NASA and AURA Sign JWST S&OC Contract

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In 1998 Senator Barbara Mikulski and then NASA Administrator, Dan Goldin, visited the Space Telescope Science Institute to announce that NASA had selected it as the Science and Operations Center (S&OC) for the *Next Generation Space Telescope*. Ed Weiler had recommended this decision on the basis of the Institute's experience with *Hubble* and early involvement in the new mission. At the Institute we looked forward to extending the services and the relationships developed for *Hubble* to the science community of its successor. Little did we know that several years would pass before NASA and the governing body of the Institute, the Association of Universities for Research in Astronomy (AURA), would establish a contract to turn the 1998 announcement into reality.

The first major step in the process was completed in 2001. NASA approved a 'JOFOC' or Justification for Other than Full and Open Competition. The JOFOC permitted NASA to issue a sole-source contract for the *NGST* S&OC. Nevertheless, much work still lay ahead. NASA issued a *Request for Proposal* in October 2001, and AURA responded within two months. On June 6, 2003, following extensive negotiations, NASA and AURA signed the S&OC contract for the newly named *James Webb Space Telescope (JWST)*.

The new contract defines for the Institute a role in *JWST* similar to that for *Hubble*. The Institute will develop the science operations systems for *JWST*, provide scientific and engineering support to NASA and the science instrument teams, and support the commissioning of the observatory. The Institute is responsible for the systems and facilities that will control the day-to-day flight operations of *JWST*. Following launch, the Institute will operate the observatory from the planning phase through the archive and distribution of scientific data. In its management of the science program, the Institute will develop the *Call for Proposals* and instructions for potential observers, organize international peer reviews, select the science programs, support the development of detailed observing plans, maintain instrument calibrations, and manage grant funding to U.S. observers. As for *Hubble*, the Institute will be responsible for education and public outreach and will assist those astronomers who wish to publicize their results. The contract will fund these efforts until one year after launch, a period that will include commissioning, early *JWST* science team observations and, very likely, a number of large community Legacy programs. Ω

Superb Detectors for JWST

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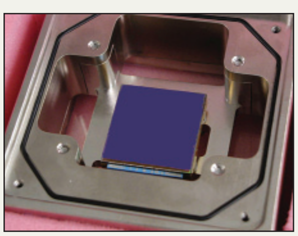

Figure 1: The Rockwell H2RG Sensor-Chip Array (SCA).

After a challenging and highly successful detector development and testing programs, the *James Webb Space Telescope (JWST)* is poised to benefit from the best infrared array detectors ever made. The University of Arizona chose HgCdTe detectors made by Rockwell Scientific Company (Figure 1) for use in the Near-Infrared Camera (NIRCam). NASA/JPL chose Si:As detectors made by Raytheon Vision Systems (Figure 2) for use in the Mid Infrared Instrument (MIRI). Three 1024 x 1024 Si:As detectors will be needed in the current MIRI design. The Near-Infrared Spectrograph (NIRSpec) and the Fine Guidance Sensors (FGS) teams are expected to announce their final selections soon.

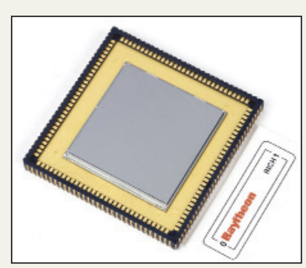

Figure 2: Raytheon multiplexer for the mid-infrared detector.

The *JWST* Project has funded both Raytheon and Rockwell to produce near-infrared array detectors for evaluation against the challenging requirements of the NIRCam, NIRSpec, and FGS. These instruments require ten, two, and four 2048 x 2048 (2K2) array detectors, respectively. Craig McCreight

(NASA/Ames Research Center) led the NASA development program that provided the vendors with the resources to build a series of progressively more capable devices, culminating in the deliveries of 2K2 'home run' devices for comparative testing. Given the original goal of developing working technology by September 2003, this program has been a great success.

Institution	Principal Investigator	Technology
University of Hawaii (UH)	Dr. Donald N. B. Hall	HgCdTe
University of Rochester (UR)	Dr. William J. Forrest	InSb
Space Telescope Science Institute (STScI)	Dr. Donald F. Figer	HgCdTe & InSb

Table 1: The near-infrared detector-testing laboratories.

In parallel with the detector development program, NASA funded a detector-testing program, which was also led by Craig McCreight. Three laboratories, selected through a competitive proposal process, evaluated the products of the development program under the ultra-low background conditions expected for *JWST*. NASA announced the test groups in January 2001, as listed in Table 1. The NASA/Ames Research Center (R. McMurray, M. McKelvey, and C. McCreight) was also a member of the *JWST* test network, with primary responsibilities for testing the mid-infrared technology and performing radiation testing of the near-infrared devices. In both the development and characterization aspects of this work, Matt Greenhouse, the *JWST* ISIM Project Scientist, played a key role in defining and clarifying requirements and approaches.

In order to perform the challenging test program, the Institute and the Johns Hopkins University set up the Independent Detector Testing Laboratory (IDTL) with a general vision "to provide world class testing and development facilities for astronomical detectors and associated technology." NASA selected the IDTL to fulfill the unique role amongst test labs of comparatively characterizing both the Raytheon and Rockwell detectors. This involved measuring first-order detector properties (read noise, dark current, persistence, quantum efficiency, etc.) as functions of environmental parameters (radiation exposure, thermal conditions, operating modes) for both detector types, using the same procedures, setups, dewars, light sources, targets, electronics, acquisition software, analysis software, and staff.

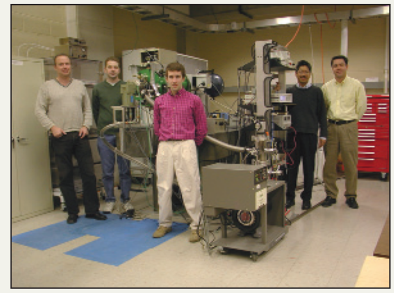

Figure 3: The IDTL test team in front of the test system. Left to right: Bernie Rauscher (Project Scientist), Ernie Morse (Data Analyst), Eddie Bergeron (Data Analyst), Sito Balleza (Project Engineer), and Don Figer (PI). Not pictured: Mike Regan (Project System Scientist).

Parameter	Requirement	Goal	Rockwell H2RG
Sensor-Chip Array (SCA) Format	Minimum of 2048x2048 pixels, with reference pixels located within or outside of the 2048x2048 field.		2048X2048
Pixel Pitch	18 – 25 μm		18
Total Noise (Quadrature sum of all sources) per pixel in 1000 s*	≤ 9 e^- rms	≤ 2.5 e^- rms	< 10 e^-
Read noise for a single read	≤ 15 e^- rms	≤ 7 e^- rms	12 e^-*
Dark current	< 0.01 $e^- s^{-1}$		0.001 $e^- s^{-1}$
Well Capacity	6 x 10^4 e^-	2 x 10^5 e^-	10% non-lin: 1.04 x 10^5 e^- saturation: 1.30 x 10^5 e^-
Electrical crosstalk between adjacent pixels	≤ 5%	≤ 2%	1.64%
Latent or Residual Images, when measured at the same integration time as was used for the near saturation image.	< 0.1% after the 2nd read following an exposure of ≥ 80% of full well	< 0.01% after the 2nd read following an exposure of ≥ 80% of full well	0.02%
Frame Read-out Time	12 s	< 12 s	10.7 s
SCA pixel readout rate	100kHz rate, 10ms/ pixel.	> 100kHz rate	100 kHz

* Estimated using digitally filtered data.

Table 2: Performance requirements, goals and measurements of the *JWST* near-infrared detectors.

In May of 2003, the IDTL test team (Figure 3) successfully completed the *JWST* detector characterization project, after obtaining two terabytes of data over two years from a half dozen prototype detectors during 25 cool-downs. Table 2 provides a summary of the measurements for the selected detector types.

The measured performance of the Rockwell detector is impressive,

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with dark currents as low as 1.3 electrons per thousand seconds per pixel, the lowest ever measured for an array having a long wavelength sensitivity cutoff at 5 mm. A typical data set is shown in the left panel of Figure 4. Equally impressive, the read noise for both vendors' devices was low, < 10 e^- per frame averaged over eight non-destructive reads. All imaging devices trap charge that can appear later while imaging another object. We measured a very low 'persistence' for the Rockwell devices of ~ 0.03% total integrated charge over 2000 seconds after a saturating exposure to light (see the right panel of Figure 4). Further details are described in Figer et al. (2003).

The future looks 'dark' for *JWST*, thanks to the superb detectors produced in an excellent development program and characterized in a successful test program. The next major task is to produce the many devices needed over the next few years to support the successful integration of the instruments into *JWST*. Ω

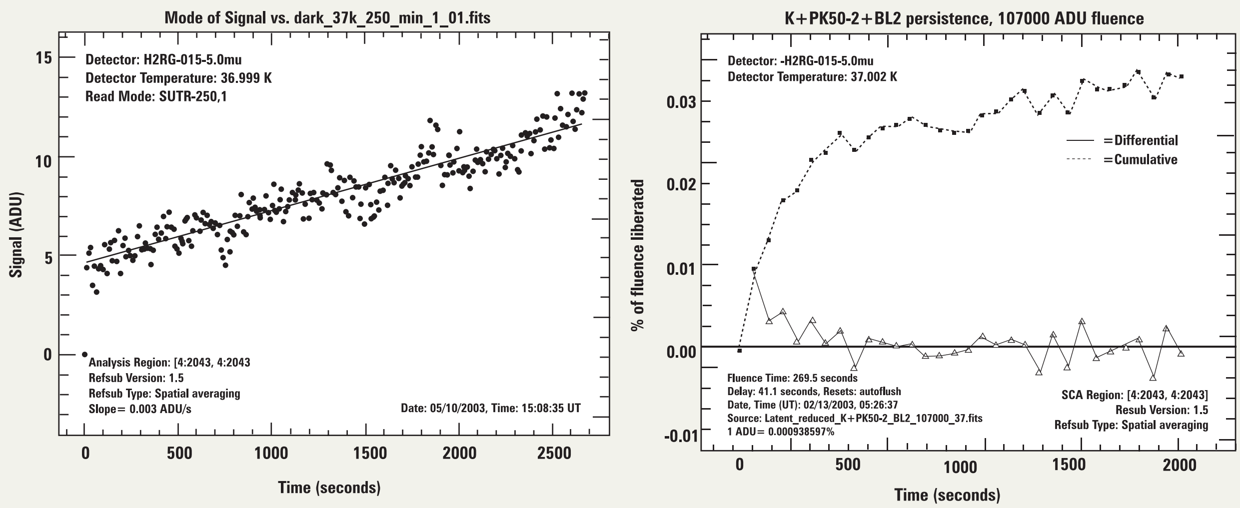

Figure 4: The diagram on the left shows IDTL measurements of accumulating charge versus time for the H2RG detector; after applying the appropriate gain, and after accounting for read-induced signal, the dark current is as low as 1 electron/1000 seconds/pixel, or a factor of ten better than the requirement. The diagram on the right shows the IDTL measurements of integrated persistent charge (top) and differential persistent charge (bottom) after exposure to saturating fluence; the performance is at least a factor of 3 better than the requirement.

References

Figer, D.F., Rauscher, B.J., Regan, M.W., Balleza, J.C., Bergeron, L.E., Morse, E., & Stockman, H.S. 2003, *SPIE*, 5167-29

Can JWST See the First Stars?

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One of the primary science goals of the *James Webb Space Telescope (JWST)* is to answer the question: "When did galaxies begin to form in the early universe, and how did they form?" Theorists predict that the formation of galaxies is a gradual process in which progressively larger, virialized masses, composed mostly of dark matter, harbor star formation as time elapses. These dark-matter halos containing stellar populations then undergo a process of hierarchical merging and evolution to become the galaxies that make up the local universe. In order to understand what are the earliest building blocks of galaxies like our own, *JWST* must be able to detect and identify 'first light' sources, i.e., the emission from the first objects in the universe to undergo star formation.