National Aeronautics and Space Administration

Technologies for the James Webb Space Telescope

The James Webb Telescope will have a unique and profound role in transforming our understanding of astrophysics and the origins of galaxies, stars, and planetary systems. To do this, and build on the successes of Hubble and Spitzer, it has invested in innovative and powerful new technologies ranging from software algorithms to optics to detectors. The Webb Project has made an early and significant investment in these technologies, and as a result, all were fully demonstrated by 2007. By proving the technology early, the mission has advanced into the construction phase, ready for launch in 2013.

These new technologies are all of the inventions that were needed to enable Webb. Each technology has been demonstrated in a space-like thermal vacuum chamber and has been subjected to noise and vibrations that simulate launch into space. In addition to their use on Webb, these inventions will help to enable other future space missions and will lead spin-off benefits here on Earth.

Lightweight Cryogenic Mirrors

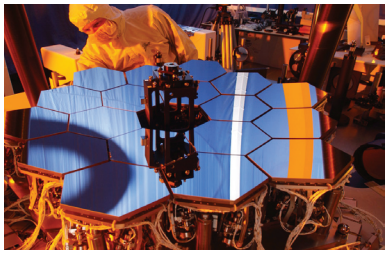
When it comes to telescopes, size matters: the sensitivity of a telescope is directly proportional to its collecting area, and the resolution goes as the diameter. That's why Webb has a 25 square-meter primary mirror, more than seven times larger than Hubble's. Webb's primary mirror is constructed of 18 mirror segments, which are aligned on-orbit to form a single optical surface. The challenge for Webb is to make the mirrors lightweight for launch, but nearly distortion-free for excellent image quality.

An early investment in a multi-year development program has demonstrated that beryllium mirrors meeting the Webb mass and optical requirements can be made. Further testing showed that the mirrors can survive launch. Manufacture of the flight mirror segments began during 2003 and currently the 18 segments are being shaped, polished and tested.

Wavefront Sensing and Control

Wavefront Sensing and Control (WFSC) is the process used to align the Webb mirror segments after launch. Through WFSC, the position of each mirror segment is measured and then adjusted to its correct position to produce a single precisely-shaped reflective surface. WFSC is accomplished by taking images of a star with a science instrument, and then processing the images through special algorithms that calculate the necessary adjustments for each mirror segment.

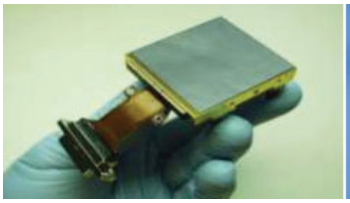
The algorithms have been proven through computer simulations and breadboard demonstrations that replicate a portion of the primary mirror. Successful algorithm tests have also been conducted on the Keck Observatory segmented mirror. The final demonstration was accomplished using a subscale WFSC testbed that simulates all 132 degrees of freedom in the Webb telescope. This testbed demonstrated nine separate algorithms which together will create a nearly perfect telescope.



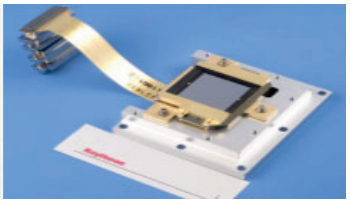
WSFC Testbed, Ball Aerospace

Infrared Detectors

Webb needs extraordinarily sensitive detectors to record the faint signals from far-away galaxies, stars, and planets, and it needs large-area detector arrays to efficiently survey the sky. Webb has extended the state of the art for infrared detectors by producing arrays that are both lower noise and larger format than their predecessors. It will use two types of detectors: four mega-pixel near infrared (IR) mercury-cadmium-telluride detectors for wavelengths 0.6-5 microns, and one mega-pixel



Near IR Dector, Rockwell



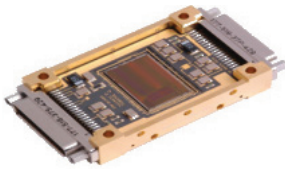
Mid-IR Detector, Raytheon

mid-IR silicon-arsenic detectors for 5-29 microns.

Testing of both the near-IR and mid-IR detectors proved that they meet Webb requirements. Production of both flight detectors types is underway.

Cryogenic Data Acquisition Integrated Circuit

To digitize the analog signals from the near-IR detectors, Webb is employing a low-noise, cryogenic application specific integrated circuit (ASIC), a computer-on-a-chip that works at the cold temperatures of the Webb cameras. This ASIC advances the state of art for such devices by delivering a micro-processor with extremely low power dissipation and a 16 bit analog-to-digital converter with noise comparable to conventional warm electronics.

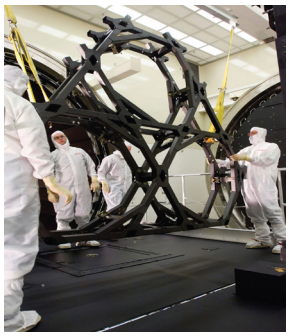


Cryo ASIC,

The noise and power dissipation performance of the ASIC have been demonstrated, and further testing showed that the ASIC will withstand the launch and radiation environments.

Large, Precision Cryogenic Structure

The composite structure that holds the Webb primary mirror must be exquisitely stable to keep the segments in alignment. While dimensionally stable structures have been built before, the combination of the 50K operating temperature and stability to tens of nanometers is unique.

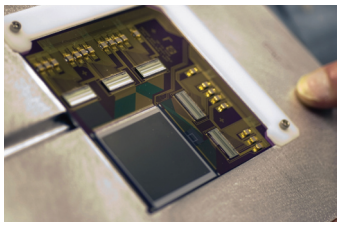


Stability Test Structure, ATK

To demonstrate the required performance, Webb has built a stability test structure using the techniques that will be used for the flight structure. Cryogenic stability tests were successful.

Micro-shutters

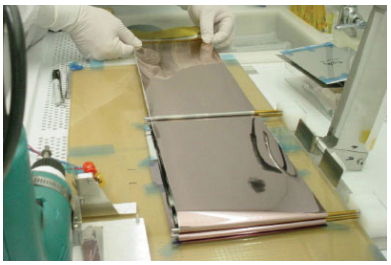
Micro-shutters are tiny, 200 micron-wide cells with lids that open and close in response to the application of a magnetic field. The micro-shutters for Webb are formed into arrays of 171 x 365 cells. Each cell can be addressed individually, allowing it to be opened or closed as required to view (when open) or block (when closed) a portion of the sky. This adjustability makes it possible to perform spectroscopy on up to 100 targets simultaneously.



Tests have proven the ability of the micro-shutters to open and close 200,000+ times, more than double the required lifetime, and the shutters have also survived launch and radiation tests.

Sunshield Coating

The Webb telescope and instruments must be cooled below 50K to allow them to see faint infrared emissions from astronomical objects. The Webb design includes a tennis-court sized sunshield to block the heat of the Sun and Earth from reaching the telescope in the cold section of the Observatory. The sunshield consists of five layers of Kapton with aluminum and doped-silicon coatings to reflect the sun's heat back into space.

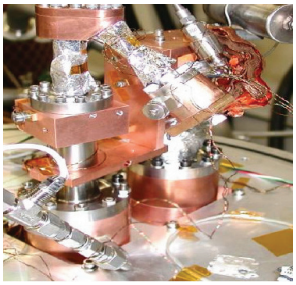


Silicon-coated Kapton,

Micrometeoroid, thermal, radiation, and mechanical tests to demonstrate the durability of the coatings were successfully completed.

Cryocooler

The mid-IR detectors must operate at 7K to detect thermal emissions at wavelengths out to 28.5 microns. A high-efficiency pulse-tube cryocooler is being developed to provide this cooling capability. The Webb cryocooler is unique in that it provides cooling remotely: the cold head is close to the mid-IR detectors which are located approximately 20 meters from the cryocooler compressor and electronics.



Cyrocoler, Northrup

A three year technology demonstration program proved the remote cooling capability, culminating in an end-to-end test of a complete cryocooler system.

About the James Webb Space Telescope

The James Webb Space Telescope is an international collaboration among NASA, ESA, and CSA. The Goddard Space Flight Center manages Webb for NASA. The prime contractor is Northrop Grumman Space Technologies. The Space Telescope Science Institute will operate Webb. Launch is planned for 2014.
www.nasa.gov