In-Space Assembled Telescope (iSAT) Study
v10

Charter

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A. Background

Large aperture telescopes benefit all astrophysics as well as planetary and Earth science. They provide unprecedented spatial resolution, spectral coverage, and signal to noise advancing all of these science areas. Envisioning the need for future large segmented telescopes to one day exceed the fairing size of existing or even planned launch vehicles, NASA will need to begin considering the in-space assembly (iSA) of these future assets. In addition, robotically assembling space telescopes in space rather than deploying them from single launch vehicles offers the possibility, in some circumstances, of reduced cost and risk for even smaller telescopes. This possibility, however, has not been proven. Therefore, following discussions within NASA's Science Mission Directorate (SMD) and Astrophysics Division (APD), the SMD Chief Technologist and APD Division Director have commissioned a study to assess the cost and risk benefits, if any, of the iSA of space telescopes. In particular, the study must answer the question: ***"When is it worth (or advantageous) to assemble space telescopes in space rather than to build them on the Earth and deploy them autonomously from individual launch vehicles?"*** This document charters the plan for the study deliverables, process, and membership. The goal for completion of the study is June 2019 culminating in a submitted whitepaper to the National Academies' 2020 Astronomy & Astrophysics Decadal Survey.

B. Deliverables

The in-Space Assembly Telescope (iSAT) Study Working Group is chartered by the NASA SMD Chief Technologist and APD Director to deliver by the goal of May 2019 a whitepaper assessing:

1. the telescope size at which iSA is necessary (an enabling capability)
2. the telescope size at which iSA is cheaper or lower risk with respect to traditional single launch vehicle deployment (an enhancing capability)
3. the important factors that impact the answers (e.g., existence of HEO-funded infrastructure, architecture of space telescope (segments or other), cryogenic or not, coronagraph capable (stability) or not, etc.)

The intention of the whitepaper is to inform NASA and the 2020 Decadal Survey of the total cost and risk benefits of the iSA of space telescopes.

The Study will focus on:

- Sensitivity of telescope size (10-20 m) to cost and risk
- Factors that impact the cost and risk for the iSA of telescopes (e.g. new I&T and V&V approaches, modularized components, etc)
- Trade parameters that impact options for iSA such as availability of resources (e.g., robotic servicers, low-cost launch vehicles, robotic assembly platforms such as the NASA Gateway), orbits for assembly, operating environments, use of coronagraphs or starshades, operating wavelength among others.

The Study is broken up into two parts – (1) a Concept Formulation phase and (2) a detailed Engineering Design phase where cost and risk benefits will be quantified across the project lifecycle and technology challenges identified.

C. Roles and Responsibilities

SMD and APD are committed to receiving an assessment produced through transparent engagement. The iSAT Study Working Group structure is illustrated in Figure 1. The following groups will participate in the iSAT Study Working Group:

1. The **Sponsors** concur with Study definition, deliverables, and timing. Low to no expectation on participation. Receive periodic status reports and briefings at key milestones.

2. **Study Members** represent the breadth of technology, engineering, and programmatic (schedule, cost) relevant to the trade study. The Study Members are chartered to reach a consensus recommendation (not a majority vote), and as such the expectations are high for Study Member participation in the Study. The Study Members will complete the trade work through these sub-groups:
    a. Advocate Teams for each architecture concept
    b. Two Evaluation Teams (one each for technical and programmatic evaluation criteria)

3. The **Steering Committee** is responsible for recommending membership in the subgroups of the iSAT Study Working Group, ensuring they are well represented in terms of expertise. The Steering Committee also advises the Study Leads, providing feedback at key junctions of the Study regarding its progress and direction in moving the work forward.

4. **Subject Matter Experts, Guests, Observers** are invited by the Study Leads and Steering Group and participate as needed. Consultants are subject-

matter experts necessary to inform the trade recommendation. Expectations on the frequency and degree of participation are lower than for the Study Members. These participants are not required to be in consensus with the Study Members, though are welcome to participate in the full iSAT Study Working Group deliberations.

5. The **Facilitator** is responsible for the process (not content) of a trade study, is accountable to the Steering Group, and is responsible for bringing the groups to a consensus recommendation by the required date and to support briefings of the final recommendation. The Facilitator in some cases may be the Study Lead.

6. The **Study Leads** are responsible for the overall Study deliverables and accountable to the Sponsors.

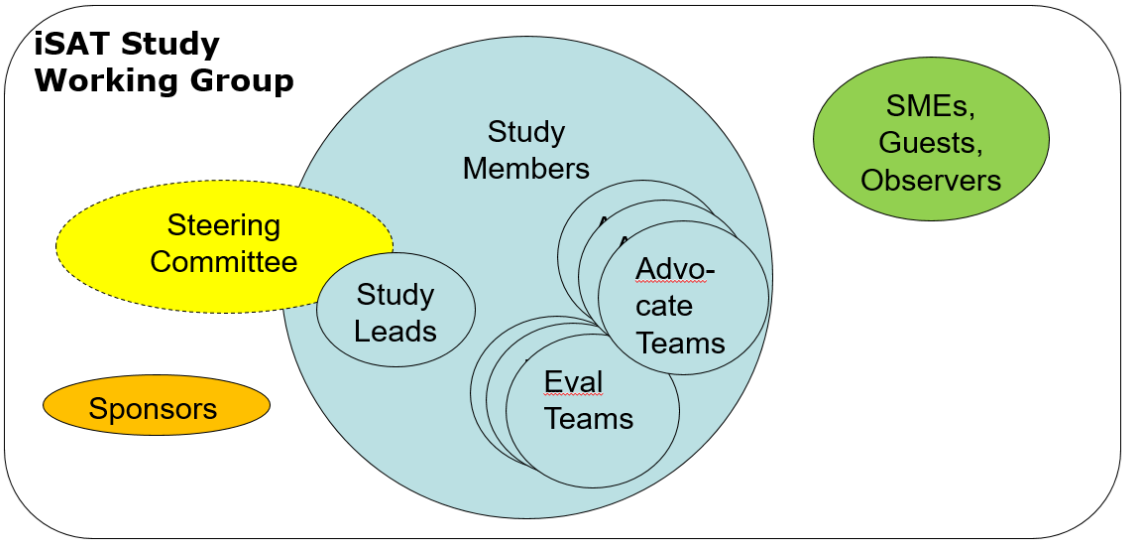

Figure 1: Illustration of the iSATS Working Group

D. Membership

Membership in each group are defined below (US Persons Only):

Sponsors

1) Mike Seablom — NASA SMD
2) Paul Hertz — NASA SMD APD

Study Members (aim to come to consensus)

- Option Advocates, Technical Evaluation Team, Programmatic Evaluation Team will come out of this group.
- This first group of Study Members are preferentially selected and focused on Activity 1a (Telescope design and architecture concept; see below for the different activities)

Name	Institution	Expertise
1. Ali Azizi	NASA JPL	Metrology
2. Gary Matthews	Consultant	Mirror Segments
3. Larry Dewell	Lockheed	Pointing/Stability/Control
4. Oscar Salazar	NASA JPL	Pointing/Stability/Control
5. Phil Stahl	NASA MSFC	Telescope Architecture
6. Jon Arenberg	Northrop	Telescope Architecture
7. Doug McGuffey	NASA GSFC	Systems Engineering
8. Kim Aaron	NASA JPL	Systems Eng/Structures
9. Sharon Jeffries	NASA LaRC	Systems Engineering
10. Al Tadros	SSL	Robotics
11. Bob Hellekson	Orbital-ATK	Telescope Systems
12. Gordon Roesler	DARPA	Robotics
13. Eric Mamajek	NASA ExEP	Astrophysicist
14. Shanti Rao	NASA JPL	Optical Design
15. Ray Ohl	NASA GSFC	Optical Alignment/Test
16. Sergio Pellegrino	Caltech	Telescope Structures
17. Tere Smith	NASA JPL	I&T
18. Paul Backes	NASA JPL	Robotics
19. Jim Breckinridge	UA	Optical Design
20. Allison Barto	Ball	Optical SE/testing
21. Joe Parrish	DARPA	Robotics
22. Acey Herrera	NASA GSFC	I&T
23. David Stubbs	Lockheed	Telescope Structures/Design
24. John Dorsey	NASA LaRC	Telescope Structures
25. Jeff Sokol	Ball	Mechanical/I&T
26. Brendan Crill	NASA ExEP	Technologist/Detectors
27. Dave Miller	MIT	Technologist
28. Atif Qureshi	SSL	Robotics Systems Engineering

29.	Jason Tumlinson	STScI	Astrophysicist
30.	Carlton Peters	NASA GSFC	Thermal
31.	Paul Lightsey	Ball	Systems Engineering
32.	Kim Mehalick	NASA GSFC	Optical Modeling/I&T
33.	Bo Naasz	NASA GSFC	Systems Engineering
34.	Eric Sunada	NASA JPL	Thermal
35.	Keith Havey	Harris	Telescopes

Subject Matter Experts, Observers, and Guests:

36.	Lynn Bowman	NASA LaRC	Program Management
37.	Rich Rynders	Orbital-ATK	Assembly
38.	Howard MacEwen	Reviresco	Telescopes
39.	Lynn Allen	Harris	Optics
40.	David van Buren	NASA JPL	Optical Systems
41.	Michael Rodgers	Synopsys	Optical Design

Steering Committee

1.	Dave Redding	NASA JPL	Study Member (mirrors, WFSC)
2.	Joe Pitman	consultant	Study Member (opto-mech struct)
3.	Scott Knight	Ball	Study Member (optical design)
4.	Bill Doggett	NASA LaRC	Study Member (telescope struct)
5.	Matt Greenhouse	NASA GSFC	Study Member (astrophysicist)
6.	Joanne Hill-Kittle	NASA GSFC	
7.	Ron Polidan	consultant	Study Member (telescopes)
8.	John Grunsfeld	NASA (ret)	
9.	Keith Belvin	NASA STMD	
10.	Brad Peterson	STScI/OSU	Study Member (astrophysicist)
11.	Florence Tan	NASA SMD	
12.	Ray Bell	Lockheed	Study Member (telescope systems)
13.	Nasser Barghouty	NASA APD	
14.	Eric Smith	NASA JWST/APD	
15.	Keith Warfield	NASA ExEP	Study Member (systems)

Facilitator

Nick Siegler	NASA ExEP/ JPL	

Study Leads

Nick Siegler	NASA ExEP/JPL	
Harley Thronson	NASA GSFC	
Rudra Mukherjee	NASA JPL	Study Member (robotics)

E. **Structure of the Work:** The process leading to a recommendation to the NASA HQ Sponsors is illustrated in Figure 2 and the schedule in Figure 3.

The iSAT Study (Activities 1 and 2 below) is expected to consist of approximately 2-3 face-to-face workshops of 2-2.5 day's duration and supporting bi-weekly telecons that enable virtual participation by all participants. Periodic briefings are provided by the Study Leads at the request of the Sponsors.

1. **Select a reference parametric design and architecture concept for a 20 m, filled aperture, non-cryogenic space telescope (and smaller) to be assembled and tested in space. (Activity 1a)**
    a. Send out invites to participants *(w/c 4/2 - 4/18)*
    b. Kickoff Telecon with Steering Committee (April)
    c. Kickoff Telecon with the Working Group (May)
    d. Establish consensus criteria for a successful telescope design and architecture outcome with Working Group (May)
    e. First face-to-face meeting with SMEs specialized in telescope building to a workshop at JPL in (June 5-7, 2018). Generate preliminary telescope design and architecture options to be assessed.
    f. If needed, through telecons, complete options to be assessed (July)
    g. Reach consensus by the Study Members of the evaluations for the criteria, risks, and opportunities (July)
    h. Reach consensus by the Study Members of the telescope design and architecture concept recommendation (August)
        - Need for a second face-to-face will be assessed in June.
    i. Study Leads deliver briefing to the Sponsors (September)

2. **Select a reference in-space assembly and testing concept for the "assemble-able" space telescope architecture, defining robotics, orbit, launch vehicle, and assembly platform. (Activity 1b)**
    a. Identify Study Members with experience in robotics, launch vehicles, orbits, telescope assembly (expect some overlap from Activity 1a) (June)
    b. Send out invites for membership (June)
    c. Telecons begin with the Working Group (August)
    d. Establish consensus criteria for a successful assembly and testing selection outcome (August)
    e. First face-to-face meeting with Working Group at TBD NASA Center *in August-September*. Generate preliminary assembly and testing options to be assessed.
    f. If needed, through telecons, complete options to be assessed. *(September)*

g. Reach consensus by the Study Members of the evaluations for criteria, risks, and opportunities *(September)*
h. Reach consensus by the Study Members of the telescope assembly and testing recommendation *(October)*
    - Need for a second face-to-face will be assessed in August.
i. Study Leads deliver concept recommendation(s) for further study and briefing to the Sponsors *(December)*

3. **Advance the engineering fidelity of the concepts selected in Activities 1a and 1b sufficiently so that they can be costed. (Activity 2a)**
    - Select a team of NASA engineers, academia, government labs, and commercial companies to conduct the work. (October 2018 - April 2019)

4. **Estimate, through an independent body, the cost of designing, architecting, assembling, and testing the reference 20 m space telescope from Activity 1. Identify its risks. Parameterize the cost to smaller apertures (Activity 2b).**
    - JPL's Team X (May 2019)

5. **Write Decadal Survey Whitepaper (Activity 3)** *(May-June 2019)*
    a) Deliver to Sponsors (June 2019)
    b) Hold last sponsor briefing (July 2019)

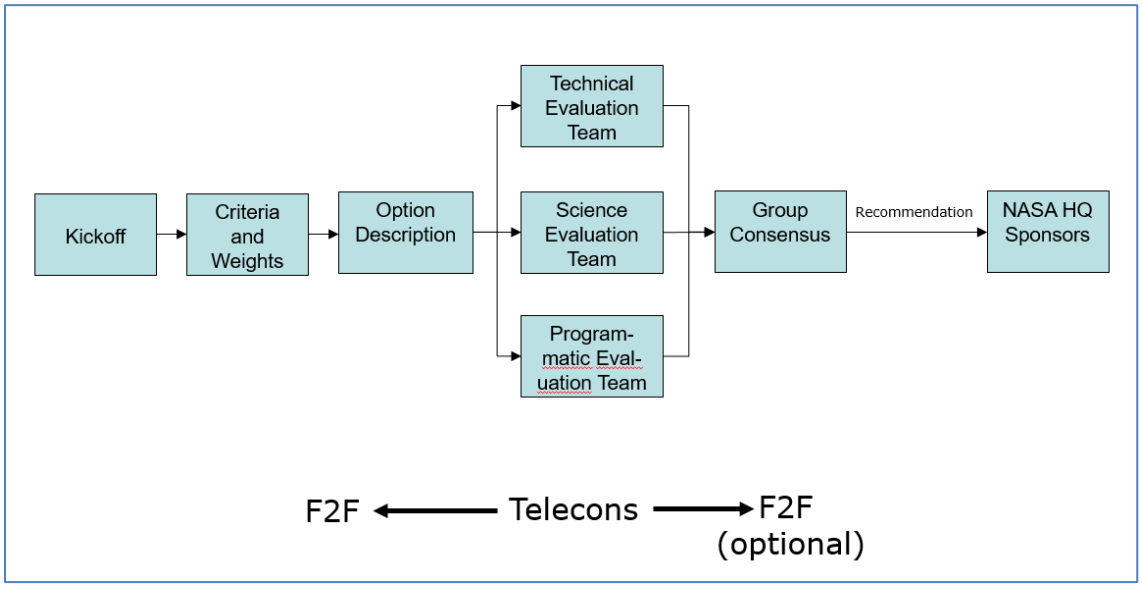

Figure 2: Work Flow

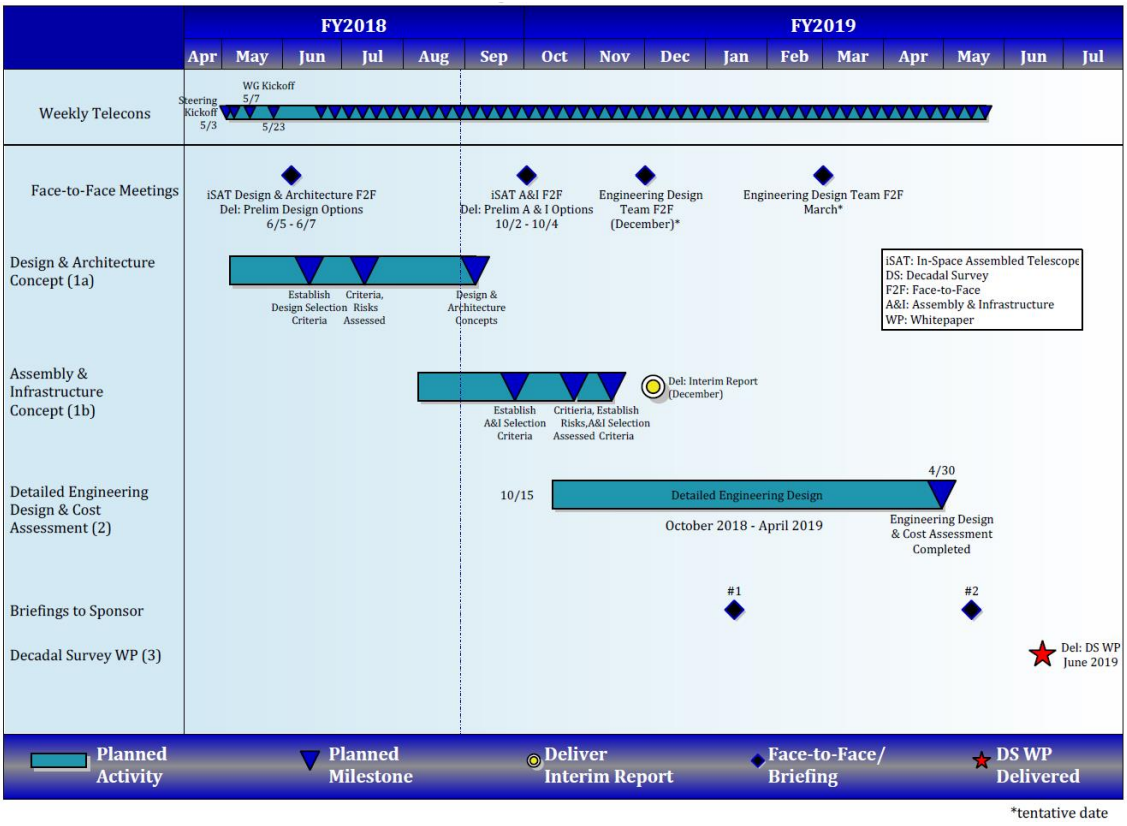

Figure 3: Study Schedule

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Division Director
NASA Astrophysics Division

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NASA Science Mission Directorate

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