Next Generation Space Telescope – Mission Update

The Next Generation Space Telescope (NGST) is a large-aperture optical and infrared telescope being designed to study the first stars and galaxies born after the big bang, and to elucidate the mysterious process of star and planet formation in our own galaxy. As a logical successor to the Hubble Space Telescope (HST), it will stress deep imaging and multi-object spectroscopy in the near and thermal infrared portions of the spectrum. The NGST project is currently in the preliminary design phase. Major studies of light-weight mirrors are underway and show encouraging results. Detector technology development appears to be on track, and promising, new focal-plane assemblies for multi-object spectroscopy are being developed. Phase-A systems architecture studies are underway by industry consortia that include TRW, Ball Aerospace, Lockheed-Martin, and Raytheon Corporation.

The NGST Science Program

The birth of stars and galaxies

NGST fills the need for a telescope that is capable of studying the early seeds of galaxies, when the universe was less than a billion years old, and the early seeds of stars and planets being formed today in the Milky Way. The high spatial resolution and low background provided by a large-aperture, passively cooled telescope in an L-2 orbit are essential for these studies. Compared to current or planned observatories, NGST will have unique advantages in image quality, field of view, low background light, and environmental stability. Observations will be background-dominated by zodiacal light for near-infrared wavelengths less than 10 μm.

NGST will be a unique international facility with contributions from NASA, the European Space Agency and the Canadian Space Agency. In the recent decadal survey of astronomy and astrophysics, sponsored by the National Academy of Science (http://books.nap.edu/catalog/9840.html), NGST was ranked as the highest-priority, new initiative for the next 10 years. This ranking reflects both the exciting nature of NGST science and the recognition that NGST is technologically within reach.

The NGST Ad Hoc Science Working Group (ASWG) has created a Design Reference Mission (http://www.ngst.stsci.edu/drm) to illustrate the kinds of observations envisioned for NGST and to help guide decisions regarding observatory capabilities and instrumentation. Of 23 science programs, seven were ranked as highest priority. These include ground-breaking surveys of the early universe, designed to detect and study galaxies at redshifts as high as z=30, detection of supernovae at z~5 for measurements of cosmological parameters and star-formation rates, studies of dust-enshrouded starbursts at redshifts out to z=10, and detailed investigations of the physics of protostars and protoplanetary systems.

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NGST Instruments

Visible/near-infrared camera

- 0.6-5 μm
- 4 ′× 4 ′ field of view

Near-infrared multi-object spectrograph

- 1-5 μm
- R~1000
- 3 ′× 3 ′ field of view

Mid-infrared camera/spectrograph

- 5-28 μm
- R~1500
- 2 ′× 2 ′ field of view

NGST Interim Science Working Group Members

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NGST at launch minus 8 years

Meeting cost and schedule constraints

The excitement of NGST has always been tempered with the realization that NGST pushes the frontiers of space technology. The last year saw both major advances toward achieving some of the core NGST technology advances, as well as major efforts to quantify the technology and cost risks. In the light of results from costing exercises for other NASA missions, and in preparation for issuing Requests for Proposal (RFPs) for the NGST prime contract in the spring of 2001, the NGST project has undertaken a detailed re-assessment of the design parameters, including the size and temperature of the primary mirror, some of the design choices for the instruments, and the division of responsibilities between NASA, the international partners, and the prime contractors. The principal goals are to get the most observatory capability per dollar and to launch in this decade. A major result of this exercise has been to relax the requirements on the diameter, areal density, and temperature of the primary mirror. A modest reduction in the aperture diameter can result in a stiffer mirror that still meets the launch weight constraints for more than one launch vehicle. Allowing the primary mirror to operate at a warmer temperature will permit active thermal control using heaters. The stiffer primary will provide better, more stable image quality at lower cost than other options. It will also enable much more complete verification of image quality and control in ground testing, reducing the need for a flight validation experiment; therefore the Nexus mission has been cancelled.

NGST will still carry three instruments: a visible / near-infrared camera with a field of view of 8-16 square arcminutes, a near-infrared multi-object spectrograph, and a mid-infrared camera / spectrograph.

It should be stressed that concepts for NGST are still in development, and it will be up to the prime contractors to propose an observatory they can build within the cost and schedule constraints.

Interim Science Working Group Replaces ASWG

The NGST Ad Hoc Science Working Group (ASWG) has been providing science guidance since its creation in September 1997. The ASWG was responsible for constructing the Design Reference Mission (DRM), which has been used heavily as a tool in design trade studies. The ASWG also made recommendations on the NGST instrument complement, taking into consideration the NASA, ESA, and CSA instrument concept studies, the NGST science goals, and the expected advances in ground-based facilities.

The ASWG has recently undergone a metamorphosis into the Interim Science Working Group (ISWG). This group will function through the formulation phase (Phase A / B), until the instrument Announcement of Opportunity is released. The ISWG was selected in September 2000, from over 100 highly qualified applicants. The resulting committee includes observers, theorists, and instrument builders and reflects both the international nature of the project and the diverse scientific goals and capabilities of the observatory. The ISWG will work in collaboration with the NGST Project, NASA Headquarters, and the astronomical community to provide input during the formulation phase of NGST. The ISWG will help provide astronomy community input on questions relating to the science mission of NGST and will help disseminate information about NGST to the community.

Technology Development

Mirrors, detectors, and wavefront control

Key technology challenges for NGST include lightweight optics, cryogenic actuators for mirror control, deployable structures, sensitive infrared detector arrays, lightweight, programmable aperture masks for multi-object spectroscopy, and coolers for the thermal infrared detectors. All have seen significant progress over the last two years; mirrors and instrumentation are highlighted here.

Mirrors

The NGST primary mirror must be lightweight (~20 kg / m^2) and deployable, and must be capable of holding its figure at cryogenic temperatures. Through the investment of NASA and DoD, substantial progress has been made in demonstrating the requisite technologies. So far, eight designs involving five industry partners — including the University of Arizona, Composite Optics Inc, Ball Aerospace, Raytheon Optical Systems and Kodak — have been built as prototype ultralight mirrors. The University of Arizona built a 2-m “bed of nails” mirror, which uses a 2-mm facesheet of glass over a bed of more than 160 actuators to control the deformable surface. COI and IABG (Germany) developed a carbon-fiber, reinforced silicon-carbide, semi-rigid mirror that uses sparse actuation to control radius of curvature and tip, tilt, and piston of the mirror. Ball Aerospace built a beryllium mirror (right), which has recently undergone cryogenic testing at Marshall Space Flight Center to quantify the changes in figure due to temperature. The results are extremely encouraging for the concept of “cryofiguring,” where interferograms taken at cryo-temperatures are used to control the last stages of polishing.

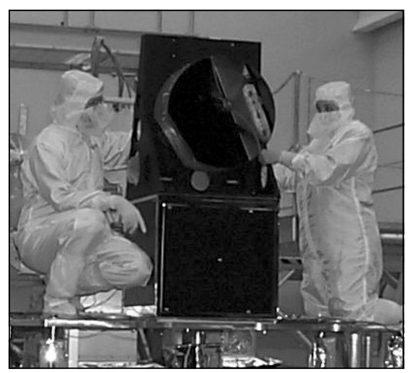


Photo courtesy of Ball Aerospace

The next stage of mirror development will include fabrication and testing of larger demonstration mirrors. Three different technologies were selected for phase II of the Advanced Mirror System Demonstrator (AMSD). Over the next two years, the three contractors will fabricate, assemble, and test full-size mirror segments. They must demonstrate manufacturing and testing techniques, and show that their mirrors will be capable of changing shape once in orbit and be able to work in temperatures that vary from 300 K to 40 K.

Advanced Mirror System Demonstrator Program

Raytheon
Glass Meniscus

Kodak
Fused Silica

Ball
Lightweight Beryllium

Detectors

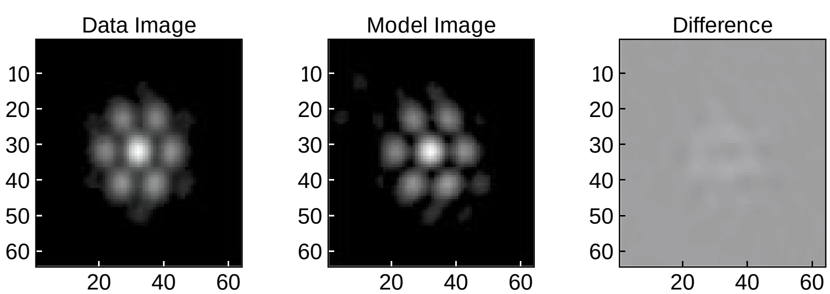
NGST requires detectors with large formats, a low dark current, and minimal readout noise. Candidates for the 0.6- to 5-micron region include indium antimonide (InSb) and mercury-cadmium telluride (HgCdTe) technologies, while arsenic-doped silicon (Si:As) holds the most promise for the longer wavelengths. The technical requirements that these detectors aim to meet are spelled out in the report of the NGST Detector Requirements Panel and summarized on the NGST web page (http://www.ngst.nasa.gov/cgi-bin/doc?Id=538 and http://www.ngst.nasa.gov/cgi-bin/doc?Id=641). For the near-IR (0.6-5μm), both HgCdTe (U. Hawaii/Rockwell Science Center) and InSb (U. Rochester/Raytheon) are being supported as candidate options. Through these contracts, multi-chip focal-plane modules will be developed, chip manufacturing will be improved, readout sensitivity will be enhanced, and potential cost drivers and cost savings will be identified.

In HgCdTe, the team has developed a pathfinder 1k × 1k readout (HAWAII 1-R), including reference pixels, and the yield has been excellent. Concepts for future NGST-optimized 18-μm-pixel 1k × 1k and 2k × 2k readouts have been developed. Lab characterization continues, and excellent dark current (0.005 e^-/s) and noise (5 e^-) data have been reported on ~5 μm cutoff material at ~60 K. Work has started on demonstrating substrate-removal techniques to promote visible response. In InSb, the team has also developed a pathfinder 1k x 1k readout (SB-226; 27 μm unit cells), including reference pixels. The design has been validated, and various lot splits are being tested. Designs for NGST-optimized, 22 μm-pixel 1k × 1k readouts have been completed. A broadband AR coating design, for 0.6 - 5 μm, has been completed and demonstrated at room temperature. Recent increases in the numbers of die per wafer (e.g., latest design includes 4 InSb die per 82 mm wafer) make detectors easier to produce overall. Excellent performance has been demonstrated, with dark currents as low as 0.019 e^-/s at 35 K and read noises of 7 e^- with 81 Fowler samples at 30 K. Work also continues at Raytheon and Ames on the mid-IR candidate material, Si:As. Bare readouts of the new SB-226 readout have been evaluated down to 5 K, and optimum lot splits will be identified soon. Prototype 1k × 1k Si:As hybrid arrays (27 μm pixels) have been fabricated, with excellent operability. Detailed low-background characterization is continuing.

Wavefront Control Testbed

The Wavefront Sensing and Control Testbed (WCT) is a joint project between GSFC and JPL for NGST. Its purposes are to simulate the co-phasing process for NGST, deepen our understanding of all aspects of this process, develop and improve the algorithms for sensing and control of each step, and characterize the effects of various parameters on accuracy, sensitivity, repeatability, and reliability. WCT1 incorporates a pair of deformable mirrors for injection of controlled aberration and correction. WCT2 incorporates a small, three-segment rigid mirror assembly with tip/tilt and piston correction. The experiment suite for WCT1 is nearly complete and the WCT2 assembly has recently been commissioned with the demonstration of the initial co-phasing (see figure).

WCT Demonstration of Image Reconstruction from Phase Retrieval



Left: A composite, high-resolution image (400 frames shifted and co-added), obtained with the three-segment mirror assembly on the WCT testbed at 633nm.

Right: A comparison model psf generated from the phase-retrieved wavefront obtained from the image data. The residual wavefront error is 0.07 waves at 633nm.