Jet Propulsion Laboratory
California Institute of Technology

In-Space Assembled Telescope (iSAT) Study Workshop

Day 1

June 5, 2018

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CL#18-3328

Logistics and Workshop Goals

Nick Siegler
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Study Objective and Deliverables

- **The in-Space Assembled Telescope (iSAT) Study is chartered by the NASA APD Director and the SMD Chief Technologist to deliver, by the goal of June 2019, a Decadal Survey Whitepaper assessing:**
  - ***"When is it worth assembling space telescopes in space rather than building them on the Earth and deploying them autonomously from individual launch vehicles?"***

- **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 in-space assembly (iSA) of telescopes (e.g. modularized components, new I&T and V&V approaches)
  - Trade parameters that impact options for iSA such as availability of resources (e.g., robotic servicers, low-cost launch vehicles, assembly platforms), orbits for assembly, operating environments, use of coronagraphs or starshades, operating wavelength among others.

Study Objective and Deliverables

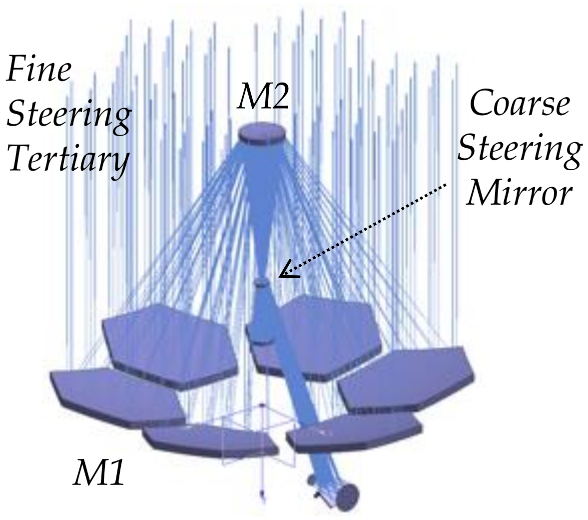
- **The Study is broken up into two parts:**
  1. a Concept Formulation phase
  2. a detailed Engineering Design phase where cost and risk benefits will be quantified across the project lifecycle and technology challenges identified.

- **The first phase is currently funded; the second is pending proposal review by APD.**

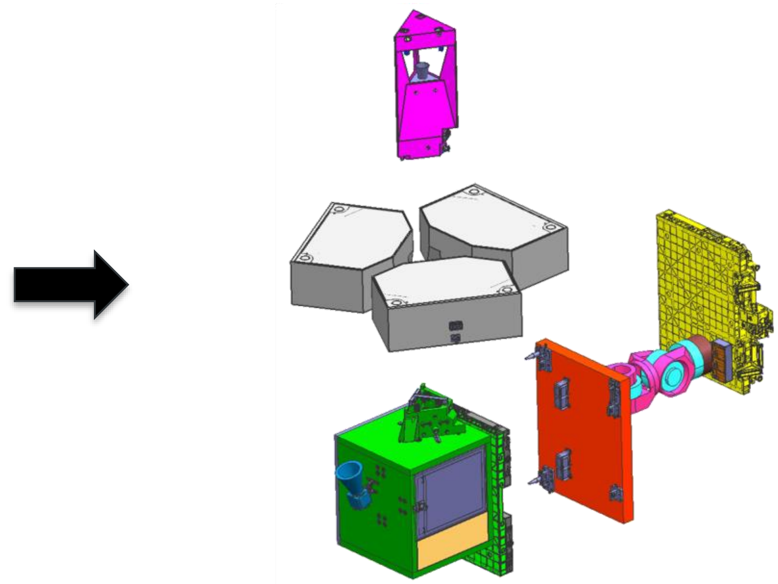
Activity 1a
Modularization of the iSAT

Select a reference design and architecture concept for a 20 m, filled aperture, non-cryogenic space telescope to be assembled and tested in space.

- Paradigm shift in architecture: Modularization
- An example, from the 2012 OpTIIX study (NASA JSC/GSFC/JPL/STScI):



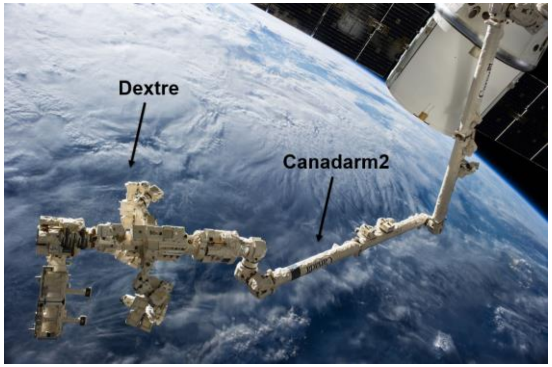
3 Mirror Anastigmat Telescope (1.45 m aperture)

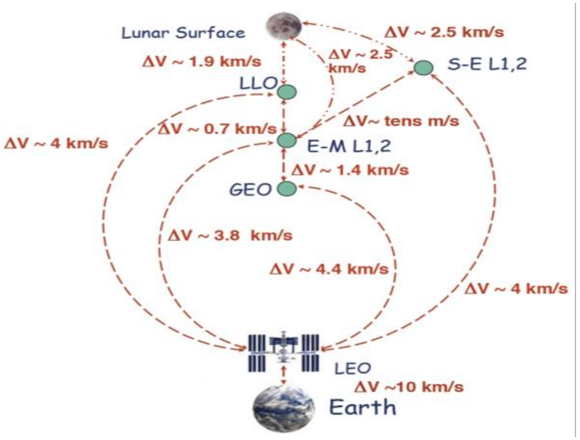


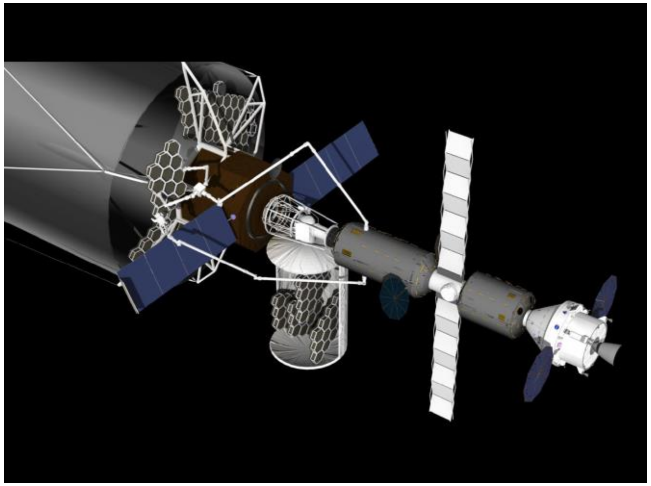
6 launch modules for assembly

Activity 1b:
Concept for Assembling and Testing the iSAT

Select a reference in-space <u>assembly and testing concept</u> for the "assemble-able" space telescope architecture, defining robotics, orbit, launch vehicle, and assembly platform.







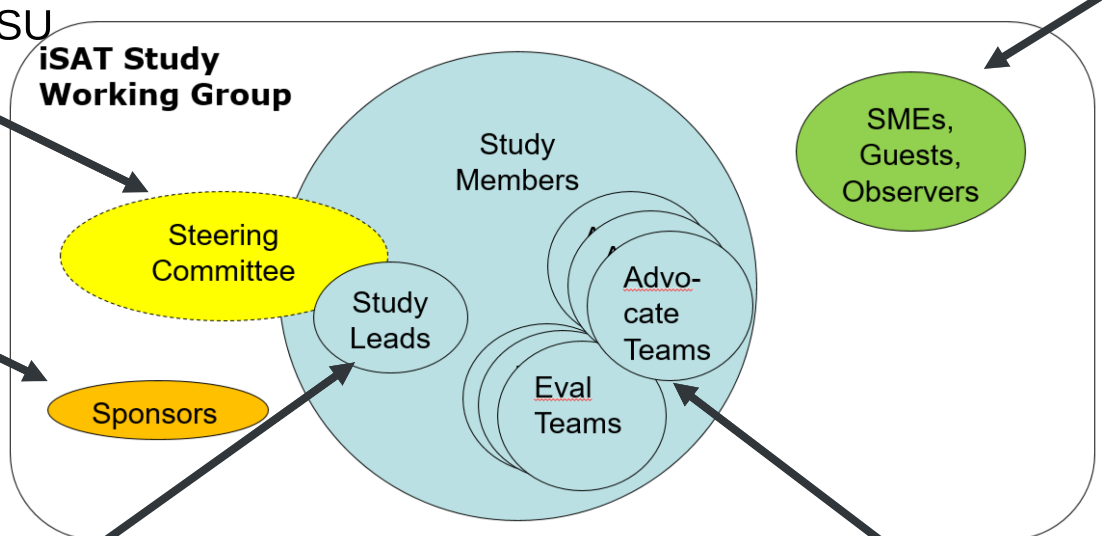
In-Space Assembled Telescope (iSAT) Study

Facilitator:
Nick Siegler

Steering Committee:
APD, JPL, GSFC, LaRC
STMD, SMD, ExEP
Ball, LMC, STScI/OSU

SME's, Guests & Observers:
LaRC, Reviresco, JPL, Orbital-ATK, Synopsys, Harris

Sponsors:
Mike Seablom
Paul Hertz



Study Leads:
Nick Siegler
Harley Thronson
Rudra Mukherjee

Study Members:
JPL, ExEP, MSFC, GSFC, LaRC
LMC, SSL, O-ATK, DARPA, MIT
Harris, Ball, Caltech, UA, STScI/OSU

Study Members

Name	Institution	Expertise
1. Ali Azizi	NASA JPL	Metrology
2. Gary Matthews	Consultant	Mirror Segments
3. Fang Shi	NASA JPL	WF Sensing/Control
4. Larry Dewell	Lockheed	Pointing/Stability/Control
5. Oscar Salazar	NASA JPL	Pointing/Stability/Control
6. Phil Stahl	NASA MSFC	Telescope Architecture
7. Jon Arenberg	Northrop	Telescope Architecture
8. Doug McGuffey	NASA GSFC	Systems Engineering
9. Kim Aaron	NASA JPL	Systems Eng/Structures
10. Sharon Jeffries	NASA LaRC	Systems Engineering
11. Al Tadros	SSL	Robotics
12. Joel Burdick	Caltech	Robotics
13. Bob Hellekson	Orbital-ATK	Telescope Systems
14. Gordon Roesler	DARPA	Robotics
15. Michael Rodgers	NASA JPL	Optical Design
16. Hsiao Smith	NASA GSFC	Robotics
17. Eric Mamajek	NASA ExEP	Astrophysicist
18. Shanti Rao	NASA JPL	Optical Design
19. Ray Ohl	NASA GSFC	Optical Alignment/Test
20. Joe Howard	NASA GSFC	Optical Design
21. Sergio Pellegrino	Caltech	Telescope Structures
22. Tere Smith	NASA JPL	I&T
23. Paul Backes	NASA JPL	Robotics
24. Jim Breckinridge	UA	Optical Design
25. AllisonBarto	Ball	Optical SE/testing
26. Jeanette Domber	Ball	SE/Structures/Instruments
27. Joe Parrish	DARPA	Robotics
28. Acey Herrera	NASA GSFC	I&T

Name	Institution	Expertise
29. David Stubbs	Lockheed	Telescope Structures/Design
30. John Dorsey	NASA LaRC	Telescope Structures
31. Jeff Sokol	Ball	Mechanical/I&T
32. Brendan Crill	NASA ExEP	Technologist/Detectors
33. Dave Miller	MIT	Technologist
34. Atif Qureshi	SSL	Robotics Systems Engineering
35. Jason Tumlinson	STScI	Astrophysicist
36. Carlton Peters	NASA GSFC	Thermal
37. Paul Lightsey	Ball	Systems Engineering
38. Kim Mehalick	NASA GSFC	Optical Modeling/I&T
39. Bo Naasz	NASA GSFC	Systems Engineering
40. Eric Sunada	NASA JPL	Thermal
41. Keith Harvey	Harris	Telescopes
42. Babak Saif	NASA GSFC	Metrology

Goals of this Workshop

1) Create concepts (Options) for modularized telescope designs

2) Advance the Selection Criteria

Features of Kepner-Tregoe Decision Process

Concepts

Selection Criteria

Decision Statement								
Description			*Option 1*		*Option 2*		*Option 3*	
	Feature 1							
	Feature 2							
	Feature 3							
Evaluation	**Musts**							
	M1		✓		✓		✓	
	M2		✓		?		?	
	M3		✓		✓		✗	
	Wants	*Weights*						
	W1	*w1%*	*Rel score*		*Rel score*		*Rel score*	
	W2	*w2%*	*Rel score*		*Rel score*		*Rel score*	
	W3	*w3%*	*Rel score*		*Rel score*		*Rel score*	
		100% Wt sum =>	*Score 1*		*Score 2*		*Score 3*	
	Risks		C	L	C	L	C	L
	Risk 1		M	L	M	L		
	Risk 2		H	H	M	M		
Final Decision, Accounting for Risks								
			C = Consequence, L = Likelihood					

Goals of this Workshop

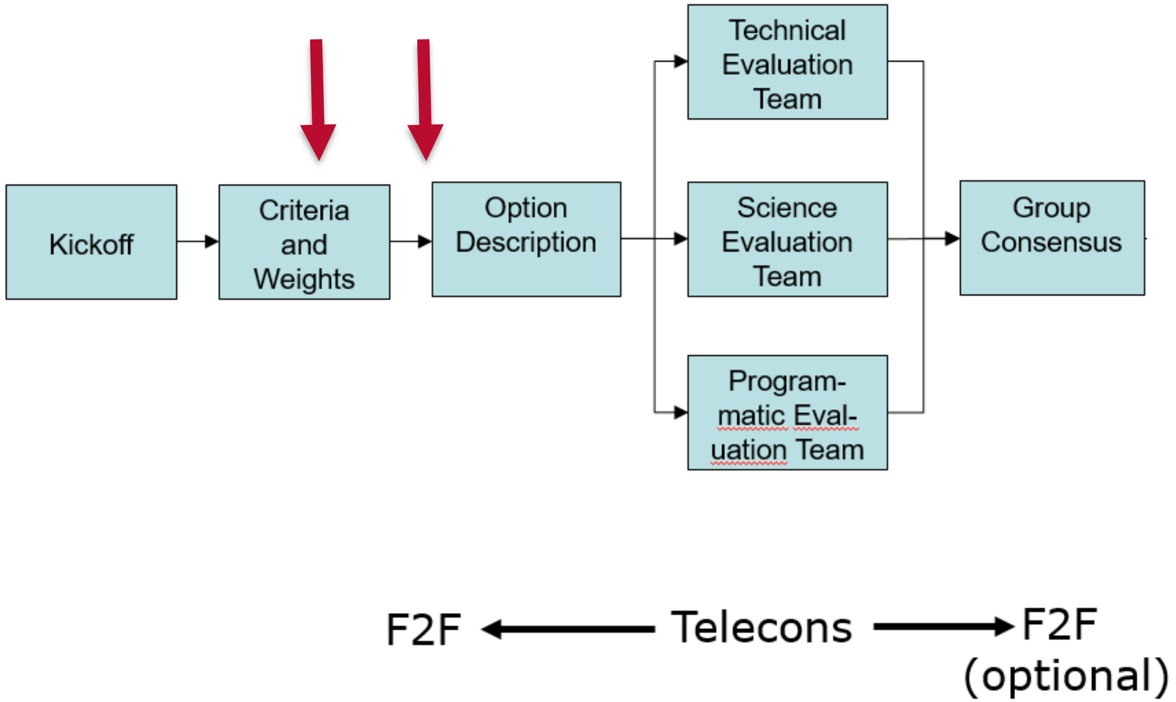
1) Create concepts (Options) for modularized telescope designs

2) Advance the Selection Criteria

3) Build a community of experts to advance in-space assembly

This Workshop is really part of the beginning not the end.

iSAT Study Process
(Activity 1a – Telescope Modularization)



Humanity's Biggest Machines Will Be Built in Space

When rockets can no longer hold oversize payloads, building in space might be the best way to go.

By Avery Thompson Feb 16, 2018

1.4k

GETTY IMAGES / JACK OLSON

Popular Mechanics Feb 2018

A R Cooray
@acooray

Following

Replying to @LeeBillings @Simberg_Space

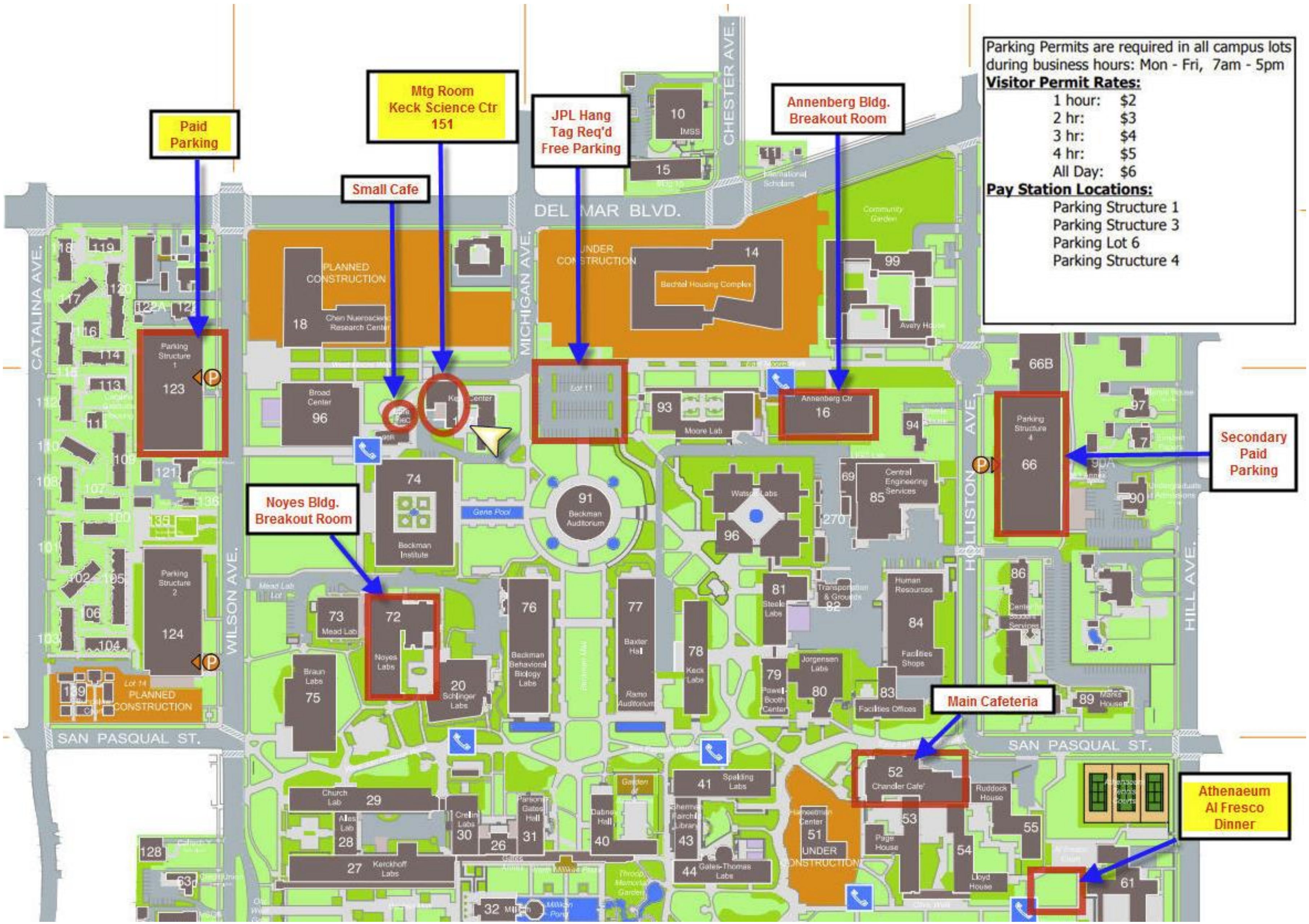
supporters of in-space assembly need to do a better job to educate the community on the likelihood of success. JWST experience has many in the community questioning what level of risk to take in during the next decade.

4:19 PM - 2 Jun 2018

1 Like 

Introductions

- **US Persons Only**
- **Logistics specialist:**
  - Jennifer Gregory



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4 hr: $5
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Parking Structure 3
Parking Lot 6
Parking Structure 4
Paid Parking
Mtg Room Keck Science Ctr 151
Small Cafe
JPL Hang Tag Req'd Free Parking
Annenberg Bldg. Breakout Room
Secondary Paid Parking
Noyes Bldg. Breakout Room
Main Cafeteria
Athenaeum Al Fresco Dinner
DEL MAR BLVD.
CHESTER AVE.
MICHIGAN AVE.
CATALINA AVE.
WILSON AVE.
HOLLISTON AVE.
HILL AVE.
SAN PASQUAL ST.
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PLANNED CONSTRUCTION
UNDER CONSTRUCTION
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Chen Neuroscience Research Center
Parking Structure 1
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Parking Structure 2
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Parking Structure 4
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Broad Center
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Beckman Institute
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Beckman Auditorium
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Lot 11
Moore Lab
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Annenberg Ctr
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Watson Labs
Central Engineering Services
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Mead Lab
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Noyes Labs
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Beckman Behavioral Biology Labs
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Human Resources
84
Facilities Shops
Jorgensen Labs
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Powell-Booth Center
79
Facilities Offices
83
Chandler Cafe'
52
Spalding Labs
41
Church Lab
29
Alles Lab
28
Crellin Labs
30
26
Parsons-Gates Hall
31
Dabney Hall
40
43
Gates-Thomas Labs
44
Kerckhoff Labs
27
Page House
53
54
Lloyd House
Ruddock House
55
61
Marks House
89
Center for Student Services
86
Avery House
99
Community Garden
International Scholars
10
15
14
18
Millikan Pond
32
Throop Memorial Garden
UNDER CONSTRUCTION
51
Lot 14
PLANNED CONSTRUCTION
139
128

Introductions

- **US Persons Only**
- **Logistics specialist:**
  - Jennifer Gregory
- **Breakout Facilitators:**
  - David Miller and John Grunsfeld
- **Note Takers**
  - Brendon Crill and Ron Polidan
- **Participants**

A Word from one of our Sponsors…

Dr. Paul Hertz
Director
Astrophysics Division
NASA Headquarters

Study Initial Conditions and Assumptions

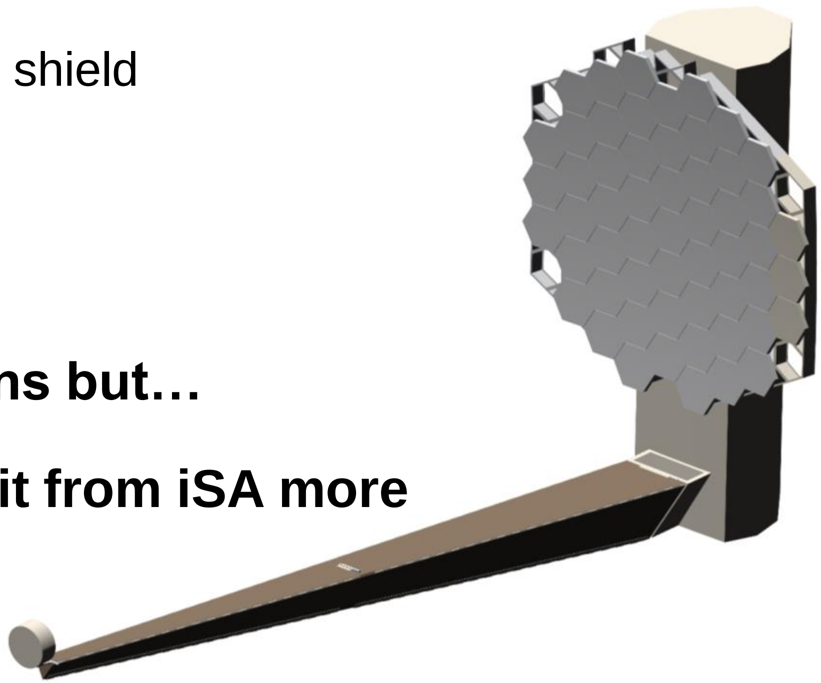
Nick Siegler
Chief Technologist, NASA Exoplanet Exploration Program
Jet Propulsion Laboratory, California Institute of Technology

Study Initial Conditions
(Activity 1a)

1. **Modularized telescope design enables both exoplanet science and general astrophysics.**
2. **20-meter, filled-aperture, non-cryogenic telescope operating at UV/V/NIR**
    - *We will examine parameterized designs so that we can also explore smaller apertures*
3. **Off-axis secondary mirror, f/(≥ 2) to assist coronagraph throughput, polarization, and performance**
4. **A high-contrast coronagraph will be an observatory instrument tasked to directly image and spectrally characterize exoplanets**
    - *The coronagraph will have the capability to actively sense and control input light wavefront errors due to all reasonable disturbance sources.*
5. **Operational destination is Sun-Earth L2**

Generating Modularization Design Options

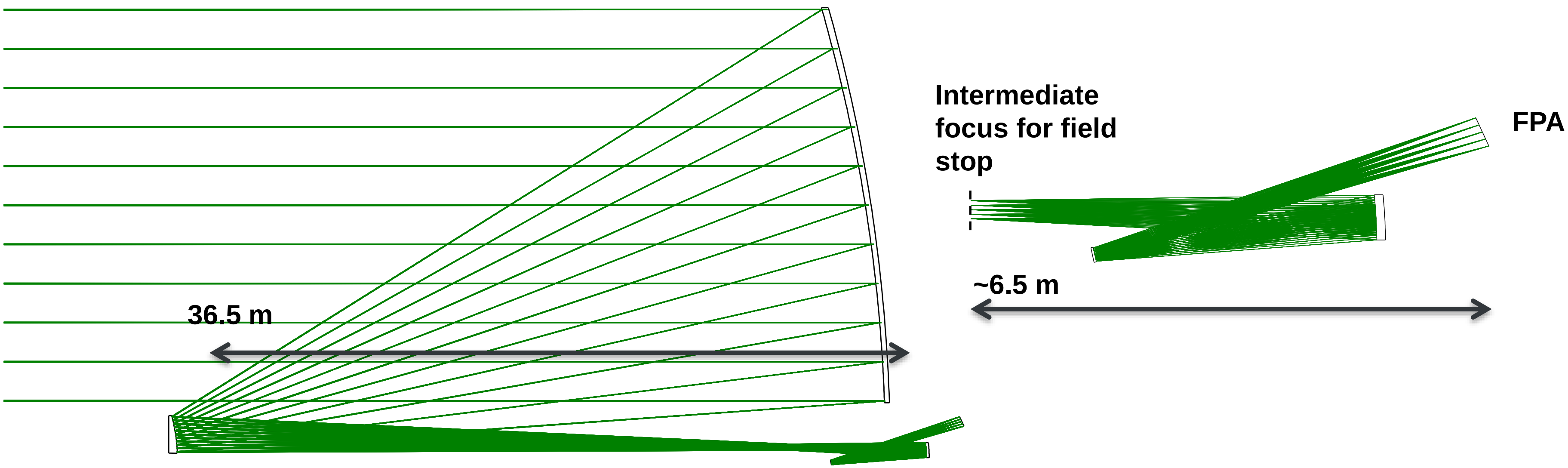
- **Trade space for <u>modularization</u> is very open**
  - Number of modules
  - Segment size, segment carriers, sun shield
  - Backplane architecture
  - Power, latching, harnessing
  - Instrument carriers, thermal
- **We're not trading telescope designs but…**
- **Do some telescope designs benefit from iSA more than others?**
  - Let's find out



- **Recommendation for Reference Telescopes Workshop in the Breakout sessions:**
  1) 20 m off-axis
  2) 20 m off-axis with opportunities to move to a different configuration if benefits noted
  3) Max 5-m class fairings

Candidate Reference Telescope Design

Off-Axis 20-Meter Optical Layout



Parameter	Assumption
Entrance pupil diameter	20 meter
Field of View	3x3 arc-minute
Final F/#	F/30
Image size	530 x 530 mm (implied by EPD, F/#, and FOV)
Primary mirror ROC and F number	80 meter ; F/2.0
Primary-secondary spacing	36.5 meter
AOI, maximum on each mirror	16.0° primary; 17.5° secondary; 5.6° tertiary; 8.4° fold.
RMS WFE (nanometer)	18.6 maximum, 10.4 average

Study Assumptions

1. **The Observatory must provide the stability requirements associated with coronagraphy of exo-planets**
   - *These are expected to be on order of 100s of pm WFE stability over time periods of ~ 10 minutes for relatively large planets.*
   - *However, 10s of pm WFE stability for Earth-sized planets*
   - *At the end of the telescope modularization activity (Activity 1a) we may assess what would have been the impact if the coronagraph was not assumed but rather a starshade. A starshade would significantly reduce the stability requirements on the telescope as well as eliminate almost all of the active optics. In Kepner-Tregoe speak, this is an Opportunity.*

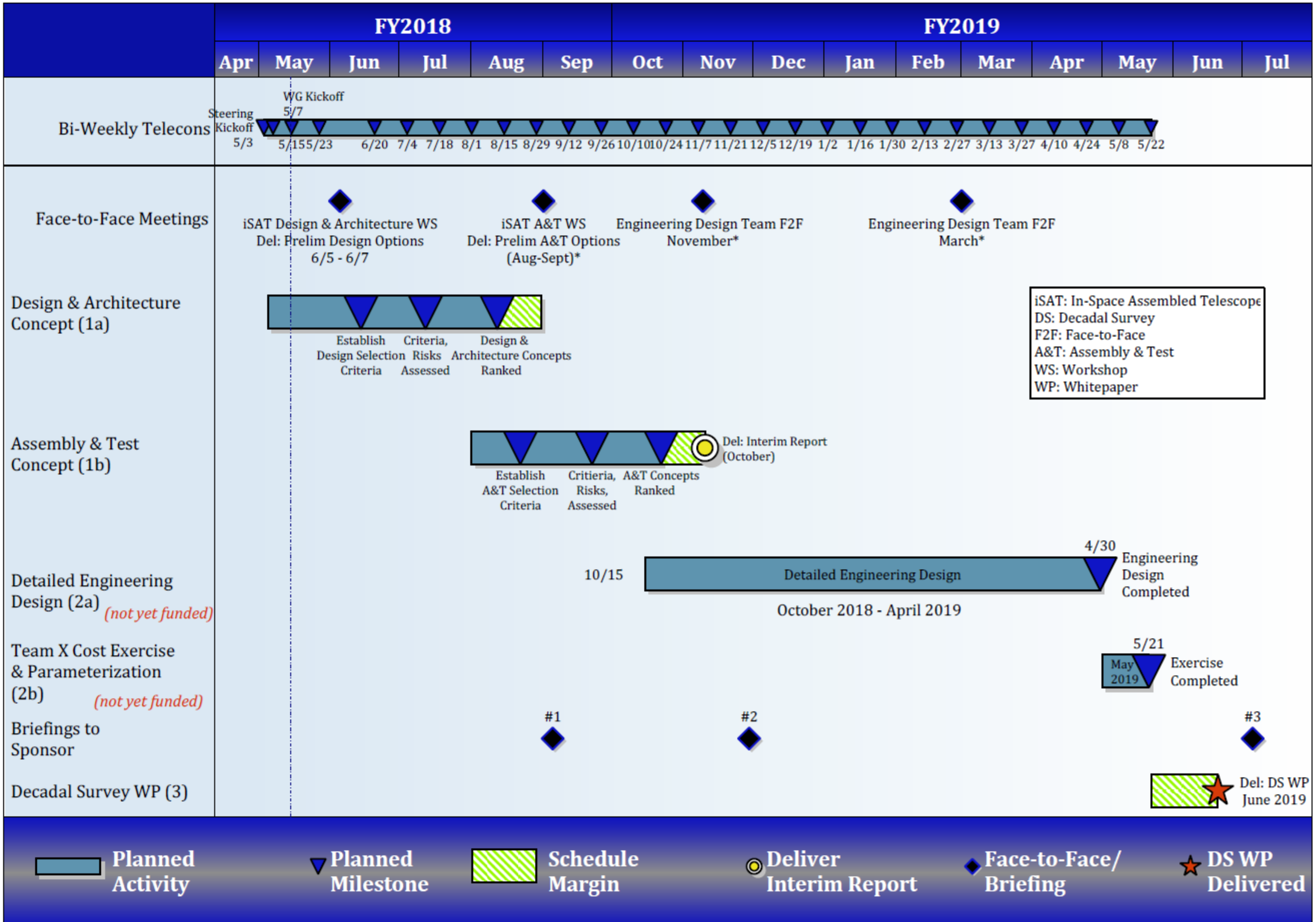
2. **Astronaut- and robotic-enabled assembly/servicing is available**

Breakout Teams

Discipline	Grunsfeld	Institution	Miller	Institution
ACS			Oscar Alvarez-Salazar	JPL
Programmatics	Lynn Bowman	LaRC		
Structures	John Dorsey	LaRC	Bill Doggett	LaRC
Structures	Sergio Pellegrino	Caltech	Lee Peterson	JPL
FASST	Harley Thronson	GSFC	Howard MacEwen	Reviresco
Optics	James Breckinridge	U of A	Jon Arenberg	Northrop
Telescopes	Keith Warfield	JPL	Dave Redding	JPL
Metrology	Ali Azizi	JPL	Joel Nissen	JPL
Metrology			Shannon Zareh	JPL
Thermal	Eric Sunada	JPL	Peters Carlton	GSFC
Science	Jason Tumlinson	STSCI	Brad Peterson	OSU
Optics	Shanti Rao	JPL	Mike Rodgers	JPL
Optics	Fang Shi	JPL	David van Buren	JPL
Scribe	Brendan Crill	JPL	Ron Polidon	PSST
Systems	Kim Aaron	JPL	Bob Hellekson	Orbital ATK
Systems	Bo Naasz	GSFC	Doug Mcguffey	GSFC
Systems	Phil Stahl	MFSC	Keith Havey	Harris
Systems	David Stubbs	LMCO	Allyson Barto	Ball
AI&T	Marshall Woods	JPL	Rich Rynders	Orbital ATK
AI&T	Raymond Ohl	GSFC	Acey Herrera	GSFC
AI&T			Suzanne (Tere) Smith	JPL
Robotics	Hsiao Smith	GSFC	Al Tadros	SSL
Robotics	Paul Backes	JPL	Joel Burdick	Caltech
Robotics	Atif Qureshi	SSL	Joe Parrish	DARPA

Additional Slides

Study Schedule



*tentative date

Activities 2a and 2b
Detailed Engineering Design and Costed

Activity 2a: Advance the engineering fidelity of the concepts sufficiently so that they can be costed.

a) Inputs from Activity 1a and 1b
b) Select a team of NASA engineers, academia, government labs, and commercial companies to conduct the work.
c) Needs funding

Activity 2b: Estimate, through an independent body, the cost of designing, architecting, assembling, and testing the reference 20 m space telescope?

a) Input design from Activity 2a
b) Identify risks
c) Parameterize the cost to smaller apertures

Activity 3
Deliver Final Whitepaper

Write and deliver the Final Whitepaper

a) Submit to APD Director who submits to 2020 Decadal Survey

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