

The Advanced Technology Large-Aperture Space Telescope (ATLAST)

1. Abstract

Thanks to two previous years of IRAD and DR&T support, our GSFC-led assessment of a large-aperture UV/vis/IR space observatory will very likely later this calendar year result in its selection by NASA HQ to be one of a handful of concepts to be studied in greater depth. This study, due to begin in mid-FY16, will be led by GSFC for consideration by the 2020 NRC Decadal Survey. Until that time, FY16 IRAD will support continued development of the ATLAST reference mission design, our detailed science priorities, and confirmation that our design achieves these priorities, in all cases sufficient to justify HQ-funded assessments and GSFC leadership of a high-priority candidate for the next Decadal Survey.

Nota Bene 1: As this is being written, NASA HQ's Astrophysics Division (APD) is developing plans to initiate a multi-year engineering design study of candidate major missions overseen by Science and Technology Definition Teams (STDTs). We have been told that, in a large part due to the successful work by our ATLAST team, GSFC will lead an engineering design team for a large-aperture UV/optical/IR (LUVOIR) observatory. This activity will begin in mid-FY16. *We are further informed that GSFC will be expected to contribute internal resources to this study to augment resources supplied by HQ.* There is significant uncertainty about the specific APD schedule, funding, guidelines, and structure of this activity, although we assume that GSFC leadership will agree to support the HQ assignment to the Center. Under these circumstances, we have in this proposal requested a full year of support. *We are fully prepared to return unnecessary and unused awarded IRAD resources once HQ has initiated the STDT and supporting engineering study activity.*

Nota Bene 2: This IRAD proposal primarily to support ATLAST science activities is a companion to that submitted by Matt Bolcar, which will support engineering activities and updating our technology plan. We divided the ATLAST funding request into two proposals (1) because of the page limitation to any single proposal and (2) for ease of reviewing two separable components of the Center's ATLAST effort. Bolcar's proposal is one of the routes that we are pursuing to seek Center support to augment HQ funding to study the concept next year.

2. Objectives: Concept Maturation of ATLAST/LUVOIR

Our eventual objective continues to be selection by the Decadal Survey as the highest-priority new space mission for the 2020s. Thanks to past IRAD and DR&T funding, our team has succeeded with our near-term goal of having GSFC selected by HQ to lead the detailed engineering design for LUVOIR beginning in mid-FY16.

Our objective for FY16 IRAD support is to substantially advance increasingly detailed science cases for the concept and position the Center to effectively use whatever resources HQ will contribute in mid-FY16. These science cases will flow down to the engineering reference design to affirm that the science goals can be achieved with this design. In addition, our multi-institutional (GSFC, JPL, STScI, MSFC) team will continue to develop and advocate to HQ the technology investment plan essential for directed and/or competitively

selected funding for priority technology areas that we identified in FY14/15. We will also broaden discussion with potential partners in the aerospace community and NASA programs that are interested in collaboration (e.g., the Space Launch System).

3. Justification: GSFC Leadership and the NRC 2020 Decadal Survey

Thanks to the past two years of support, an impressive engineering design for ATLAST, an increasingly detailed technology plan, and a powerful science case – all areas being led by GSFC – will lead to selection of LUVOIR/ATLAST by NASA HQ APD in late autumn as one of the few Flagship concepts to be studied further in advance of the 2020 NRC Decadal Survey.

It is critical for GSFC to demonstrate scientific and engineering leadership by continuing this design work, technology development, and science simulations up to the time of the establishment of the STDTs next calendar year. Moreover, we have been informed that the Center will be expected to contribute internal resources to support whatever HQ supplies next year for this activity. In addition to maintaining the Center's primacy in the design of large space optical systems, we are positioning GSFC to be the recipient of new FY16 technology funding, if available. Eventually, of course, the "big payoff" will be assignment after success in the next Decadal Survey of GSFC as the lead Center in development of the mission, just as has been the case with JWST.

Progress to Date

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 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 for FY16

1. ATLAST and the Search for Earth 2.0: Are We Alone? (Domagal-Goldman, Stapelfeldt, Roberge, Mandell, *et alia*)

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 ($\sim 4 \mu\text{m}$) planet transit spectroscopy with a room temperature telescope to search for diagnostic molecular lines that may be observable no other way.

2. ATLAST and “Cosmic Dawn” (Heap)

We will concentrate on developing the scientific and performance requirements of ATLAST for investigating “Cosmic Dawn.” Recent studies of primitive galaxies (including Heap’s) suggest that JWST will be challenged to obtain some important observations of this earliest epoch of the universe. The reasons include: (1) the metallicity of these galaxies is very low, so the metal lines are weak, requiring spectra having a S/N higher than JWST is predicted now to be capable of and (2) the search for Pop III stars through detection of He II 1640-A emission has gotten complicated by the fact that young, massive Pop II stars can also produce HeII emission in the stellar winds and/or surrounding nebulosity. This makes it necessary to understand the properties of the stellar population. We need the large aperture of ATLAST to obtain spectra of sufficient quality.

In coordination with our exoplanet colleagues, we will also produce realistic simulations of imagery, as well as spectroscopy, of habitable planets using different values of residual speckles and instrumental noise as well as exo-zodi brightness.

5. **Future Development and Funding Plan**

Our long-range goal for our team continues to be for the design to be selected for development and led by GSFC as a major new mission in the 2020s.

In the near term, we are actively seeking external support via three routes in FY16: (1) NASA SMD support for a Flagship concept study, (2) competitively selected proposals to SMD, and (3) targeted technology funding from, for example, STMD. In the case of #1, as noted above, we have been informed that SMD APD intends to support a GSFC-led multi-year engineering design study. In the case of #3, we continue to present our technology

development plan to SMD and STMD, as recently as last month (as invited by Deputy Associate Administrator Andrucyk, joined by Paul Hertz). Budget constraints are severe within STMD, although our presentations to both SMD and STMD are welcomed. For route #2, our team will have another coordinated round of proposals to SAT/APRA. This could include Lyon's Visible Nulling Coronagraph work under SAT/TDEM, detector and coating work under APRA, and structures and mirror work under SAT/COR. Our team members have been successful with these modest sources of funding in the past, although specifically what we will submit depends upon what is specifically asked for in the ROSES call.

Our team is producing an increasingly detailed technology roadmap for ATLAST, which has been supported largely by Bolcar's IRAD funding. Over the past year, our roadmap was significant input to the AURA study, to the technology roadmaps of the Exoplanet and Cosmic Origins Program Offices, and by invitation to NASA HQ STMD.

Partnerships: GSFC has been the lead institution for the two years (as of spring, 2015) of this study activity. We have worked closely and actively with partners at STScI, which has contributed significantly to the ATLAST science case, and with JPL and MSFC, primarily on reference mission design and technology planning and priorities.

6. Resources

6.1 Procurement

We are requesting \$10 K to upgrade and increase the detail of the ATLAST/LUVOIR visualization produced by the GSFC Science Visualization Studio. The current version of this visualization was highlighted at the evening keynote talk by Marc Postman at Hubble 2020: Celebration of 25 Years of HST (<https://webcast.stsci.edu/webcast/detail.xhtml?talkid=4566&parent=1>) This upgraded version will be part of special "splinter session" at the January 2016 AAS conference.

6.2 Civil Servant Time (FTE)

For Civil Service FTE support for science activities, 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 (Schnittman, Heap, plus two 690 colleagues we are currently in discussion with).

$$\text{FTE} = 2.7$$

7. Related Proposals

M. Bolcar: Advanced Technology Large Aperture Space Telescope (ATLAST): Optical Systems Engineering & Technology Development.