In-Space Assembled Telescope (iSAT) Study

Study Members Telecon 12

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Today's Agenda

1. **Cis-Lunar vs SE-L2 Orbits for Assembly**
   - Looking for technical as well as programmatic justifications

2. **Proposed Description of Activity 2: Cost Estimate and Risk Assessment**

Cis-Lunar vs SE-L2 Orbits for Assembly

K-T Matrix To Date

Problem Statement (Activity 1b): Prioritize assembly and infrastructure concepts for a 20 m modularized in-space assembled telescope.			
ID		Concept A	Concept B
	OPTION DESCRIPTORS	Assembly at cis-Lunar	Assembly at SE-L2
D1	**Describe the Concept architecture.**	**Assembled at cis-lunar**, modules are launched to cis-lunar via upper-stage cargo vehicle and either (1) transferred to a space tug for delivery to the assembly location; (2) the cargo vessel has 6 DOF RPO sensor capabilities and delivers the modules directly to the (3) assembly location or (4) depot. Any depot would require a tender to transfer modules to the assembly location. Assembly of the modules occurs with multiple walking and stationary long-reach robotic arms along with dextrous robotic arms directly on the telescope S/C bus or on some building way, entirely detached from the telescope other than docking points. **Other trades:** (a) First light at cis-lunar with 1-2 instruments, then propels to SE-L2, subsequent instruments installed and serviced at SE-L2 versus full telescope assembly at cis-lunar then transfer to SE-L2. (b) Can take advantage of Gateway infrastructure, including astronauts, for contingency if available. (c) Modules are delivered to LEO via cargo vessel and transferred to space tug for delivery to the assembly location.	**Same as Concept A but assembly occurs at SE-L2**

Cislunar vs SE-L2 Assembly Location Trade (excluding Gateway assumptions)

Red text - updates

	Earth Orbit	Cislunar	Sun-Earth L2	Preferred location w/ rataionale
Launch Window Frequency (days)	1	**2-6**	180??	**Cislunar Significant Strength** – SEL2 launch windows are 180 (TBR) – probably can trade fuel to improve the situation, need some help here. See this slide
Transfer Time from launch to assy orbit per module (days)	<1	**6**	100	**Cislunar Significant Strength –** For 9 launches, Cislunar is total of 9*94=850 days less cargo transfer operations, could be a significant reduction in cargo delivery cost
Total assy time (years) (see charts 4-8 for details)	<1	**0.4-0.6**	0.7-2.9	**Cislunar Significant Strength** - Especially if capture and/or assembly verification prior to subsequent launch is desired – could cut assembly time in a quarter. Cislunar has less risk for the same amount of time, or less time for the same amount of risk. Note SEL2 numbers do not consider launch window frequency.
Launch C_3	1.3-3.22	-2.0	-0.7	**Cislunar Minor Strength** – LV performance - 250kg more per launch to cislunar (assuming not volume limited), for a total of 9*255 = 2,295kg more performance in 9 launches.
Teleoperation time delay (sec)	6-Jan	<2 sec	5 sec	**Cislunar Minor Strength** – Assume much of the work is automated, but even if it isn't, increased latency from 2 to 5 seconds will not have a a major impact on telerobotic task timing
Comm	TDRS	DSN + LC	DSN + LC	**Cislunar Minor Strength -** Cislunar is closer, improved link margins

Credit: Bo Naasz (NASA GSFC)

Cislunar vs SE-L2 Assembly Location Trade (excluding Gateway assumptions)

Red text - updates

	Earth Orbit	Cislunar	Sun-Earth L2	Preferred location w/ rataionale
Inertial Nav performance				Question: Nav performance in Cislunar is likely better, this could simplify rendezvous
Cargo Delivery stage Delta V	N/A	Low	Low	See Folta – not sure if there's a discriminator here – insertion delta V's are typically minimized (almost zero) by trajectory design
Maneuver loads on assemblage	High	Very Low	Very Low	Question: Does the maneuver from Cislunar to SEL2 present a vibration/load challenge? For a 10 m/s maneuver using biprob (Isp=300) • 50,000kg assemblage, 1000N thrust, accel = 0.02m/s^2 (2 mili gees), 500sec burn • 100,000kg assemblage, 100N thrust, accel = 0.001m/s^2 (0.1 mili gees), 2.8 hour burn These loads may be lower than assembly or slew loads, anyway – can someone look at this?
Environment	High TID	1 AU	1 AU	No preference
Sun/Earth/Moon thermal and lighting geometry	Very Complex	Mild	**Constant**	**SEL2 Minor Strength** – need to find assy attitude in Cislunar that keeps dark side shaded from sun, all light out of optical path. Would pointing out of ecliptic at EML2 do this? If so, preference is slight. If Earth/Moon light on dark side during assembly is not acceptable, this could become a major strength for SEL2. Solved by adding a barrel? **Question: What is the requirement for thermal stability during assembly? Commissioning? Ops? Is there a combination of EML2 orbit and attitude that meets these requirements? If not, Question: How long after the transfer burn from Cislunar to SEL2 is the system thermally stable enough for commissioning? Ops?** Scott Knight: When we specify optical assembly we generally require control of temperature to +/- 1 deg C. Non-precision things like the space craft are much more forgiving. +/-1 deg C is easy to do in a cleanroom, maybe quite a bit harder in space. Flight Dynamics: Provided more info on EML2 orbit (see subsequent charts from Folta and Davis). Investigating max duration at EML2 with no eclipse (we should assume no eclipse is allowed during assembly, yes??)
Transfer time from Assy to Ops	90	90?	0	**SEL2 Minor Strength** – but this is very very minor, Telescope can operate during transfer **Question: how long after the transfer burn is the system thermally stable enough?**
Delta V Assy to Ops Orbit (m/s)	3,500	30?	**0**	**SEL2 Minor Strength** - for a 50,000 kg observatory, this would be ~500kg bi-prop

Credit: Bo Naasz (NASA GSFC)

In Support of cis-lunar

Comments from Study Members

- **More frequent launches enables quicker assembly and earlier workforce roll off ($'s!)**
  - *But advantage depends on funding profile*
- **Important to conduct at least partial telescope verification quickly before transferring to SE-L2**
  - Potential problems would be identified earlier
- **Cis-lunar assembly offers potential collaboration/asset sharing/infrastructure support with a potential Gateway.**
- **Potential Gateway offers potential astronaut support (EVAs for trouble-shooting and verification)**
  - *But aren't we designing for robotic assembly only?*

➢ **But, other than maybe thermal, are there any technical reasons to conduct the assembly at cis-lunar when the "simplest" location at the final location?**

Proposed Description of Activity 2:

Cost Estimate and Risk Assessment

Phase 2 Plan (1/2)

Objective: Develop an understanding of the value proposition of iSA for large telescopes.

Challenge: iSA mission is not well understood and a definitive cost and risk posture is difficult to postulate in the absence of a clear lifecycle plan, schedule, and a bounded technical approach.

Opportunity: A well qualified team of experts across a diverse set of technical and programmatic fields are involved in this study. The team is self motivated and we have the benefitted from some excellent technical inputs.

Must do: Answer the sponsor question: When is iSA favorable compared to current paradigm?

Activity 1: Consensus on optical design, on the overall architecture and module concept definitions, orbits and robotic systems, some clarity on mission concept, fairing size among others. Provides a good launching point for a more focused Activity 2

Phase 2 Plan (2/2)

Two pronged approach:

Anectodal Assessment

1. A subjective study quantifying the connections between different aspects of an iSA mission to glean the expert opinion based expected impact of iSA, provide qualitative measures for understanding cost and risk postures; also identify technology readiness

Detailed Assessment

2. A more focused product lifecycle plan for parameterized telescopes (5-20 m) that follows the paradigm of a step 1 New Frontiers proposal concept plan with granularity at major subsystems, bounded with clear statement of assumption and projected uncertainties

Constraint: Must finish in time to inform the Decadal Survey

The Subjective Effort

Not so subjective

Expected Steps:

- Create a list of all important parameters that define an iSA mission versus current approach
- Capture interactions/dependencies between these parameters
- Show qualitatively how these parameters alone impact cost and risk
- Then show the impact of these parameters collectively via their interactions
- Discern **nuggets** that provide positive and negatives of iSA as a paradigm vs current approach. Support **nuggets** with clearly understandable rationale
- Must close, do not leave things hanging – i.e. cover the full iSA spectrum
- Identify areas where analyses may be needed – do not do analyses
- Identify technology enablers and risks

Deliverable:

- An initial presentation capturing the parameters and their relations (+4 weeks)
- A plan of action demonstrating feasibility (+8 weeks)
- A report summarizing the findings, and the cost and risk posture of iSA mission vs current paradigm (+16 weeks)

The Detailed Study

Expected Steps:

- Create a project WBS and identify major subsystems
- Create separate small teams from the WG for each subsystem and WBS element (as appropriate)
- Each team studies Phase A-E. Generates, with bounds/uncertainties:
  - ❑ a schedule,
  - ❑ implementation plan, including testing, V&V and integration
  - ❑ resource and budget,
  - ❑ technology heritage, technology development plan
  - ❑ MEL, PEL
- An overarching systems team shadows and integrates each study team
- An overarching formal costing team shadows and integrates each team

Notional Studies:

- Structure, joining means and metrology
- Sunshade
- Spacecraft
- Robotics
- Reflector Rafts, Secondary Mirror, and metrology
- Launches and RVC
- System Engineering

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