SLS Launched Missions Concept Studies for LUVOIR Mission

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ABSTRACT

NASA's "Enduring Quests Daring Visions" report calls for an 8- to 16-meter Large UV-Optical-IR (LUVOIR) Surveyor mission to enable ultra-high-contrast spectroscopy and coronagraphy. AURA's "From Cosmic Birth to Living Earth" report calls for a 12-meter class High-Definition Space Telescope to pursue transformational scientific discoveries. The multi-center ATLAST Team is working to meet these needs. The MSFC Team is examining potential concepts that leverage the advantages of the SLS (Space Launch System). A key challenge is how to affordably get a large telescope into space. The JWST design was severely constrained by the mass and volume capacities of its launch vehicle. This problem is solved by using an SLS Block II-B rocket with its 10-m diameter x 30-m tall fairing and 45 mt payload to SE-L2. Previously, two development study cycles produced a detailed concept called ATLAST-8. Using ATLAST-8 as a point of departure, this paper reports on a new ATLAST-12 concept. ATLAST-12 is a 12-meter class segmented aperture LUVOIR with an 8-m class center segment. Thus, ATLAST-8 is now a de-scope option.

Keywords: Large Space Telescopes, UV/Optical Space Telescopes, ATLAST, LUVOIR, Heavy Lift Launch Vehicle

1. INTRODUCTION

The 2010 *New Worlds, New Horizons* Decadal Report[1] recommended as its highest priority medium-scale activity a "New Worlds Technology Development Program" to "lay the technical and scientific foundations for a future space imaging and spectroscopy mission". NASA's *Enduring Quests Daring Visions*[2] called for an 8- to 16-meter Large UV-Optical-IR (LUVOIR) Surveyor mission to "enable ultra-high-contrast spectroscopic studies to directly measure oxygen, water vapor and other molecules in the atmospheres of exoEarths"; and, "decode the galaxy assembly histories through detailed archeology of their present structure." AURA's *From Cosmic Birth to Living Earths*[3] details the potential revolutionary science that could be accomplished with a 12-m class space telescope: from "directly finding habitable planets showing signs of life" to "producing transformational scientific advances in every area of astronomy and astrophysics from black hole physics to galaxy formation, from star and planet formation to the solar system." The proposed High-Definition Space Telescope (HDST) concept would achieve unprecedented angular and spectral resolution from the UV to Near-IR. The baseline concept is a 12-m serviceable observatory, diffraction limited at 500 nm, operating at Sun-Earth L2 (SE-L2) with a versatile instrument package to optimize its scientific yield. Finally, a LUVOIR surveyor concept will be studied in detail in preparation for the 2020 Decadal Survey.[4]

There are many potential LUVOIR architectures,[5-8] including several proposed by the 2008 ATLAST study. Continuing the ATLAST effort, we have assembled a multi-institutional team, with members from NASA's Goddard and Marshall Space Flight Centers, Jet Propulsion Laboratory, and Space Telescope Science Institute, to study candidate mission concepts for LUVOIR and HDST. This paper offers one potential design developed by the MSFC Team for a 12-m class mission that takes advantage of the mass and volume capacities of NASA's Space Launch System (SLS).

2. ATLAST

ALTAST started in 2007 with a MSFC mission concept study for a 6-m Ares-V launched telescope.[5-6] In 2008, NASA awarded the Space Telescope Science Institute and its NASA Center Partners (GSFC, JPL and MSFC) an Astrophysics Mission Concept Study called Advanced Technology Large-Aperture Space Telescope (ATLAST). The ATLAST final report[9] documents three potential mission concepts: ATLAST-8m (MSFC), ATLAST-9.2m (GSFC) and ATLAST-16m (JPL). ATLAST-8 is an 8-meter monolithic aperture UVOIR space observatory[10-16]. It has a dual foci optical design: narrow FOV Cassegrain focus for the coronagraph and UV spectrometer; and, wide FOV focus for an imager and multi-object spectrograph.[12-13] A key element of the ATLAST-8 concept was to take advantage of the Ares V's enormous mass (56 mt to SE-L2) and volume (10-meter fairing) capacity[17-18] to launch a 22 mt solid meniscus 8-meter diameter Zerodur mirror telescope to SE-L2. The MSFC ATLAST-8 Team included Goddard Space Flight Center (GSFC), Ball Aerospace Technology Corporation and Northrop Grumman. GSFC's ATLAST-9.2m was a 36-segment 9.2-meter telescope similar to JWST and designed to be launched in a 6.5-meter fairing on a modestly upgraded Delta-IV Heavy[19]. JPL's ATLAST-16 concept also required the Ares V.

In response to the 2010 Decadal recommendations we have continued the ATLAST effort to study mission concepts that are responsive to the *Enduring Quests Daring Visions* LUVOIR mission and the *From Cosmic Birth to Living Earths* HDST mission. Table 1 summaries the top-level telescope specifications derived from science requirements. The GSFC team has continued to refine ATLAST-9 and have produced ATLAST-9 and ATLAST-11 concepts that can be packaged inside of a standard Delta-IV Heavy launch vehicle[20]. Similarly, the MSFC team has updated and expanded its ATLAST-8 concept to produce a new ATLAST-12 concept. ATLAST-12 was developed as a direct response to the AURA report. ATLAST-8 is now a descope option. Both concepts are designed to fit inside of the planned Space Launch System (SLS) Block II-B. With its 10-m diameter x 30-m tall fairing and 45 mt payload to SE-L2, SLS allows considerable design margin flexibility.

Table 1: Telescope Specification flow-down from Science Requirements

Parameter		**Requirement**	**Stretch Goal**	**Traceability**
Primary Mirror Aperture		≥ 8 meters	12 meters	Resolution, Sensitivity, Exoplanet Yield
Telescope Temperature		273 K – 293 K	-	Thermal Stability, Integration & Test, Contamination, IR Sensitivity
Wavelength Coverage	UV	100 nm – 300 nm	90 nm – 300 nm	-
	Visible	300 nm – 950 nm	-	-
	NIR	950 nm – 1.8 μm	950 nm – 2.5 μm	-
	MIR	-	~ 5.0 μm	Transit Spectroscopy
Image Quality	UV	< 0.20 arcsec at 150 nm	-	-
	Vis/NIR/MIR	500 nm Diffraction-limited	-	-
Stray Light		Zodi-limited between 400 nm – 1.8 μm	Zodi-limited between 200 nm – 2.5 μm	Exoplanet Imaging & Spectroscopy SNR
Wavefront Error Stability		~ 10 pm RMS uncorrected system WFE per control step	-	Starlight Suppression via Internal Coronagraph
Pointing	Spacecraft	≤ 1 milli-arcsec	-	-
	Coronagraph	< 0.4 milli-arcsec	-	-

The purpose of the ATLAST Engineering Design Reference Missions (EDRMs) are to provide a basis for deriving a validated set of mission requirements from the science objectives and top level science requirements. The EDRMs allow the engineering design trade space to be explored in depth and determination in detail where the stressing requirements are and where there are opportunities for margin against requirements. The EDRMs provide access to a rich trade space where implementations and requirements can be analyzed and evaluated against each other to formulate the most effective, well balanced, and lowest risk designs. Two of the key words in "Engineering Design Reference Mission" are "reference" and "design". The EDRMs are not the final mission design. The EDRMs are conceptual designs used for deriving and validating requirements and identifying implementation technology gaps which need development.

3. DESIGN FOR AFFORDABILITY – COMPLEXITY VERSUS COST

There are many different potential architectures for a large UVOIR space telescope; but, they are all limited by the same logistical constraints of launch vehicle mass and volume capacities and authorized budget. It is the fundamental premise of the MSFC team that complexity drives cost. And, that the best way to reduce complexity and lower mission cost is to use a launch vehicle with a large payload mass and volume capacity. Having a large payload volume capacity allows for a simpler mission concept. Having a large payload mass capacity allows for increased design margins which makes ground handling and launch survival easier. And, having more mass and volume allows for a stiffer telescope with more stable on-orbit performance.

Our commitment to simplicity is based on lessons learned from JWST and the analysis of David Beardon. Beardon[21-22] has shown that there is a direct correlation between mission payload complexity and total mission cost; and, between complexity and cost and schedule growth. Also, the greatest predictor of mission success is technology maturity. The reason for these relationships is because the only way to achieve increasingly demanding performance requirements in a mass and volume constrained launch vehicle is to design increasingly complex mission payload architectures. Consider for example how JWST's cost was driven by the complexity needed to package a 6.5 meter telescope inside a 4.5 meter fairing with a 6500 kg mass capacity. The JWST Independent Comprehensive Review Panel found that JWST is "one of the most complex science missions carried out to date and therefore falls at the high end of the range, greater than 90%, on the complexity index. JWST is consistent with being "in family" for an LCC around $6 billion–$7 billion"[23] (Figure 1). This cost versus complexity relationship is also evident in the NASA Advanced Mission Cost Model[24] (Figure 2) which is typically used to justify (possibly incorrectly) that mass is the dominant mission cost driver. A closer look at the model indicates that Difficulty Level may be a larger cost driver than mass.

Given the available mass and volume capacity of the SLS, designers can use simpler more-mature (and massive) technologies or higher design rule margins to eliminate complexity, lower risk and lower cost. By using mature technology, projects will save money on sub-system acquisition as well as engineering labor and management overhead. Because of program overhead and 'wrap', a savings of $500M in component cost might reduce total program cost by $1.5B to $2.5B. And, while potential cost savings from relaxing the mass constraint is difficult to quantify, anecdotal evidence suggests that early in a mass constrained mission, it may cost $100K of design effort to eliminate 1 kg of mass; while once the design is mature, it may cost as much as $1M to eliminate 1 kg of mass.

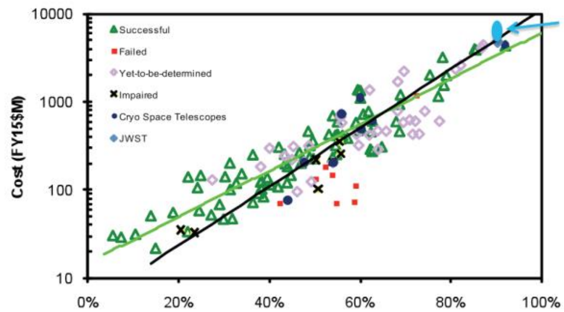

Figure 1: JWST on the Aerospace Complexity Index[23]

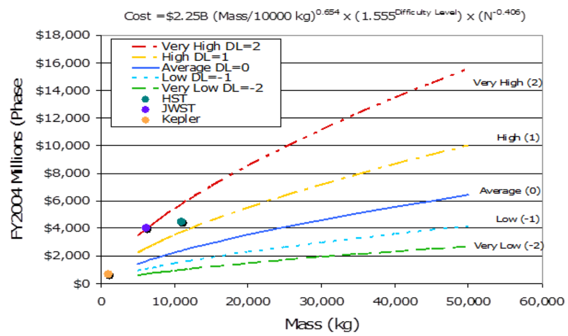

Figure 2: NASA Advanced Mission Cost Model[24]

4. NASA'S SPACE LAUNCH SYSTEM (SLS)

In 2005 NASA's Constellation program initiated the Ares V Cargo Launch Vehicle. The Ares V (baseline 51.01.48) was projected to have the ability to launch 65 mt payload into a Sun-Earth Lagrange point (SE-L2) transfer orbit (with a C3 = -0.7 km2/s2), inside of a 10 meter diameter by 23 meter tall fairing. This shroud had a dynamic envelope of 8.8 meter diameter by 17.2 meter tall, and a payload volume of 860 cubic meters.[25] In September 2011, the Ares V program was cancelled and replaced by the Space Launch System (SLS) program. The SLS program is conducting a phased development effort. Figure 3 summaries the key features of the SLS launch capacities. Block I (scheduled for 2018) will have a 5-m 'commercial' fairing and provide 25 mt to SE-L2. Block IB (2024) will have an 8.4-m 'short' fairing and provide 35 mt to SE-L2. Block II (2026) will have an 8.4-m 'long' fairing and an additional booster segment to provide ~45 mt to SE-L2. Finally, Block IIB (2028) will have a 10-m fairing with a 9.1-m dynamic envelope. While the Block IIB has the same diameter as the Ares V, it will be much longer. At 31.1 meters the Block IIB fairing provides 1600 m3 of payload volume. The longer fairing slightly reduces the mass which can be delivered to SE-L2 to ~45 mt (but a planned advanced booster and composite fairing shell enhancements are expected to raise this mass to ~55 mt). For the ATLAST-12 study we assume an SLS Block-IIB (scheduled for 2028) with a 10-m fairing (9.1-m dynamic envelop diameter) and 45 mt mass capacity to SE-L2.

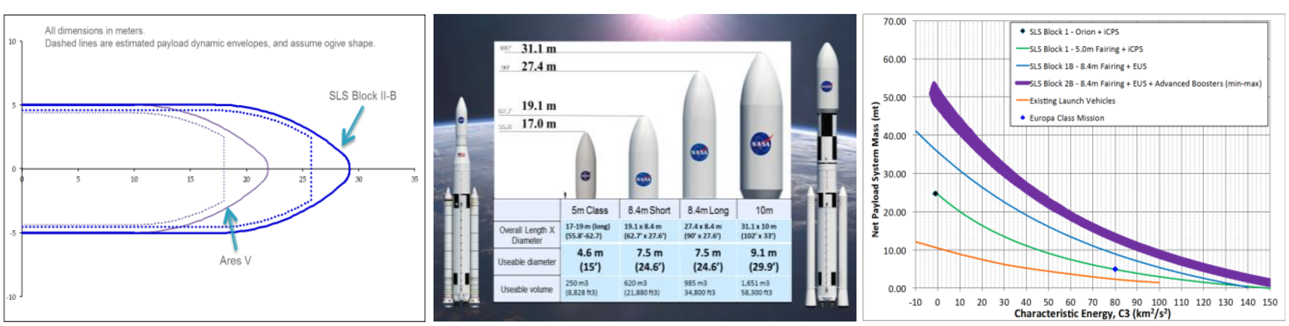

Figure 3: Planned SLS Block II-B Payload Fairing Volume and Mass Capacity

5. MASS BUDGET

Table 2: Mass Budget for SLS Block-IIB	
Capacity [kg]	Margin
46,300	0%
40,260	- 15% Launch Vehicle Margin
35,630	- 13% Propellant 'wet' Mass
27,400	- 30% Dry Mass Reserve

Independent of architecture, what is possible for a potential large ATLAST mission is completely dependent on the mass and volume capacity of the launch vehicle. The SLS Block II-B has a planned up-mass capacity to SE-L2 of between 45 and 55 mt (depending upon booster capabilities and whether the fairing is aluminum of composite). To be conservative, the MSFC design team is assuming the lower mass capacity estimate of 46,300 kg. As summarized in Table 2, after taking into account a 15% launch vehicle reserve, propellant and a 30% payload mass margin, any potential mission (independent of its architecture) is allocated a total dry mass budget of ~27 mt and a total wet mass budget of ~35 mt.

For ATLAST-12, we start with ATLAST-8. In 2009, ATLAST-8 was specifically designed to take advantage of the planned Ares V. The Ares V vehicle (baseline 51.01.48) was projected to have the ability to launch ~65,000 kg payload into a Sun-Earth Lagrange point (SE-L2) transfer orbit (with a C3 = -0.7 km2/s2), inside of a 10 meter diameter by 21.7 meter tall fairing with an 8.8 m diameter and 17.2 m tall dynamic envelop. The ATLAST-8 observatory (telescope, science instruments and spacecraft) had an estimated dry mass of ~50,000 kg with a 45% margin against the Ares V 65,000 kg capacity. As summarized in Table 3, this mass budget allocated 38,000 kg to the telescope, 2,000 kg for the science instruments and 5,000 for the spacecraft. Additionally, there was 5,000 kg for propellant. The single most massive item was the 22,000 kg solid meniscus Zerodur primary mirror.

As shown in Table 3, for ATLAST-12, we assume the exact same mass as ATLAST-8 for the Science Instruments and Spacecraft. We reduce the propellant mass by 1000 kg because the total observatory mass is smaller. And, we allocate the remaining mass to the telescope assembly. The resulting ATLAST-12 dry mass estimate is 27.6 mt (36 mt with 30% reserve) and wet mass estimate is 32 mt (40.6 mt with 30% reserve).

Table 3: Mass Budget for ATLAST-8 on Ares V and ATLAST-12 on SLS

-	Ares V ATLAST mass [kg]	SLS ATLAST mass [kg]
TOTAL OBSERVATORY WET MASS	50,449	32,310
TOTAL OBSERVATORY DRY MASS		27,644
Optical Tube Enclosure (OTE)	38,417	21,658
Primary mirror assembly	29,800	12,738
Primary mirror	22000	8500
Primary mirror support truss	4000	4000
Primary mirror flexures	-	6
Launch lock mechanisms	3500	132
Primary mirror central baffle	300	100
Secondary mirror assembly	1,050	637
Aft Optics	2,167	1,481
Structure	5,400	5,350
Active Thermal Control	-	1,452
Science Instruments	1,789	1,789
Spacecraft Bus	4,577	4,197
Attitude Control System	312	499
Command And Data Handling (C&DH)	120	140
Instrumentation and Monitoring	212	0
Communications	114	114
Power Subsystems	1104	1,104
Thermal Management System	974	554
Structures	1300	1,345
Propulsion	401	401
Docking	40	40
Propellant allocation	5,666	4,666

6. PRIMARY MIRROR ASSEMBLY

In both the original ATLAST-8 and the new ATLAST-12 concepts, the primary mirror assembly is the single most important design feature. In the 2009 ATLAST-8 design, the primary mirror assembly had an allocated mass of 30 mt with no margin. In the new ATLAST-12 design, the primary mirror assembly has an allocation of 12.5 mt with 30% margin. Using this budget, it is possible to calculate a mass constrained aperture diameter based on the areal density state of the art for manufacturing optical telescope. The lower end of the state of the art is defined by JWST whose primary mirror segments have an areal density of 30 kg/m^2. The upper end is defined by the Thirty Mirror Telescope project whose prototype mirror segments have an areal density of 250 kg/m^2. And, the Advanced Mirror Technology Development (AMTD) project is developing technology to make 4-meter class and larger mirrors with an areal density of 50 to 75 kg/m^2.[26-27] Table 4 calculates the maximum primary mirror aperture diameter which can be fabricated for a range of potential mirror substrate areal densities. An important observation is that by using the SLS Block IIB mass capacity, the *Cosmic Origin to Living Earths* 12-meter aperture desire can be easily achieved using existing technology with low cost and schedule risk.

Table 4: Aperture as a function of Areal Density for 8,500 kg mass budget

Areal Density [kg/m^2]	Primary Mirror	
	Area [m^2]	Diameter [m]
30	280	19.0
50	170	14.7
75	110	12.0
100	85	10.4
250	50	6.6

For the ATLAST-12 study, the team was instructed to determine the largest primary mirror that could be packaged inside the SLS Block IIB fairing using a center core surrounded by a single ring of petal segments architecture. This segmentation architecture was specified for five reasons: 1) It provides a cleaner and potentially more coronagraph friendly point spread function (PSF) than a hexagonal segmented aperture (Figure 4).[28] 2) The wavefront stability requirements are more relaxed for an architecture with a central core element surrounded by a single ring of segments whose size is smaller than the central core radius than for a hexagonal segmentation architecture with multiple rings of equal size segments.[29] 3) Unless there is an existing manufacturing facility to mass produce hexagonal segments (i.e. for TMT), it is more cost effective to manufacture multiple copies of a single petal than 3 or more different hexagonal prescription. 4) Having the large central core provides a simple descope path. And 5) other members of the ATLAST team were investigating hexagonal segmentation. Additionally, the team was constrained to segments which could be fabricated from commercially available 2.4 m or 4 m mirror blanks. The result (Figure 5) is a 12.7 m diameter primary mirror architecture composed of an 8-m center core surrounded by twelve 2.35 m tall by 3.3 m arc length segments. To fit inside the 9.1 m dynamic envelope of the SLS Block IIB fairing, a fold-forward/fold-aft deployment was selected.

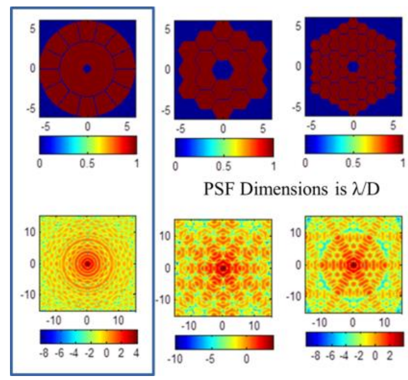

Figure 4: Segmented Aperture PSF

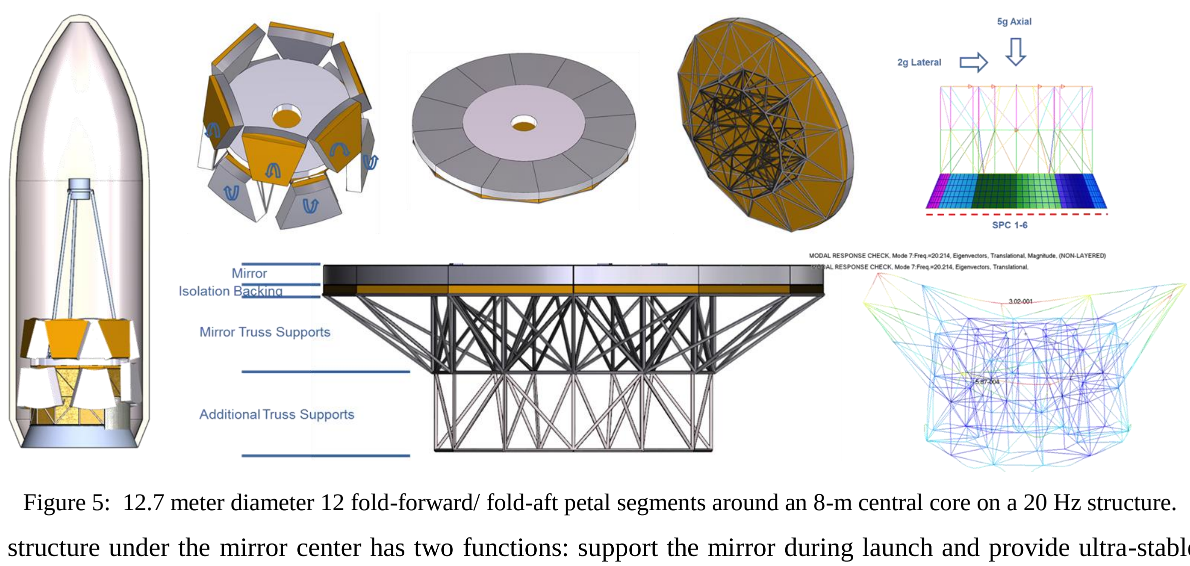

Figure 5: 12.7 meter diameter 12 fold-forward/ fold-aft petal segments around an 8-m central core on a 20 Hz structure.

The structure under the mirror center has two functions: support the mirror during launch and provide ultra-stable on-orbit optical performance. Given that exoplanet science is a primary mission of this telescope, it is necessary for the telescope's on-orbit wavefront to be stable on the order of 10 picometers per 10 minutes.[28-29] Since the JWST structure has a 13 Hz first mode and because preliminary analysis indicates that it might be possible to achieve the required wavefront stability using an enhanced JWST structure and next generation isolation system[30], the team was instructed to design a 20 Hz first mode structure (Figure 5 lower right image). And, as shown in the upper right image of Figure 5, to survive launch (according to NASA Standard 5001A and anticipated SLS launch loads), the structure was designed to support 5g axial and 2g lateral loads with a 1.4 ultimate safety factor. The structure is constrained at the bottom by the payload adaptor fixture (PAF) which connects the payload to the SLS and has a mass of 320 kg. Finally, the primary mirror structure has an estimated mass (before 30% contingency) of 4036 kg. The structure mass is driven by the 20 Hz requirement and not launch survival.

7. MISSION CONCEPT

The 2009 ATLAST Mission Concept Study developed a detailed design for an 8-m monolithic observatory. Specific studies included: optical design; structural design/analysis including primary mirror support structure, sun shade and secondary mirror support structure; thermal analysis; spacecraft conceptual design including structure, propulsion, GN&C, avionics, thermal and power systems; mass and power budgets; and system cost.[9] The 2015 ATLAST-12 mission concept team produced updated studies for: structural design/analysis including primary mirror support structure, sun shade and secondary mirror support structure; thermal control analysis; spacecraft conceptual design including structure, propulsion, GN&C, data communication, avionics, thermal and power systems; docking and servicing; mass and power budgets; and system cost (note: we are not publishing the cost estimate).

ATLAST-12 is envisioned as 30 year (or longer) lifetime observatory at SE-L2. We assumed the JWST orbit because it has the advantage of not requiring an insertion maneuver at SE-L2. Once at SE-L2 the spacecraft only has to begin station keeping. Lifetime can be achieved either by redundancy or servicing. We expect the observatory to be serviced using modular on-orbit replaceable units. The observatory will carry sufficient propellant to either stay at SE-L2 for 30 years, or to bring itself back from SE-L2 to EM-L2 for servicing. We assume an average servicing interval of 5 year and a maximum servicing interval of 10 years (Table 5). Reaction wheels are sized to slew the observatory 60 degrees in 180 minutes and roll the observatory around its line of sight +/- 30 degrees in 30 minutes. The spacecraft is designed to provide 1 arc pitch/yaw/roll accuracy and 1.6 mas stability. The observatory uses body pointing for coarse alignment and fine steering mirrors for the precision alignment. Finally, our unique momentum management system allows the observatory up to 3000 minutes of continuous observation. Analysis indicates that only 7 m/s delta-v is needed per year for station keeping and momentum unloading. Given the 6-month period of the halo orbit and the 45-degree keep-out angle between the telescope's line of sight and the sun, the telescope can see the entire sky in approximately six months. As an example of a spacecraft design study, we estimate an end of life power budget of 13kW.

	dV		
Manuever	**No Servicing, 30-year mission**	**5 Year Servicing (@EML1/L2)**	**Per Year at SEL2, no servicing**
Launch Correction	52.0 m/s	52.0 m/s	-
Mid-Course Correction	10.0 m/s	10.0 m/s	-
Station Keeping (SEL2)	208.8 m/s	34.8 m/s	7.0 m/s
Station Keeping (EML2, ~6 months)	-	52.8 m/s	-
Momentum Unloading	35.4 m/s	5.9 m/s	1.2 m/s
Transfer from SE L2	-	50.0 m/s	-
Transfer to SE L2	-	50.0 m/s	-
Margin	-6.2 m/s	44.5 m/s	
Margin (%)	-2%	15%	
Total	**300.0 m/s**	**300.0 m/s**	**8.14 m/s**

Table 5: dV Propellant Budget

System	Full Power	Maintenance Mode
Thermal	4040	4080
C&DH	240	240
Comm	128	128
Propulsion	220	220
ACS	1256	1256
Science	3500	0
Instrumentation	620	620
Totals	10004	6544
With 30% Margin	**13005**	**8507**

Table 6: Power Budget

Similar to ATLAST-8, ATLAST-12 has a scarfed Kepler style forward baffle tube (Figure 6). For packaging reasons, the scarf is at 45 degrees. It is deployed on orbit using 40 ATK booms which have already successfully flown on NuSTAR. The tube has sufficient insulation for the telescope to passively reach 200K for infrared operation. For UV/Optical operation, zonal heaters in the baffle tube and around the primary mirror and secondary mirrors heat the optical surfaces to above 0C (to prevent ice or frost). The primary mirror assembly requires an R-θ heater system to compensate for sky view factor induced power and lateral solar load. Finally, active thermal sense and control keeps the telescope at a constant temperature regardless of where it points on the sky. As the observatory slews or rolls, sensors monitor the change in solar thermal load and adjust the zonal heaters to compensate for the change.

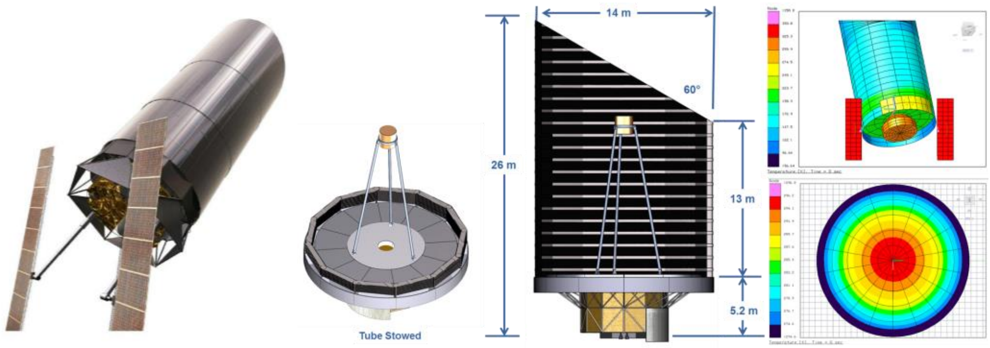

Fig 6: ATLAST-12 has a heated scarfed forward baffle tube for straylight control and thermally stable wavefront error.

The most important technical challenge for the spacecraft is to body point the observatory with a stability of < 1 mas for a period of up to 3000 minutes without interruption. Pointing stability is required to enable exoplanet and UV science. Exoplanet science requires stability to minimize contrast leakage. UV science requires stability to maximize throughput, telescope pointing places the science object of interest directly onto the entrance slit of the UV spectrograph, i.e. without the aid of a fine steering mirror. Pointing duration is required to enable faint object science.

Pointing is accomplished via the attitude control system (ACS). The main ACS components include the Fine Guidance Sensor (FGS); a coarse pointing system on the spacecraft that includes gyros, star-trackers, reaction wheel assemblies (RWA), and/or control moment gyros (CMG); a propulsion system that provides attitude control and momentum unloading; and Active Vibration Isolation (AVI) System between the spacecraft and observatory. Star Trackers command the telescope bore-sight pointed to within a few arc-sec of the desired target. The active isolation system then engages using feedback to minimize the apparent motion of the guide star centroid for the duration of that science exposure. Thrusters provide the means to unload momentum periodically. The AVI system eliminates jitter to achieve < 1 mas pointing stability. There are two potential approaches for the active vibration isolation system, Lockheed's disturbance free payload[31] and Northrop's active strut technologies. Active isolation has two roles. First, it isolates the science payload from spacecraft disturbances, such as vibrations from the RWA. Second, it provides fine pointing control for the science payload, which requires a pointing stability of < 1 mas. During a science observation, sensors continuously monitor the active isolation system and command the reaction wheels, changing the orientation of the spacecraft to keep the AVI actuators at or near their center of travel. This feedback loop between FGS, AVI system, and RWAs continues until the end of the science observation. To enable up to 3000 minutes of continuous observing time, the reaction wheels must be sized to provide the necessary momentum storage capability. The problem is that ATLAST-12 is very large and solar pressure on the baffle tube during observation could quickly saturate the reaction wheels. To compensate, ATLAST-12 uses two solar panels, each with a solar pressure kite, on 10 m deployable booms to balance solar pressure exerted on the tube. As the observatory slews relative to the sun, the solar panel booms extend and rotate to keep the center of pressure as close as possible to the center of mass (Figures 7). The required area of the solar pressure kites depends on the length of the boom (Figure 8).

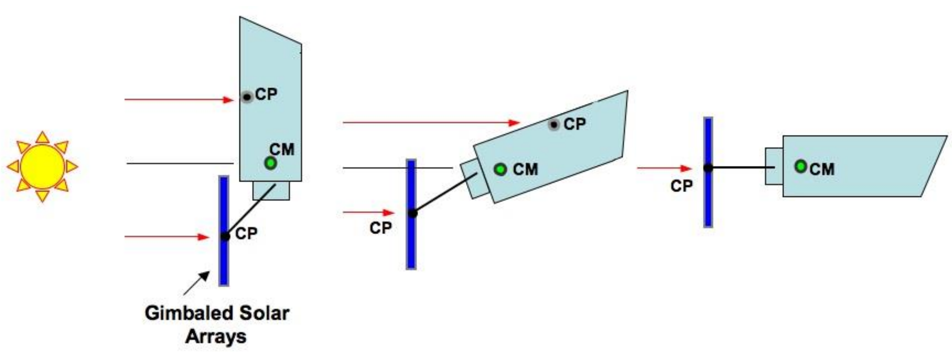

Figure 7: Solar Torque / Momentum Build-Up Mitigation Scheme for ATLAST-12

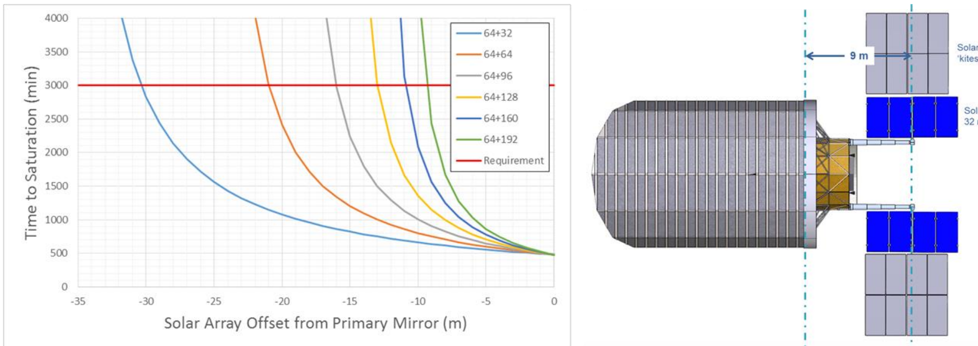

Figure 8: Required Area of Solar Pressure Kites depends on the boom length.

8. CONCLUSION

The ATLAST Study has developed a preliminary point design for a 12.7 meter segmented aperture UVOIR space telescope called ATLAST-12. The mission concept is specifically designed to take advantage of the mass and volume capabilities of NASA's SLS Block IIB heavy lift launch vehicle. The fundamental design paradigm for ATLAST-12 is simplicity. Simple high TRL technology offers lower cost and risk. The capacities of heavy lift launch vehicles allow one to use mass to buy down performance, cost and schedule risk. The segmented aperture architecture of a single ring of petals around a central core was specifically chosen for its potentially coronagraph friendly point spread function, relaxed stability requirements, easier manufacturing flow and descope potential. A baffle tube with active zonal thermal sense and control was selected to keep the telescope at a constant temperature independent of where it points on the sky. Finally, an adjustable solar pressure kite system in combination with active vibration isolation allows the observatory to point with < 1 mas stability for up to 3000 minutes without interruption.

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