The Advanced Technology Large-Aperture Telescope (ATLAST)

1. Abstract

In coordination with (mainly) IRAD support for our engineering colleagues, we will develop in greater depth the ATLAST reference mission concept, including science priorities, professional presentations, and confirmation that the reference mission concept achieves these priorities. Our priority near-term goal remains a sufficiently compelling science case and engineering design to motivate (1) HQ SMD to assign formally to GSFC the responsibility for a major study of a large UVOIR observatory and (2) SMD, STMD, and other organizations, to fund technologies needed to reach TRL = 5 - 6 by the early 2020s.

2. Long-Term Objective: Concept Maturation for Selection by the NRC 2020 Decadal Survey

We will continue the GSFC-led multi-institutional design of a large-aperture space observatory operating over 0.1 – 2.5+ μm, which will build upon 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 new space mission for the 2020s, which will require a compelling science case, detailed engineering design, and key technologies at least at TRL = 5 – 6 in the early 2020s. Success with the Decadal Survey will lead to a major new mission for which GSFC is likely to be the lead center.

With IRAD support in 2016, we will 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 continue to press the case for FY16 directed and/or competitively selected technology funding targeted at three priority technology areas that we identified almost from the time that our studies began in spring 2013. We will continue discussion in FY16 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).

Nota Bene – NASA SMD's Astrophysics Division (APD) will be identifying within the next very few weeks the lead Center for the study of a large-aperture UVOIR space observatory, which is almost certainly going to be GSFC. In mid-FY16, APD will establish the Science and Technology Definition Team (STDT) for this study. As of this writing we do not know the detailed schedule for these activities nor whatever guidance the APD might give the STDT and Center-led study teams. For this reason in this work plan we are assuming a year-long study plan directed solely by the GSFC ATLAST team leadership.

3 Justification

3.1 FY16 – Building on the Successes of 2015

Our increasingly detailed engineering reference design and compelling science case over the past year has led to an almost-certain assignment to GSFC as lead Center for the study of a large UVOIR space observatory for the late 2020s. We intend to build on this success with increasing depth of our design for ATLAST, as well as sophistication of our science case.

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 beginning in about three years 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.

Although it is premature to reliably estimate the total cost of ATLAST, the long-term, total **return on investment (ROI)** to GSFC will be comparable to that of JWST: several hundred million dollars and an incalculable reputation as one of the world's leading science institutions for the first half of the 21st century.

Over the coming few years, the **ROI** to GSFC is probably in the few millions of dollars, although only to the degree that NASA HQ intends to fund major technology areas to enable future missions. The NRC recommended in 2010 an investment of $100 – 200 M this decade in necessary technologies necessary for ATLAST's primary science goal. In response to this advice, and at the request of SMD and STMD, this past year we updated a detailed description of needed technology development. As of this writing, SMD has declined significant FY16 funding for relevant technologies. As a consequence, we are preparing a highly focused technology plan that we intend to continue to advocate to senior levels at NASA HQ. Optimistically, an increase of funding in FY16 to relevant technology areas of $5 M is possible.

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 approach TRL 5, the major science goals to be developed and vetted in depth, and the engineering design and trade studies to be completed.

3.2 Progress to Date: Recent Accomplishments

Our team will achieve its primary near-term goal in the near future when GSFC is identified formally as the lead Center for a multi-year detailed engineering assessment of the LUVOIR Surveyor. To achieve this milestone, our team carried out a number of activities over the past year:

ATLAST Science Activities in FY15

The science emphasis at GSFC for this past year continued to be advancing our simulations of major challenges in observing exo-Earths. Our ATLAST Exoplanet Science Team (Domagal-Goldman, Roberge, Mandell, Stapelfeldt, and colleagues outside GSFC) assisted the engineering effort by exploring the impact of various design decisions on the final yield of directly-imaged exoplanets, specifically the discovery and spectroscopic characterization of Earth-like planets. Through our work in FY15 we improved our initial set of mission simulation tools, the "Design Reference Mission (DRM) Simulator," which allows us to evaluate the importance of critical mission architecture parameters (aperture size, inner working angle, pointing stability, mission lifetime, etc.) on our ability to achieve the detection of Earth-like planets around nearby stars. We increased the sophistication of the analysis, including 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. We also began tackling the complex 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. For this effort we began developing a realistic 2-D image simulator for coronagraphic imaging, which includes a realistic source field, source confusion due to background galaxies, and field motion due to time delays between repeat images.

Our team also contributed supporting material to the recently released AURA report, *From Cosmic Birth to Living Earths* (http://www.hdstvision.org/), which recommended a mission very similar to ATLAST as a future major priority for NASA. In addition, this work has been presented at numerous professional conferences, usually by invitation, (e.g., Astrobiology Science Conference 2015, Pathways to Habitable Planets II) and at multiple meetings of NASA's Exoplanet and Cosmic Origins Program Analysis Groups (ExoPAG and COPAG). We have also established a regular every-other-Wednesday seminar series on topics relevant to relevant to a future large-aperture observatory (http://asd.gsfc.nasa.gov/colloquia/atlast/), as well as a Google Hangout on future space science missions, including the search for life (https://plus.google.com/u/0/events/ctmuvcgmi57opjes0o13dk2nr0g).

Our study partners at STScI are contributing science cases in star formation and evolution, galaxy structure and composition, as well as the high-z universe

ATLAST Reference Mission Design Activities in FY15 (supported mainly by DR&T with augmentation using IRAD procurement dollars and a fraction of an FTE)

Development work for mission requirements and reference mission design deepened this past year. Work concentrated on assessing an initial wave front error budget to support the allocation and validation of performance requirements across the telescope-instrument system. We formulated preliminary observatory mass estimates for the purposes of guiding engineering design trades. This involved

requirements and design contributions from across the flight system engineering disciplines. Initial thermal analysis supported by IRAD procurement funds was carried out in order to understand thermal stability requirements. Work continued in the development of models to analyze the effects of jitter on the observatory performance, again supported by IRAD procurement funds. Our results are being reported at several professional conferences as part of our campaign to establish among major stakeholders the credibility of our designs. Just as with our science team analyses, we contributed significant supporting material to AURA's *From Cosmic Birth to Living Earths* and will present our latest work at August's SPIE conference.

4. Research and Development Plan

ATLAST Science Activities for FY16
In FY16 we will continue to improve our current simulations especially to improve the fidelity of the optical system requirements. This will include noise from starlight (after starlight suppression), dust in the target system, and detector performance. This will be done for at least our baseline reference mission design and one starlight suppression technique. We will also expand our analysis to new science cases in the areas of exoplanets and stellar astrophysics. We will begin simulations of the time-dependent noise in transit spectra, based on a similar simulator for JWST. This will allow us to explore the potential for very high-resolution transit spectral analysis as a means of detecting specific lines that would otherwise be unavailable due to coronagraphic constraints. We will also continue to improve our estimates for the overall planet yield from ATLAST observations; that is, understanding the yield of rocky versus gaseous planets, and the overall number of non-Earth planets that will be discovered over the mission lifetime.

Additionally, we will lead professional outreach activities for those scientific communities relevant to ATLAST. These activities will include co-organizing workshops with other exoplanet-related NASA organizations such as the NASA Astrobiology Institute and the NASA Exoplanetary Systems Science (NExSS) Network. We will leverage public science engagement opportunities, such as the autumn celebration of the 20th anniversary of first
exoplanet detection at National Air and Space Museum. And, of course, we will continue to collaborate with stellar astrophysics and galaxy science colleagues in 660 to increase the focus on non-exoplanet astrophysics science with ATLAST and to engage planetary sciences colleagues (690 and beyond) on Solar System science.

Finally, we will work with colleagues at JPL (M. Werner) and STScI (J. Green) to assess the feasibility of mid-IR (~ 4 μm) planet transit spectroscopy with a room temperature telescope to search for diagnostic molecular lines that may be observable no other way.

ATLAST Technology Activities for FY16
This activity is described in the work plan submitted by Matt Bolcar.

ATLAST Reference Mission Design Activities for FY16
DR&T support will not be available in FY16. We therefore are planning to carry out those engineering activities that would have been funded via DR&T as part of this IRAD effort as described below. The proposed effort will continue the bare minimum "keep-alive"-level of engineering analysis, which includes part-time support from a network of multi-disciplinary engineers who are already familiar with ATLAST. I have agreed to provide 0.5 – 0.7 FTEs this year to Norman Rioux, our mission systems engineer, to support this design work.

Development work for mission requirements and reference mission design will continue in this coming year. Work will continue on developing an initial wave front error budget to support the allocation and validation of performance requirements across the telescope-instrument system. Analysis will improve upon our 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. Further 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 continue to be reported at several professional conferences this coming year as part of our campaign to establish among major stakeholders the credibility of our designs.

5. Future Development and Funding Plan

5.1 Near-Term Funding Opportunities

As noted above, we continue to advocate within both NASA SMD and STMD for funding for key technologies as recommended to the agency by the 2010 NRC Decadal Survey. Although our presentations have been well-received by senior SMD and STMD leadership, there has been no resultant funding support our activity. However, the NRC this year is reviewing the NASA Astrophysics Division's response to the 2010 Decadal Survey, which may lead to new funding for ATLAST-related technologies. In addition, the recent AURA report, *From Cosmic Birth to Living Earths,* identified increased technology funding as essential to enable the next major space observatory after JWST and WFIRST/AFTA. In the meantime, our team is continues to be supported modestly via APRA and SAT opportunities.

5.2 Long-Term Funding Opportunities

Our longer-term – that is, few years – funding source plans are focused on obtaining major funding from NASA HQ SMD and STMD in response to the NRC's Mid-Decade Review now under way. As noted above, the NRC 2010 Decadal Survey recommended major technology funding during this decade with a mid-decade review of SMD's progress toward achieving this priority goal. We consider it highly likely that the formal NRC review of SMD's technology funding will support

significant directed funding relevant to ATLAST and available to GSFC, as well as our partner institutions (JPL and MSFC). At this stage, it is purely speculative, although eventually a few tens of millions dollars annually is reasonable.

5.3 Technology Development Plan

Our technology team led by Matt Bolcar has produced as part of our advocacy effort at HQ an extensive technology development plan that is too long to include here. [The Executive Summary is ten pages long.] We are pleased to make it available upon request.

6. Resources

6.1 Procurement

With $10 K we will update our visualization of the ATLAST concept.

6.2 Civil Service Time (FTE)

As the funding requested for a major space observatory can only be justified by an extremely strong science case, we received 2.2 FTEs to continue to support our excellent science team (See Section 3.2 and opening paragraphs in Section 4). In addition, because of the termination of DR&T funding, which we use for engineering studies, we intend to use 0.7 FTE of our IRAD to support increasingly detailed ATLAST engineering.

7. Intern Request

We are not requesting an intern.

8. Related Work

Although I am not included directly on his IRAD proposal, *Advanced Technology Large Aperture Space Telescope (ATLAST): Engineering & Technology Development,* the PI, Matt Bolcar will be leading complementary activities to this proposal.

In addition, Aki Roberge was awarded an FY16 SIF proposal to develop a starshade concept: *Finding the Needles in the Haystacks: Simulating Realistic Exoplanet Imaging Observations with Starshades.* There also is a funded STG, the Exoplanet Climate Group, for which the goal is to bring together the four science divisions to create a "center of excellence" for exoplanet climate research.