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REPORT IN BRIEF

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# NASA's Beyond Einstein Program: An Architecture for Implementation—*Report Brief*

**SPACE STUDIES BOARD and BOARD ON PHYSICS AND ASTRONOMY**

## Background

The Beyond Einstein (BE) program is a set of five space missions designed to address important questions about physics and astrophysics. In 2003, NASA prepared a research roadmap proposing these five missions in order to study dark energy, black holes, gravitational radiation, inflation of the early universe, and Einstein's theory of gravitation. In FY2007, congressional language prompted NASA and DOE to request the NRC to assess these missions and recommend which to develop and launch first using a funding wedge that will start in 2009. This report provides, for each mission, an analysis of its scientific impact, an examination of technical risk and a cost assessment, and a review of related policy and programmatic issues. The report concludes with recommendations to guide program development.

## Missions

***Black Hole Finder Probe (BHFP)* –** This mission would be a hard X-ray telescope designed to find black holes and explore how they form and grow. There are two candidates for this mission and the science risk for each is rather high. Only high mass black holes will be observed, growth rates measurements will be very uncertain, and interpretation of results will be difficult. Each probe is now estimated to cost about a billion dollars, well above the original estimates. Judicious technology tradeoffs may enable a smaller telescope that could perform key BHFP science at lower cost.

***Constellation-X (Con-X)* --** This mission would be a general purpose astrophysical observatory with substantially advanced capabilities. It will make the broadest and most diverse contributions to astronomy of any candidate BE mission. Other missions, however, will provide more focused and definitive tests of program goals. Further, NASA understates its significance to general astronomy by characterizing it as a BE mission. While there are technical risks, current project plans provide a reasonable expectation of resolving them given adequate resources. Given its broader capabilities, however, Con-X development should not be funded from the BE wedge.

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***Inflation Probe --*** This mission's goal is to study conditions that existed during the period of exponential expansion of the early universe. Three of the four proposed IP missions—based on polarization of the cosmic microwave background—are at earlier stages of development than the fourth—the cosmic inflation probe (CIP). The former concepts all require extremely sensitive detectors, and significant continued support is needed to push these three concepts forward. The CIP concept would also benefit from intensive theoretical investigations and further refinement of key technology.

***Joint Dark Energy Mission (JDEM) --*** This NASA and Department of Energy mission would use a wide field survey telescope to investigate the distribution of dark matter. JDEM will greatly advance both dark energy and general astrophysical research. The principal science risk arises from the need to control systematic uncertainties sufficiently to allow much improved precision. Techniques are planned for JDEM to attempt to mitigate this risk. Two of the three candidate concepts are relatively mature technically, while critical technology for the third has flight heritage and no major challenges.

***Laser Interferometer Space Antenna (LISA) --*** This mission would consist of three space craft arrayed as an interferometer designed to detect gravitational waves from a variety of stellar objects. Success would permit observations of very energetic processes in the universe in an entirely new manner with profound consequences for physics and astronomy. LISA has undergone extensive technical development since beginning development. Still, a number of critical technologies must be developed and verified. While many of these will be tested on LISA Pathfinder, NASA should set a high priority for the BE program accelerating the development of the remaining critical technologies.

## Major Findings and Recommendations

Realistic costs ranges for each of the missions are likely to be significantly higher than current mission team estimates. Furthermore, the BE funding wedge alone is inadequate to develop any mission beyond its nominal schedule, although adjustments to the JDEM and LISA development and funding profiles could be adjusted to fit the wedge. Also, the current wedge will not support technology development beyond JDEM and LISA.

All five BE mission areas address questions that will significantly move the boundaries of physics and astronomy. The LISA and JDEM missions address BE goals most directly and have broader scientific potential than the other missions. LISA should be the flagship mission of a long-term program addressing BE goals. JDEM will set the standard for precise determination of dark energy distribution in the distant universe. A JDEM mission selected in 2009 could proceed smoothly to a successful launch.

NASA and DOE should proceed immediately with a competition to select a JDEM for a 2009 new start. NASA should also invest additional BE funds in LISA technology development and risk reduction. Finally, NASA should take steps to increase the readiness of the three remaining mission areas for consideration in the next NRC decadal survey of astronomy and astrophysics.

Future technology investment is required for all the BE mission areas. For the highest priority—JDEM—funding is needed for all three candidate concepts until selection. The competition should also be open to other concepts. The next highest priority for the BE funding wedge should be critical technology maturation for LISA. No priorities are set for the other three missions, and continued technology development of each should be supported in the broader astrophysics program.

**For Further Information** Copies of the complete report, *NASA's Beyond Einstein Program: An Architecture for Implementation*, can be obtained from the Space Studies Board or the Board on Physics and Astronomy, The National Academies, 500 Fifth St., NW, Washington, DC, 20001, 202-334-3477, <http://books.nap.edu/catalog/ >.

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