The Advanced Technology Large-Aperture Telescope (ATLAST)

1. Abstract

Supported by IRAD FY15 funding, GSFC will continue to lead our joint assessment with JPL, STScI, and MSFC of a large-aperture UV/vis/NIR space observatory concept to be proposed to the 2020 NRC Decadal Survey. In coordination with expected DR&T support for our engineering and technology colleagues, this IRAD will support development of the ATLAST reference mission concept, including science priorities, professional presentations, and confirmation that the ATLAST reference mission concept achieves these priorities. Our priority near-term goal for IRAD support remains a sufficiently compelling science case and engineering design to motivate HQ SMD and STMD, and other organizations, to fund technologies needed to reach TRL = 5 by the time the NRC Survey is underway in 2019.

2. Description of FY15 Task: Concept Maturation for Selection by the NRC

We propose to continue the GSFC-led multi-institutional design study for a large-aperture space observatory operating over 0.1 – 2.5 μm, which will continue the heritage of HST as a powerful, broadly capable program that will also be the first astronomy mission capable of an extensive search for evidence of life beyond Earth.

The overarching, long-term objective of the project is selection by the NRC Decadal Survey as the highest-priority space mission for the 2020s, which will require a compelling science case, detailed engineering design, and key technologies at least at TRL = 5 no later than 2020. Success with the Decadal Survey will lead to a major new mission for which GSFC is likely to be the lead center.

Our goal for 2015 joint IRAD and DR&T support is to substantially advance the detailed science case for the concept, which will flow down to the engineering design reference mission to achieve these goals. Most importantly, our multi-institutional team will press the case for FY15 directed and/or competitively selected technology funding targeted at three priority technology areas that we identified during the current funding period (Section 4). We will also initiate discussion in FY15 with potential partners in the aerospace community, other government agencies, and other NASA programs that are interested in collaborative studies (e.g., the Space Launch System (SLS) and human space flight operations).

More specifically:

ATLAST Technology Activities for FY15

There is an active year ahead for our technology activities. If selected by STMD, early next fiscal year we will initiate our Game Changing Technology (aka, mid-TRL) technology activity, which as of this writing is likely to be the mechanical stability system, coronagraphic starlight suppression, and/or a major improvement in integrated systems modeling. In addition, we plan our first ATLAST "Industry Technology Fair" for November in which we will discuss coordinated investment in key technologies and observatory design. Evaluation and selection of next year's

Phase 1 SBIR proposals will take place in spring 2015. We have advocated for key technologies as part of this program. Finally, in March we will submit in response to the SMD Strategic Astrophysics Technology (SAT) solicitation.

The NRC recommended an investment of $100 – 200 M this decade in necessary technologies to enable a mission to search for biomarkers in neighboring Earth-like worlds. In response to this advice, and at the request of SMD and STMD, this past June we prepared a detailed description of needed technology development. As of this writing, SMD has demurred in significant FY14 funding for relevant technologies. As a consequence, we are preparing a highly focused technology plan that we intend to be attractive to the stated priorities of STMD, which we will present to them within about a month. Optimistically, an increase of funding in FY15 to relevant technology areas of $5 M is possible.

ATLAST Reference Mission Design Activities for FY15
Development work for mission requirements and reference mission design will continue in this coming year. Work will concentrate on developing an initial wave front error budget to support the allocation and validation of performance requirements across the telescope-instrument system. Analysis will formulate preliminary observatory mass estimates for the purposes of guiding engineering design trades. This will involve requirements and design contributions from across the flight system engineering disciplines. Initial thermal analysis will be carried out in order to support the understanding of thermal stability requirements. Work will continue in the development of models to analyze the effects of jitter on the observatory performance. Our results will be reported at several professional conferences this coming year (Section 3) as part of our campaign to establish among major stakeholders the credibility of our designs.

ATLAST Science Activities for FY15
The science emphasis for this past year has been on advancing our models of the major challenges in observing exo-Earths. However, more work needs to be done to provide robust predictions for the number of Earth-like planets that can be spectroscopically characterized under realistic observing conditions. A more sophisticated analysis of factors such as instrument characteristics, telescope and instrument overheads, requirements on spectral coverage and resolution, and the importance of re-visits for detection verification must be implemented. In our work in FY15, we will tackle the much more detailed problem of quantifying how well we understand the different input parameters to these simulations: sources and levels of noise and confusion in high-contrast imaging architectures, realistic observing efficiencies due to data analysis requirements, and the actual spectral resolution, wavelength coverage and S/N required to unambiguously confirm habitability.

3. Justification: FY15 – ATLAST's "Watershed Year"

A successful engineering reference mission to justify ATLAST's technology program in the coming years and a powerful science case – all areas being led by GSFC – has a high probability for being chosen by the NRC as the highest-priority major

astronomy mission for the 2020s. It is almost equally important for progress by the ATLAST team to be understood and recognized by the science and engineering communities. If successful, this will likely lead to a major role – presumably leadership – in NASA's most important astronomy project for the 2020s and beyond.

It is critical to pursue this development work and technology development now: the next Decadal Survey will begin as early as 2018, thus allowing very few years for technologies to reach TRL = 5, the major science goals to be developed and vetted in depth, and the engineering design and trade studies to be completed.

The coming year will be a watershed for ATLAST and GSFC as several decisive events will occur that our team is targeting. For example:

- The AURA "Beyond JWST" study will be released and highlighted at the January 2015 AAS Meeting. As we expect a large-aperture observatory to figure prominently in the AURA report, our ATLAST team will very visibly present at that meeting to discuss our most recent compelling results.
- The NRC Mid-Decade Review will begin in summer 2015 its review of NASA's progress toward achieving the priority recommendations of the 2010 Decadal Survey. The highest priority "medium scale" activity in that survey was investing in key technologies to enable a mission capable of searching spectroscopically for indicators of biological activity in the atmospheres of Earth-like worlds in the solar neighborhood. Our team will prepare significant input to this activity.
- Major conferences critical to recognizing the importance of ATLAST will be held next summer and we are likely to be invited to present our latest work: the conference on the 25th anniversary of the launch of HST (April), the combined AAS/IAU conference (August), and the Astrobiology Science Conference (AbSciCon; June).

4. Accomplishments this Past Year

In FY14, the project was awarded 2.4 FTE and $40 K via IRAD, which supported GSFC scientists and engineers, and contractors, who (1) assessed the ATLAST concept with respect to its ability to achieve the priority science goals; (2) developed in greater depth the ATLAST technology roadmap, which was presented (often by invitation) to SMD ASD, STMD, the ExoPAG and COPAG, and the NASA Chief Technologist and Chief Scientist; (3) advanced the detailed engineering design, with significant improvements in the architecture; and (4) reported on this work via a special 90-minute "splinter session" at the 224th Boston AAS meeting and at the Montreal SPIE Conference on Astronomical Telescopes and Instruments. More specifically:

ATLAST Technology Activities in FY14

The ATLAST technology roadmap team had a number of accomplishments this past year once the team was formed among GSFC, JPL, MSFC, and STScI in early

FY14. Our technology roadmap was presented for discussion and review at the AAS and SPIE meetings in June, followed by briefings to NASA HQ SMD (Grunsfeld and Hertz in attendance). This was followed by a presentation made to NASA's Chief Technologist and Chief Scientist. In parallel, the ATLAST technology needs were submitted to the Cosmic Origins Program Office for its technology prioritization process, which is used as input and selection in ROSES solicitations. Specifically, a plan for directed FTEs in FY15 for the ATLAST technology task was proposed. Meanwhile, the ATLAST technology team won three Phase 1 SBIRs in high-contrast imaging and spectroscopy, as well as high-reflectivity UV mirror coatings. Finally, members of the technology roadmap team continued to contribute to the AURA "Beyond JWST" study.

ATLAST Reference Mission Design Activities in FY14

In FY14 the ATLAST team formulated the Engineering Design Reference Mission (EDRM). An early purpose of the EDRM is to validate the largest primary mirror that will plausibly fit inside an existing launch vehicle (Delta IV Heavy). Our current EDRM offers the advantages of lower launch vehicle risk by adopting a proven launch vehicle. The Delta IV heavy offers the largest mass to orbit – and, hence, the largest aperture – of any current vehicle with a proven track record. In FY 14 technical design work included CAD studies improve the geometric "fit" within a 5-meter Delta IV fairing. A variety of mirror deployment options were examined and a design for multiple chord folds with standard JWST-type mirror segment sizes produced a capability for deploying a 9.2-meter telescope aperture. This design forms the basis for the ATLAST 10 meter-class EDRM. Other concepts might yield apertures as large as 11 or 12 meters, depending on the outcomes of detailed design work this coming year. Preliminary work on refining the characteristics of the observatory stray light shield based on the L2 Sun-Earth orbit geometry were also carried out in FY14. Preliminary work is underway to model of the dynamic stability of the telescope and instrument payload.

ATLAST Science Activities in FY14

Our combined 660/690 ATLAST Exoplanet Science Team works closely with our reference design team to improve our knowledge of the effect of various observatory designs on the final yield of directly imaged exoplanets, specifically the discovery and spectroscopic characterization of Earth-like planets. Through our work in FY14, we completed an initial set of mission simulation tools that allow us to evaluate the importance of critical mission architecture parameters (aperture size, inner working angle, pointing stability, mission lifetime, etc.) on our ability to detect Earth-like planets around nearby stars. Our "Design Reference Mission (DRM) Simulator" models the brightness of Earth-sized planets over a wide range of orbits for every known nearby star and calculates how many of these planets could be discovered by ATLAST based on various design parameters. This allows improved insight into the trade-offs between different mission and instrument architectures, and the ultimate limits of what is required for a confirmed detection of a habitable Earth-like planet. We developed an innovative new target selection algorithm, the "Altruistic Yield Optimization," that increases our planet yield by a

factor of two compared with previous work. It seems clear that apertures of 10 meters or greater are required to detect a significant number of Earth twins. This ground-breaking work was recently submitted to *The Astrophysical Journal.*

5. Resources

We are requesting slightly greater FTE support for our ATLAST activities in FY15 and a significant increase in funding, justified by a steady increase in professional engagement activities that are an essential part of our strategy for selection by the 2020 Decadal Survey. This latter includes presentations and invited talks at professional conferences and Technical Interchange Meetings (estimated at ten for the coming year @ $2000, plus $5 K for a senior ATLAST team member (Stapelfeldt) to participate in the Kavli Institute exoplanets study program) and $5 K for generation of visualizations of the observatory. In addition, we intend to continue expert SAO design work on detailed thermal stability analysis at $50 K , as well as $25 K for advanced mechanical systems design, including stray light shielding (Perrygo). Finally, it is essential to develop an integrated model of the entire ATLAST system. Such analysis tools do not exist at GSFC or with our current collaborators and we wish to contract this work with Sigmadyne (http://sigmadyne.com/) for a first-year cost of $25 K.

For FTE support, we are requesting 1.3 FTE for Code 600 exoplanet scientists (0.4 for each of Roberge, Mandell, and Domagal-Goldman; 0.1 for Stapelfeldt), 1.3 FTE distributed among general astrophysics and Solar System scientists (Gull, Schnittman, Padgett, plus two colleagues we are currently in discussion with). Finally, we are requesting 0.5 FTE to match an equivalent contribution from the GSFC TESS team for a individual serving both as deputy project scientist for that mission and expert in direct exoplanet detection for ATLAST.

FTE = 3.1 Procurement = $130 K

6. Related Proposals

Mallik: Fast wavefront control for VNC; Dean: FPGA WFSC; Lyon: Next Generation VNC; Bolcar: ATLAST optical systems engineering; Del Hoyo: UV mirror coatings.