telescope will demonstrate again US leadership in international scientific endeavors through the excitement of scientific exploration of our Universe. Both the European and Canadian space science communities are significant partners with NASA in JWST precisely because JWST, with 100 times the power of Hubble, is a unique scientific endeavor that only the US can do.

The importance of JWST for US leadership in space

For over 30 years, the astrophysics community, through its Decadal Surveys, has reaffirmed that what is needed to carry out its scientific objectives are a balanced program of small, medium and

large missions and projects. What has become evident with Hubble, Chandra, and Spitzer is that Observatory-class missions (sometimes called "flagships") are very cost-effective research tools. They are expensive, but they return cutting-edge results in diverse research areas for years while serving a very broad community. For example, the current number of Hubble users exceeds 8,000 scientists. In addition, missions of this scale have a demonstrated potential to engage the public in the excitement of scientific discovery. While we, and others, remain concerned about JWST's cost growth, we still see continuing interest in having flagship missions as central to the astrophysics community's strategic plans, and we offer strong support for JWST in particular.

We emphasize two important points regarding US leadership in space science. First, doing any mission in space is hard, but doing significant cutting-edge missions (that is, missions that will have a revolutionary impact on science) are -- *by their very nature* -- "one off" endeavors and hence will always be extraordinarily challenging to design, develop, and operate. Second, medium or small science missions are within the capabilities of other space science agencies such as ESA or JAXA. As the recent debate over ESA's Euclid mission verses NASA's WFIRST mission demonstrates, US "leadership" becomes far more complex at the smaller mission scale. The US space science program will remain unique only so far as it retains the capability to field powerful missions such as Hubble, the Mars Surface Lander, and JWST.

JWST cost

The cost growth for JWST was thoroughly investigated by the Congressionally-mandated Independent Comprehensive Review Panel (ICRP) in 2010. Mistakes were made and management failures occurred. NASA Administrator Mike Griffin realized early in his tenure that big programs at NASA had inadequate reserves (that is, the mission budgets did not have adequate funds to quickly rectify problems that naturally arise during development of a new, one-off high-technology mission). Administrator Griffin established a new agency policy that missions like JWST were to be costed and budgeted to 70% confidence level (a 70% likelihood that the project could be accomplished within the allocated budget). Unfortunately, JWST continued to be run with inadequate reserves, deferring work whenever problems arose. The recognition of this problem by the middle of 2008 led to efforts to apply additional reserves to the JWST project. However, the lag in the federal budget process meant that reserves could not be made available quickly. As the ICRP highlighted, this deferral of work drove up the cost of JWST (such deferral in high-technology projects typically leads to the work costing 2-3 times as much). A key lesson from the ICRP is that adequate reserves must be carried by budgeting to a high level of confidence: 80% confidence.

NASA conducted a thorough replan of the JWST project in response to the ICRP, identifying the comprehensive cost for JWST with the full 80% confidence. The design and development cost in this replan was $8.0B to launch in 2018. NASA, OMB and Congress eventually responded positively to NASA's replan, and Congressional action in late fall 2011 finally gave JWST the required FY2012 funding needed to achieve launch in late 2018. We were delighted with the positive response of NASA to the ICRP recommendations, and were similarly delighted with the response of Congress to NASA's replan, as well as the positive response of the science community and the interested public.

Congress has played a very important role in helping NASA identify the problems with the JWST program and in getting it back on track to launch. The House Appropriations Committee initiated an intense and wide-ranging discussion of JWST and its role in the nation's scientific arsenal. It, along with the earlier requests from the Senate for clarification on what was happening on JWST, led to a broader understanding of the issues surrounding the JWST project and of what was needed to complete and launch a mission of JWST's size and scientific importance. The action by the House Appropriations Committee in early July 2011 particularly provided a crucial incentive for NASA and the Administration to explain to Congress what it would take to complete JWST. While it was a challenging period for all, the JWST program was undoubtedly strengthened by the actions of the Congress.

Importance of JWST to astronomy

JWST is incredibly more powerful than current telescopes. While it is hard to capture the gains from a telescope in a single number, JWST can be characterized as having about 100 times the power of the Hubble Space Telescope and about 1000 times the power of the Spitzer Space Telescope. Hubble has revolutionized our knowledge of the growth of the universe, of galaxies like our own Milky Way, of the role that the still-unexplained dark matter and dark energy have played in the life of our universe, and played a major role in the characterization of planets around other stars. Yet so much more remains to be discovered. JWST will explore parts of our universe that cannot be detected by any other operational or planned facility. JWST will provide insight into the first stars and galaxies in the universe to help us understand far better how galaxies assembled from the first tiny objects to the massive spirals of today. JWST will make major steps forward in measuring how dark energy influences the nature of our universe and in understanding the impact of dark matter on galaxies. When JWST was first conceived we had only just begun to discover planets around other stars. Today we know of thousands, and because of JWST's unique capabilities, this telescope will become a powerful tool for searching for liquid water on extra-solar planets – a goal that was unimaginable a decade ago. Beyond these things (things that we can anticipate), lie the great unknowns of our Universe. The most exciting results usually arise from the unexpected. A telescope that is 100-1000 times better than today's best will undoubtedly reward us with serendipitous discoveries that we haven't yet imagined.

Summary for NASA and JWST

NASA is as much a part of our national heritage as apple pie and baseball. Among the iconic successes of NASA's space program, the Hubble Space Telescope will be remembered as an amazing achievement for the US. JWST is a worthy successor to Hubble. With the recent help of this Committee, JWST is now on track for its 2018 launch. Since the program's difficulties were brought to light and addressed, the JWST project has achieved a steady stream of milestones (updated monthly at (http://www.jwst.nasa.gov/recentaccomplish.html). We hope that the Committee continues to support the James Webb Space Telescope at the full level requested by NASA. Adherence to the replan's funding profile will enable the launch of this facility in 2018 at the lowest cost to the US tax payers, and will poise the United States for another decade of leadership in the field of space science.

AURA recommends $627,600,000 in accordance with the request level. NASA has provided a revised cost profile in the FY13 budget submission, and is reporting positive progress in meeting a 2108 Launch Readiness Date. The successful execution of the remaining development program within the Congressional cap of $8,000,000,000 requires adequately funding the program and planned reserves throughout the remaining construction period.

National Science Foundation

As the principle agency responsible for ground-based astronomy, it is critical that the NSF maintain an infrastructure that provides the general astronomical community with open access to federally funded observatories. Implementation of the highest priorities of the 2010 Decadal Survey will require a rebalancing of the NSF investments in astronomy; NSF has thus initiated a Portfolio Review. Key to this exercise will be assumptions regarding the potential growth in the level of funding for astronomy. From 2000 to 2010, the funding for astronomy within the NSF doubled, which represents growth of nearly 50% accounting for inflation. Although the NSF does not forward-project substantial increases for astronomy, it has managed to keep pace. In FY13, the NSF has proposed holding its funding for astronomy infrastructure constant while increasing cross-cutting initiatives.

It is crucial that the Portfolio Review result in a balance between optical and radio astronomy and sustain an infrastructure that ensures continued open access to public astronomical facilities.

AURA welcomes the line item identification of pre-construction funds for future major construction projects, including the Large Synoptic Survey Telescope, the top ranked ground-based priority for astrophysics in the coming decade. This joint NSF DOE project will provide unprecedented views of the changing sky and will drive key advances in cyber-infrastructure and large-volume data management.

AURA requests $7.5 M for LSST in accordance with the request level in order to make progress towards a potential new start in 2014 or 15. This will enable the project to address all remaining risk areas prior construction.

For the Advanced Technology Solar Telescope (ATST), construction has been impeded by a lack of access to the site in Haleakala for legal and administrative reasons. As a result, planned contingency funding for ATST has eroded and it will exceed the authorization by the National Science Board. The ATST was approved for construction in 2009 with a total construction cost of $297.9M. Of this, the Congress appropriated $153M in FY09 and $13 M in 2010. In 2011, the appropriations fell considerably short of what was requested, resulting in some re-adjustment of out-year funding.

It is important to ensure that the FY13 request of $25M be fully met and that a re-base lining of the remaining construction project be established.