Origins Space Telescope (OST) Study Status and Plan

("Pause and Learn" October 2016)

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Topics

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Study Status

- The OST Science Technology and Development Team (STDT) has 19 members
  - Community Chairs are Margaret Meixner/STScI and Asantha Cooray/U.of CA at Irvine
- The OST Study Office is at GSFC
  - Study Scientist: Dave Leisawitz/GSFC
  - Study Manager: Ruth Chiang Carter/GSFC
- Held two Face-to-Face (F2F) meetings: May and August this year
  - STDT selected single aperture mission architecture concept at the August F2F meeting
- Next F2F meeting will be held in November 2016
  - Continue to refine science and mission traceability requirements and select instruments
- Identified potential enabling technologies in June 2016
  - Details (e.g., detector NEP and pixel count) will be refined as the design study progresses
- Team is exploring mission trade spaces

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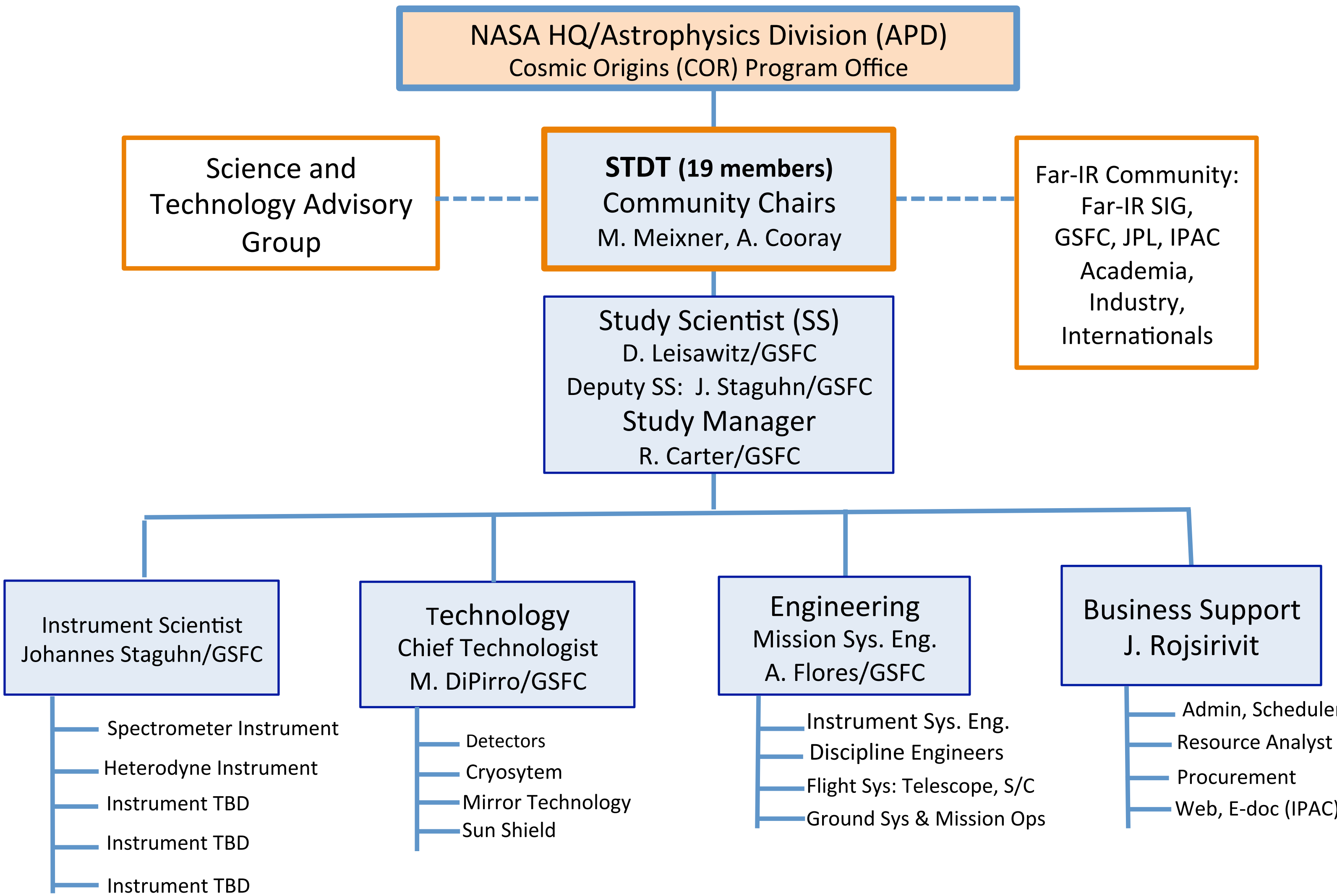
Study Organization



GSFC Study Office

- Study Office Management
  - Study Scientist: D. Leisawitz
    - Deputy Study Scientist/Instrument Scientist: J. Staguhn
  - Study Manager: R. Carter
- Core engineering team has been formed:
  - Mission Systems Engineer: Anel Flores/599
  - Instrument Systems Engineer: Jim Kellogg/592
  - Chief Technologist: Mike DiPirro/552
  - Mechanical Designer: Andrew Jones/543
  - Thermal Systems: Lou Fantano/545
  - Optical Design: Joe Howard/551, James Corsetti/551
  - Cryo Systems: Ed Canavan/552
- Additional discipline engineers will be added to the team in calendar year 2017 as needed
- GSFC Code 400 provides admin and resource support

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Study Office and STDT Interface

- Science and Technology Definition Team (STDT) conducts bi-weekly telecons
  - Study office, including its key engineers, participates in the bi-weekly full STDT telecons
- OST Mission Concept Working Group (MCWG) has been formed and it holds weekly telecons
  - The MCWG members include both STDT members and GSFC engineers
  - The MCWG is a vehicle to review and identify areas of improvement in requirements and mission design trades such as on-axis vs. off-axis telescope design concept
- Study Scientist and Deputy Study Scientist serve as points of contact for GSFC engineering team for science requirement interpretation and potential mission implementation options
  - Specifically, Deputy Study Scientist serves as Instrument Scientist. Thus, he provides critical role of reviewing proposed instrument requirements for implementation.

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OST Architecture

- The choice: Single Aperture Telescope or Interferometer
- The process:
  - STDT organized into five Science Working Groups, each with one or two leaders
  - Science use cases for a large far-IR space observatory were developed in collaboration with the science community
    - Aimed for visionary goals that will persist into the 2030s, until a far-IR observatory flies; the team considered contributions from other major facilities and unique potential capabilities (within established boundaries) of a far-IR observatory
    - Outreach and a welcoming study environment led to strong community participation, expert advice even when not present in the STDT
    - 32 use cases developed and documented, with measurement requirements
  - Using blind ballot, STDT members ranked use cases for perceived importance to the 2020 Decadal Survey
    - 14 top-ranked use cases emerged as mission drivers
    - All others will be retained and given further consideration
- The top-ranked science requires spectroscopic measurements and superlative sensitivity, but does not require that the far-IR observatory spatially resolve the objects of interest, the domain most accessible with interferometry.
- Accordingly, the STDT unanimously chose a Single Aperture Telescope architecture.

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Science Themes

Tracing the Signatures of Life and the Ingredients of Habitable Worlds

Origins will trace the trail of water through the stages of star and planet formation, to Earth itself and other planetary systems, while also characterizing water and greenhouse gases in potentially habitable worlds.

Unveiling the Growth of Black Holes and Galaxies over Cosmic Time

Origins will reveal the co-evolution of super-massive black holes and galaxies, energetic feedback, and the dynamic interstellar medium from which stars are born.

Origins will trace the metal enrichment history of the Universe, probe the first cosmic sources of dust, the earliest star formation, and the birth of galaxies.

Charting the Rise of Metals, Dust, and the First Galaxies

Origins will chart the role of comets in delivering water to the early Earth, and survey thousands of ancient Trans Neptunian Objects at distances greater than 100 AU and down to sizes of less than 10 km.

Characterizing Small Bodies in the Solar System

Science Requirements

Example: top ranked science case *"The Rise of Metals"*

OST Science Case Number/Title Theme	OST Science Theme NASA Science Goal Decadal Science Goal	Science Objectives	Science Requirements		Instrument Requirements		
			Science Observable	Measurement Requirement	Technical Parameter	Technical Requirement	Instrument(s)
19, Rise of Metals, Dust, and the First Galaxies Trace the dust and metal enrichment history of the early Universe. Find the first cosmic sources of dust, and search for evidence of the very earliest stellar populations forming in pristine environments.	***OST-2:*** *(Charting the) Rise of Metals, Dust, and the First Galaxies* ***NASA-2:*** *How did we get here?* ***Decadal-1:*** *Cosmic Dawn*	Trace the rise of metals and (a) determine the evolution in metallicity from z=1 to z=3 to 0.1 dex down to $10^{11}L_{sun}$; (b) determine the cosmic metal abundance Ωmetals from z=0 to z=8 to 0.1 dex accuracy in 8 redshift bins; and (c) measure the multiple phases of the ISM to infer the physical phenomena that regulate SF efficiency at the peak of cosmic star formation at z=1-3.	z=1-3 relative metallicity tracer: [NeII]12.8, [NeIII]15.6, [SIII]18.7, [SIV]10.5; z=0-8 relative metallicity tracer: [OIII] 52+88 µm, [NIII] 57 µm ; cooling and heating of the ISM through [OI], [OIII], [NII], [CII]. A multi-tiered survey, with a wide tier of ~10 deg^2, with sensitivity down to $10^{11}L_{sun}$ galaxies at z=3 and $10^{12}L_{sun}$ galaxies at z=8. Aim is a sample with >10000 galaxies with IR luminosity $>10^{11}L_{sun}$ at z=1-3	Rest-frame mid and far-IR spectral mapping to select z=0 to 8 galaxies	Wavelength range	20-800 µm	incoherent spectrometer, low res mode
				Identify galaxies in a tiered spectral mapping survey	Spatial resolution	5 arcsec at 200 µm (min. 9 m Telescope)	
				Measure line flux densities of identified galaxies	Spectral line sensitivity	1e-21W m-2 (driven by the MIR lines)	
					Spectral Resolving power	λ/Δλ = 500	
					survey area, instan-taneous FOV, FoR	10 deg^2	
					Mapping Speed		

Candidate Science Instruments

- Incoherent spectrometers
  - Low (R ~ 100), medium (1000s to 10^4), high (10^5 or greater) resolution
  - Spanning 9 to 800 μm wavelength range
- Heterodyne spectrometer to provide spectral resolving power $R > 5 \times 10^6$ in selected wavelength bands
- Continuum imaging and polarimetry
- Coronagraph

Engagement with Other STDTs

- Engagement on exo-planets with HabEx/LUVOIR through Exoplanet Standard Definition Team (ExSDET)
- Internal Study Center consultations with LUVOIR Study Office at GSFC – on procedures, initial point designs, industry engagement approach & etc.
- Community Chairs engagement with other Chairs

Overall Study Plan

- The OST Decadal Study Plan is supported by HQ funding augmented by Goddard Center funding
  - HQ funding alone is insufficient to develop a mission concept that can demonstrate a scientifically compelling and executable mission beginning in the mid-2020's for launch in mid-2030's
  - Goddard Center management is supporting the OST engineering team at GSFC
  - OST management team is actively seeking external contributions
- The Goddard OST engineering team, in collaboration with the GSFC Integrated Design Center (IDC), will develop a Design Reference Mission (DRM) concept for the OST Decadal Mission
- The Goddard engineering team will generate design studies for the following:
  - Telescope
  - 2 Instruments and Instrument Accommodation Module
  - End-to-end Mission Design
- For additional instruments, OST Decadal Mission study will rely on instrument design study contributions from external organizations

Study Contribution Status

- JPL has signed up to provide a spectrometer instrument study and collaborate in the mirror design
- MSFC is providing mirror material study
- IPAC contribution: communication tool and outreach
- Europe is considering to provide a heterodyne instrument study
  - European team has submitted funding request to CNES
- Canadian Space Agency (CSA) and JAXA have expressed interest in contributing to study
- JAXA is considering Mid-IR Coronagraph Instrument contribution and contributions to cryo-system

External Community Involvement

- Informal discussions with industry
  - Industry represented in our STDT through advisory panel/review board. Attendance at face-to-face meetings.
- We do not have a formal process to engage with the industry and get their contributions to the study.
  - Would be valuable for four study centers to share information on how to partner with industry.
  - Need guidance on which mechanism to implement in order to obtain formal contributions to studies.
  - Are the study centers under any obligation to advertise a partnership opportunity with industry?

External Community Involvement - Contd.

- Jan 2017 AAS plans: 2-hour joint splinter session on OST with Far-IR SIG/CoPAG. Chairs will give talks during joint PAG & NASA Special sessions.
  - STDT represented at COR exhibit booth, hyper-wall talks. Publicity materials: flyer etc.
- STDT engaging community through seminars, conferences, online forms (Google hangouts), talks to industry etc.
- We Plan to engage the general public in future (when we have an initial design). We are aiming to build a general-interest public website.
- We have seven ex-officios from foreign space agencies. Discussions and plans made for an instrument study in Europe (CNES) and possible contributions from other agencies (CSA/JAXA).

OST Mission Design Flow (FY17 only) - notional

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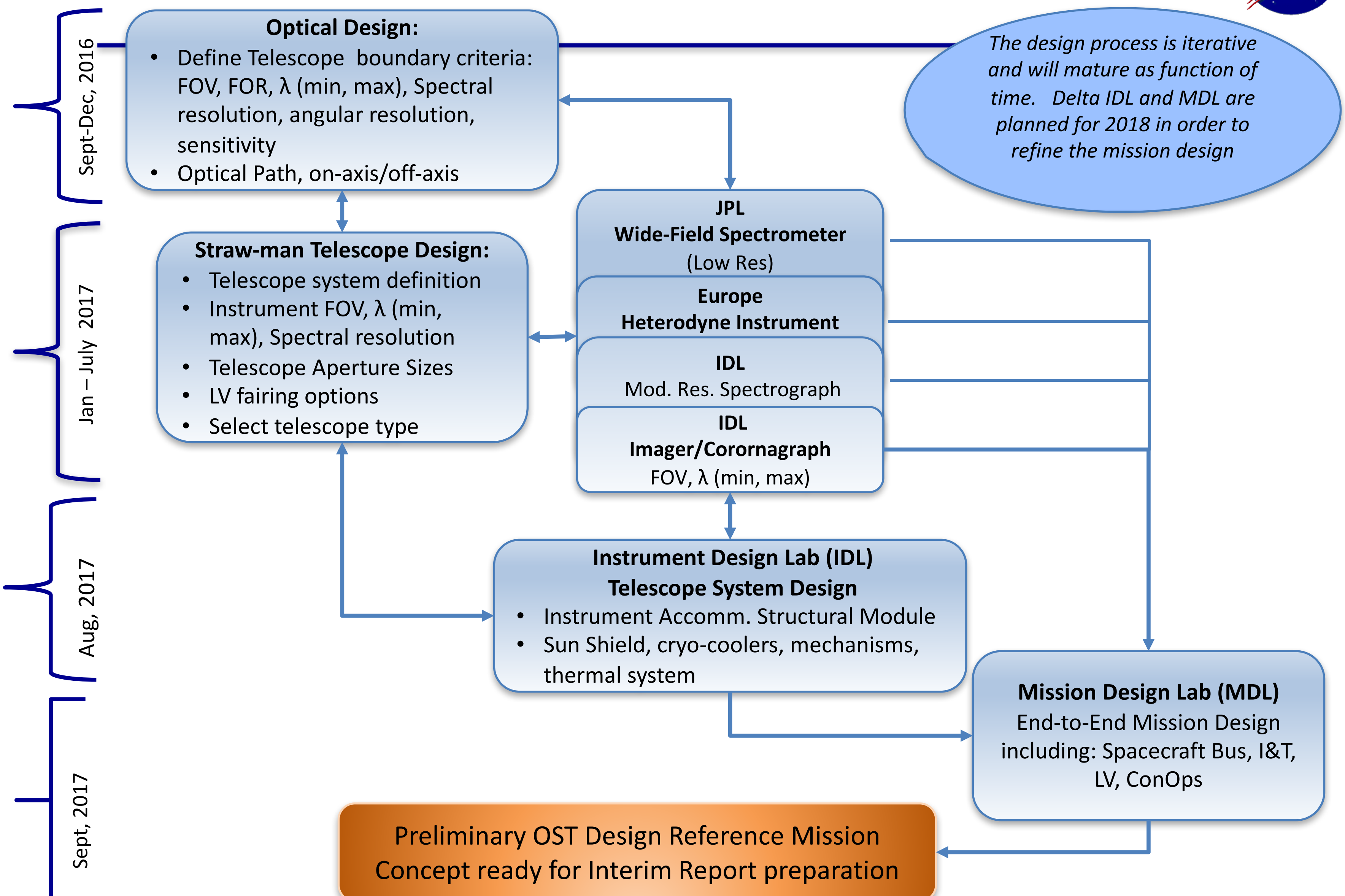

Fiscal Year 2017 Tasks

- Continue the development and refinement of science requirements
- Develop mission and instrument requirements, including interface requirements (S/C to Instruments, Telescope): Develop and implement requirements tracking process
- Finalize the type and number of instruments prior to the beginning of the IDC studies
- Determine telescope size, optical configuration, cooling approach, and sun-shield concept
- Update technology gap assessments and submit to HQ
- Develop a preliminary mission design concept by the end of fiscal year 2017 (9/30/17) to allow time to prepare and submit interim report to HQ in early December 2017
  - Mission design elements are 4 or 5 instruments, instrument accommodation module (concept similar to JWST's ISIM), telescope, sun shield, cryo-cooler, spacecraft, launch vehicle options, and mission operations concept
- Engage Goddard Integrated Design Center (IDC) for preliminary mission design
  - Four Instrument Design Lab (IDL) sessions are planned:
    - 2 instruments, telescope and the instrument accommodation module including instrument-to-telescope and instrument-to-spacecraft bus interfaces
  - One Mission Design Lab (MDL) session is planned for developing a preliminary end-to-end mission concept design, including launch vehicle options
    - Estimate end-to-end mission cost
- Start Identifying risk items and developing risk mitigation strategies

Fiscal Year 2018 Tasks

- Conduct an Independent Technical Review (ITR) of the preliminary OST DRM prior to submitting the interim report
  - The technical review of the DRM will include instruments, instrument accommodation module, telescope, cryo-system, sun-shield, spacecraft bus, and overall mission operations and concept
- Address ITR comments and incorporate relevant comments into the DRM
- Prepare and submit the Interim Report to HQ
- Prepare and present OST mission concept design at the 2018 winter American Astronomical Society (AAS) meeting
- Engage Goddard Integrated Design Center (IDC) for a final refinement of the mission design
- Conduct the second ITR after the final and the second MDL run
- Conduct internal mission cost review
- Review and refine risks and risk mitigation strategies
- Conduct CML 4 assessment and prepare for CML 4 audit
- Converge on the mission cost strategy and refine the end-to-end mission cost estimates
- Start preparing the OST mission study report

Fiscal Year 2019 Tasks

- Finalize end-to-end mission cost estimates and develop basis of estimates (BOE)
- Estimate the cost to advance mission-enabling technology to TRL 6
- Complete the mission study report and submit to HQ
  - Science goals and objectives
  - DRM Concept
  - End-to-end mission cost estimates with BOE
  - Mission development schedule: Phase A to E
  - Mission enabling technology list and technology advancement schedule and cost estimates
  - Science and Mission Requirements Traceability Matrix
  - Mission risk analysis: risk identification and mitigation approach
- Community Chairs for the OST team will present the mission concept to the Decadal Committee with support from the Study Office and the engineering team.

Issues and Concerns

- The amount of funding provided to conduct the study is of concern.
  - Goddard Center Contribution beyond FY17 is unknown
  - Partner study contributions from external entities are being activity pursued but it is not a certainty that these sources will be consistent throughout the study period, which could impact the final design and mission study.
  - Committed study resources are insufficient to develop a demonstrably executable mission concept with enough detail to estimate its cost confidently to "1.5 decimal places" (we are unclear on this informal requirement).
- Mission Cost Risk
  - Under-funding at this stage may lead to a design with partial information at major subsystem level, leading to a large cost uncertainty and, thus a large added cost risk during CATE process.

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Moving Forward

- HQ can provide:
  - (i) Uniform guidelines on industry engagement/contributions.
  - (ii) Guidance to the study teams on requirements for on-orbit serviceability.
  - (iii) Guidance to the study teams on availability and expected cost for SLS launches in 2030s.
- Keep STDTs updated on information that will be provided to Decadal survey on exactly this issue.
- HQ/PO can keep an eye out for synergies between studies at a top level and facilitate necessary discussions between studies.
- HQ should provide guidance on the major components of the final report to the Decadal survey.
- We have provided technology gaps. Upcoming ROSES/SAT NRA should reflect the prioritized gap list and the crucial technologies are funded as part of SAT/APRA etc.
- We need guidance from HQ on what product STDTs can expect from Aerospace Advocacy Group.