James Webb Space Telescope

Science Assessment Team

Final Report

23 August 2005

1.0 Introduction

The *James Webb Space Telescope* (JWST) Science Assessment Team (SAT) submitted its interim PowerPoint report on 8 July, 2005 and as a written document on 27 July, 2005. The SAT found that the scientific case for the JWST mission has become even stronger since its highest ranking by the Decadal report in 2000. The SAT found that to carry out the core JWST science, the observatory requires the basic instrumental capabilities of the NIRCam, NIRSpec and MIRI in the wavelength range longward of 1.7 μm, where thermal emission from the atmosphere and ground-based telescopes exceeds atmospheric OH emission and continues to increase dramatically at longer wavelengths. The SAT found that future giant ground-based facilities and instrumentation may eventually provide comparable capabilities to JWST at wavelengths less than 1.7 μm. As a result, the SAT recommended that NASA, its international partners CSA and ESA, and the PIs of those instruments reduce the risk and costs of JWST by reducing or eliminating requirements on the JWST architecture related to its performance below 1.7μm, while not eliminating either imaging or spectroscopic capability in this wavelength range. In addition, the SAT indicated that the scientific cases for the 2μm – 4μm TFI channel and the coronagraphs in MIRI needed additional study to determine their relative importance to the scientific mission of JWST. Since that time, the SAT has received input from the PIs of all four instruments and a supportive response from the Science Working Group (SWG, 19 July). It has also heard a presentation from the FGS-TFI PI and Co-PI on 17 August. This final report summarizes the consensus and recommendations of the SAT with respect to these instrumental capabilities.

2.0 NIRCam and NIRSpec Shortwavelength Capabilities (< 1.7 μm)

The SAT received documents from Marsha Rieke (NIRCam PI, 29 July) and Peter Jakobsen (NIRSpec PI, 31 July) regarding the scientific benefit of maintaining these capabilities versus the cost, risk, and mass savings in involved with their elimination. Both PIs indicate that maintaining these capabilities would be predicated on the minimization of future risk to the program and outline how that would be accomplished. The SAT found the arguments by the PIs that retaining these capabilities would not significantly drive costs or increase risk to the mission to be compelling. For both instruments, the short-wavelength extensions are important for the JWST First Light goals. *Contingent on the assumptions and undertakings of the instrument PIs that retention of these capabilities will pose relatively little additional costs (net) to NASA, the SAT would recommend that the short wavelength capabilities of NIRSpec and NIRCam be maintained.*

3.0 The MIRI Coronagraph

The SAT received a memo from George Rieke (MIRI US PI, 3 August) and Mark Clampin (Observatory Project Scientist) concerning the scientific importance of the MIRI coronagraph and the modest amount of mass saved from its removal (~0.14 kg). In studying debris disks by direct imaging, because nearby stars are bright (the Sun at 10 parsecs is 5th magnitude), even the wings of their images will saturate the MIRI imager in a matter of minutes. This makes the study of the spatial structure of these disks through PSF subtraction techniques impossible, even at tens of AU from the central star. A coronagraph reduces the core intensities of the stellar image and its Airy rings by several orders of magnitude. This enables the detailed study of the considerably fainter (in terms of surface brightness) debris disk systems discovered by *Spitzer* or through future JWST surveys. Even the simple MIRI coronagraph (Lyot spot and pupil mask) would enable these observations. Such a coronagraph carries no significant technical risk to the mission.

In the interim report, the SAT identified the study of debris disks around nearby stars as a major JWST science goal. The SAT finds that at least a simple coronagraph is essential to enabling this science with JWST. *Therefore, the SAT recommends that the basic MIRI coronagraphic capabilities be retained in the instrument payload. Like other coronagraphic capabilities, this recommendation is contingent that this represents no significant cost or risk increase to the project, as there should be no need for system-level testing* of this capability.

4.0 The Tunable Filter Imager (short and long wavelength sides)

John Hutchings (FGS-TFI PI) attended the 17 August telecon with the SAT and presented the scientific goals of the TFI and its technical and financial impact on NASA. The SAT also had access to a draft of the Tunable Filter Science Requirements Document (December 2003) and the FGS-TFI Performance and Functional Requirements Document (PFRD, 28 February, 2005).

Hutching's presentation focused on two scientific programs for the TFI: the identification of First Light Objects at a known redshift and the coronagraphic imaging of planets and disks around nearby stars. As described in the presentation (*Science and Future of TFI Instrument*), under the assumptions of the TFI Team, the TFI has two significant advantages over ground-based and other JWST instruments in these areas. First, the search for First Light emission-line objects at a given redshift (as suggested from redshifted 21 cm flux detected by LOFAR and PaST and other planned low-frequency radio telescopes) can be done more rapidly by the TFI than with a NIRCam survey and NIRSpec follow-up. Second, the TFI scanning coronagraph can reduce speckle noise and achieve an additional factor of ten reduction in light from the central star compared to NIRCam or MIRI at similar wavelengths (~ 5 μm). This reduction should enable the discovery of Jupiter-sized extra-solar planets around nearby stars in the important 4 μm - 5 μm region where both young and old Jupiter-mass planets are relatively bright.

The SAT was impressed by the apparent speed advantage for detecting Ly_{α} emitters at a given redshift (z~10-20), nominally a factor of 4.5. Since the nature of First Light objects is unknown, it is important to maintain the capability to detect these objects that might otherwise be missed by broadband imaging techniques. Similarly the SAT found the speckle suppression to be an important capability, though it generally finds planet-finding to be a lower priority for JWST (see interim report). Given these TFI projected advantages over other JWST instruments and the relatively low NASA cost and risk on the JWST project, the SAT finds that a single channel TFI, with emphasis on the wavelengths > 1.7 μm, would an important complementary capability for JWST, though lower than the priority for the three other instruments. The single-channel TFI would simplify the science payload and provide a ~30 kg mass savings compared to the two-channel TFI.

In making its recommendation on the TFI, the SAT used performance figures provided by the PI. The SAT notes, however, that the current PFRD and other TFI documents do not reflect the performance needed to achieve the speed advantage for Ly_α emitters:

- The change in central wavelength across the TFI field of view must be less than 0.5% in order to achieve the stated speed advantages. The PFRD value is 5%, ten times greater.
- The advantage in imaging speed for detecting a given line flux must be NIRCam/TFI ~ 3.4 at ≥ 2 μm to achieve the stated speed advantages. The PRDF sensitivity at 2 μm relative to the NIRCam MRD sensitivity implies a speed advantage of NIRCam/TFI ~ 0.7 for a spectral resolution ratio of 4:100. This discrepancy was explained by the PI as being due to an overly conservative calculation of the effective photometric aperture for point sources, yet the NIRCam sensitivity calculation uses a similarly conservative aperture definition.

The SAT recommends that the single-channel TFI be retained in the JWST science payload contingent on revised sensitivity requirements showing that the speed advantage of the TFI in detecting Ly_α emitting sources at 2 μm is at least three times that of the NIRCam and NIRSpec for the scenario described (known redshift, z~15).

The SAT recommendation on the TFI is also contingent on:

1. That NIRCam and TFI sensitivity requirements be derived and compared in a consistent fashion.
2. That CSA and/or NASA revise the relevant requirements documents for the TFI to reflect the newer sensitivity performance and wavelength uniformity presented to the SAT.

We assume that the TFI will meet the reported performance level. However, our recommendation on the TFI would change if these performance requirements cannot be formally modified.

5.0 Conclusions

The SAT reiterates that the prioritization of JWST's current capabilities described in our Interim and Final Reports enable a significant de-scoping of the current JWST mission. In some cases the low priority modes can simply be left untested as long as this does not drive mission cost. However, the SAT would support the actual elimination of low-priority modes only if doing so would significantly reduce risk and the potential for future cost growth.

The SAT has received no additional requests for assistance from either NASA HQ or the Project and will dissolve accordingly. The members of the SAT appreciated the opportunity to assist the JWST program and would be willing to help NASA HQ and the Project in the future if called on to do so. However, the SAT is sensitive to the role of the JWST SWG and believes this is the appropriate group to follow through our recommendations.

Summary of Recommendations by Science Capability

- Medium & Broadband Imaging ($\lambda < 1.7\ \mu$m, NIRCam): Maintain scientific capability with a minimum of associated risk to the mission. Coronagraphy would be low priority
- Medium & Broadband Imaging ($1.7\ \mu\text{m} < \lambda < 5\ \mu$m, NIRCam): High Priority: includes simple coronagraphy for debris disk science.
- Medium & Broadband Imaging ($\lambda \geq 5\ \mu$m, MIRI): High Priority: includes simple coronagraphy for debris disk science.
- Narrow band imaging ($\lambda < 1.7\ \mu$m, TFI): Low Priority
- Narrow band imaging ($1.7\ \mu\text{m} < \lambda < 5\ \mu$m, TFI): Medium Priority, Maintain scientific capability with a minimum of associated risk to the mission and contingent on a formalized speed advantage over the NIRCam and NIRSpec of at least a factor of three for detecting Ly_α emission sources with redshifts known in advance at 2 μm.
- Spectroscopy ($\lambda < 1.7\ \mu$m, NIRSpec): Maintain scientific capability with a minimum of associated risk to the mission: includes MSA, fixed slits, and IFU
- Spectroscopy ($1.7\ \mu\text{m} < \lambda < 5\ \mu$m, NIRSpec): High Priority: includes MSA, fixed slits, and IFU
- Spectroscopy ($\lambda \geq 5\ \mu$m, MIRI): High Priority: includes long-slit and IFU