In-Space Assembled Telescope (iSAT)

Study Members Telecon 2

May 17/18, 2018

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CL#18-2543

Today's Agenda

1. **Review of Study Goals and Activities**
2. **Review of Roles**
3. **Workshop Update**
4. **Towards a Reference Telescope** *(Dave Redding)*
5. **Short Tutorial on Decision-Making Process**
6. **Begin Selection Criteria Brainstorming**

Telecon #1 presentation slides:
https://exoplanets.nasa.gov/exep/technology/in-space-assembly/iSAT_working_group_telecons/

Study Charter:
https://exoplanets.nasa.gov/internal_resources/864

Review of Study Goals and Activities

Study Objective and Deliverables

- **Study Objective:**
  - *"When is it advantageous to assemble space telescopes in space rather than to build them on the Earth and deploy them autonomously from individual launch vehicles?"*

- **Deliverables:**

A whitepaper by May 2019 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 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.)
4. A list of technology gaps and technologies that may enable in-space assembly

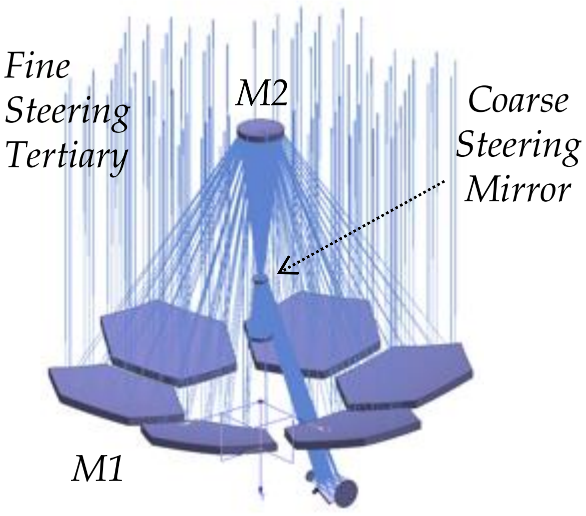
The intention of the whitepaper is to inform NASA and the 2020 Decadal Survey of the cost and risk benefits of the iSA of telescopes.

Activity 1a

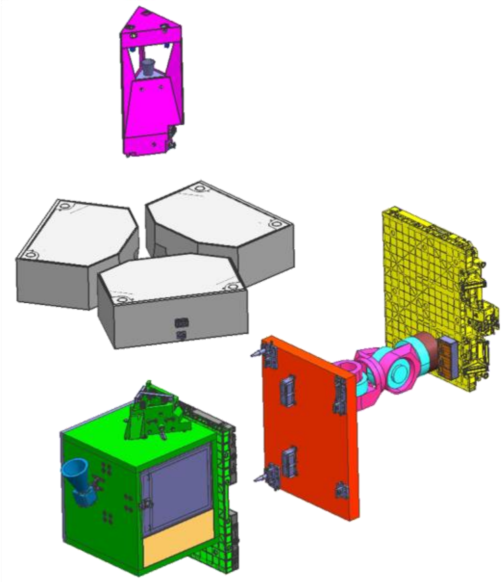
Concept Design and Architecture for the iSAT

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)

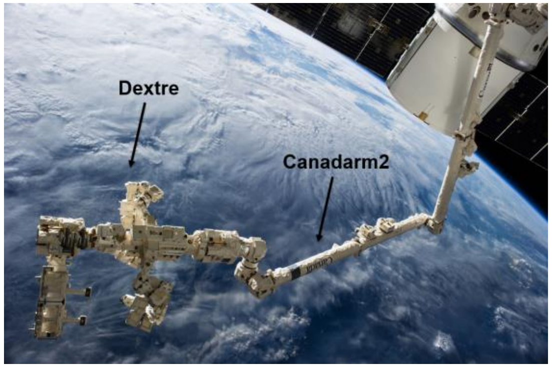


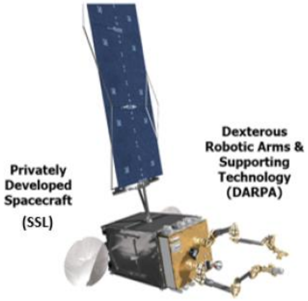
6 launch modules for assembly

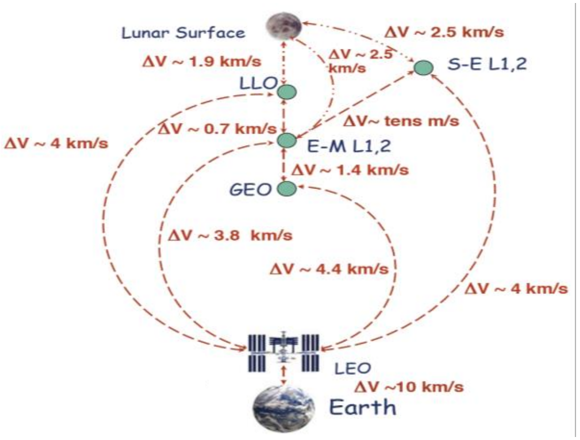
Activity 1b:

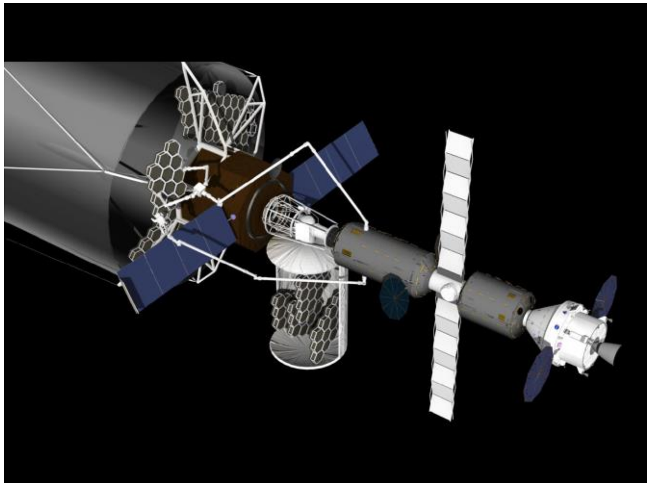
Concept for Assembling and Testing the ISAT

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









Activities 2a and 2b

(Not Yet Funded)

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

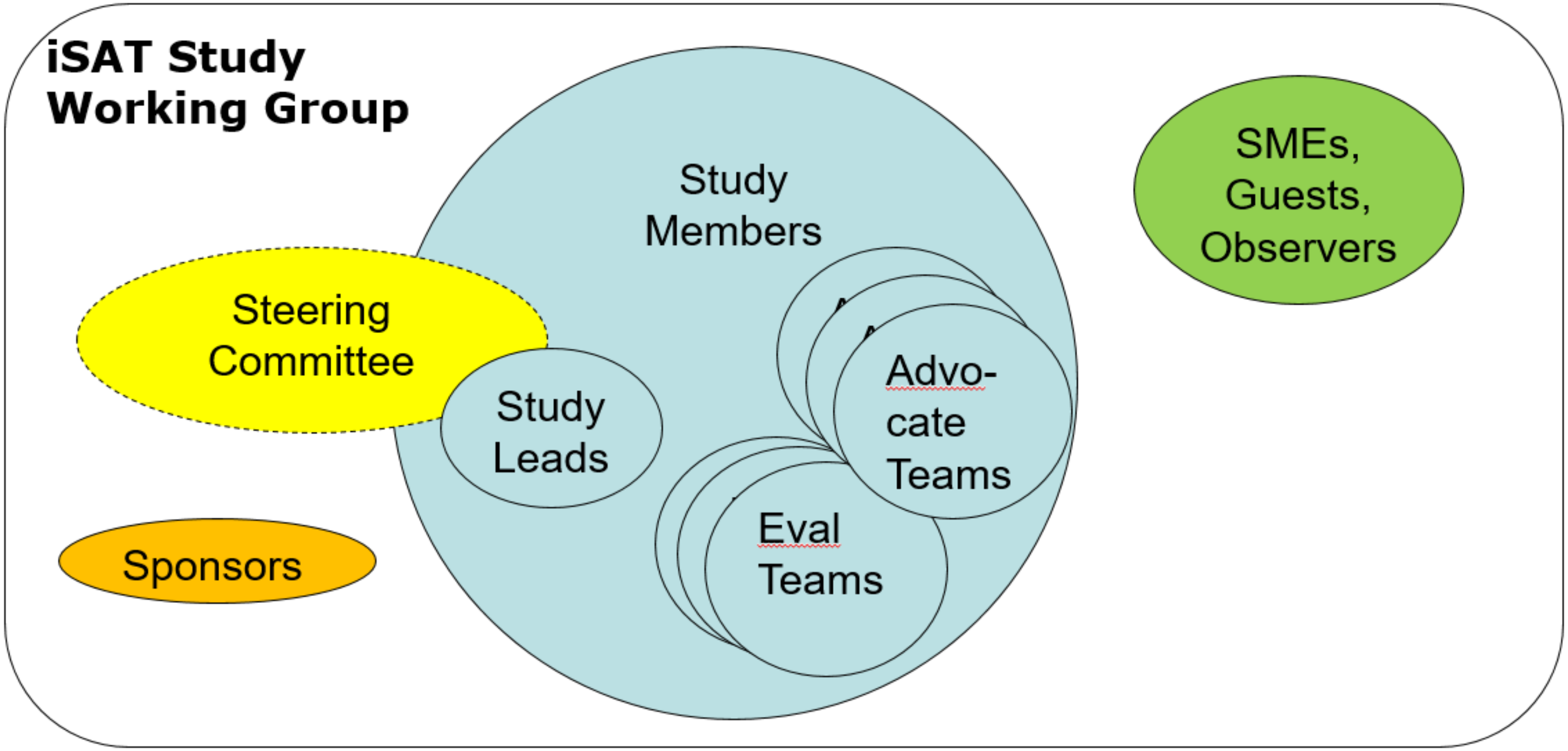
Write and deliver the Final Whitepaper

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

Review of Roles

(US Persons Only)

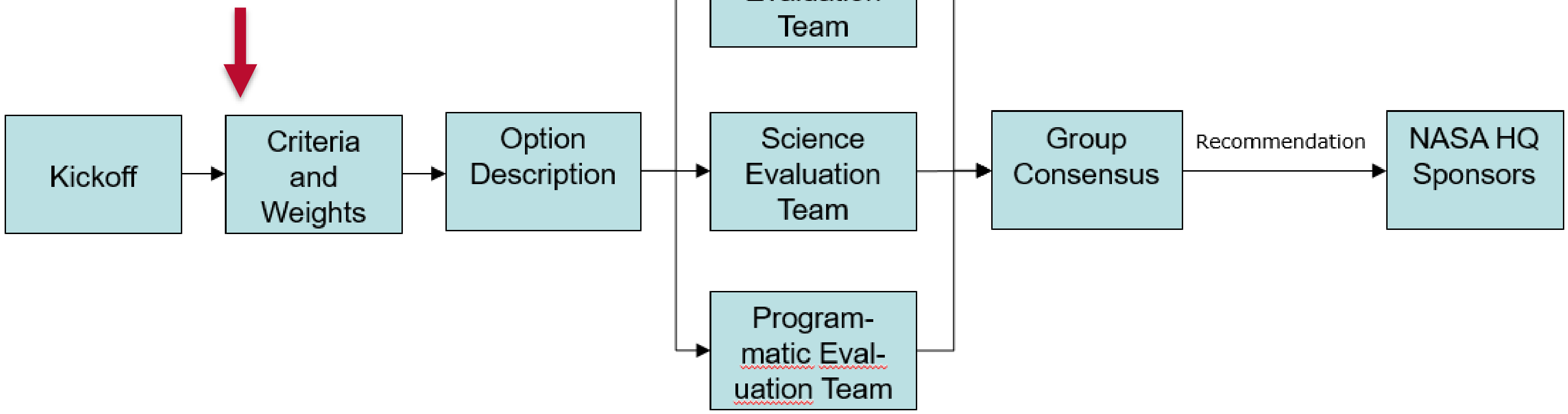
The iSAT Study Working Group



Role of the Study Members

1. **The heart of the Study – the folks whose recommendations will lead to a new paradigm (or not)…**
2. **Will generate criteria of evaluation**
3. **Will generate concepts of modularized telescope designs and architectures (a.k.a. options)**
   - …and later the assembly and testing concepts
4. **Will provide the Study with evaluation teams**
5. **Will reach consensus on the criteria assessment for each concept**
6. **Membership will change from "telescope design and architecture" focus to "robotic assembly, orbit, platform, launch vehicle, and test" focus**
7. **Bi-weekly telecons**

How will iSAT Study WG Produce a Recommendation?



Kickoff

Criteria and Weights

Option Description

Technical Evaluation Team

Science Evaluation Team

Programmatic Evaluation Team

Group Consensus

Recommendation

NASA HQ Sponsors

F2F ← Telecons → F2F (optional)

Workshop Update

Telescope Modularization Workshop

June 5-7, Caltech, Pasadena, CA

- **Goal:**
  - *Generating concepts for a 20 m modularized telescope*

- **Draft Agenda:**
  - https://exoplanets.nasa.gov/exep/technology/in-space-assembly/iSAT_study_workshops/

- **A block of rooms is available at the Marriott Residence Inn Old Town Pasadena**
  - **Deadline to book is May 18th**
  - https://exoplanets.nasa.gov/exep/technology/in-space-assembly/iSAT_study_workshops/

- **Logistics questions:**
  - Jennifer Gregory (jgregory@jpl.nasa.gov)

Towards a Reference Telescope

Dave Redding

NASA Jet Propulsion Laboratory, California Institute of Technology

Telescopes for Astronomy and Exo-Planets

Context for iSAT

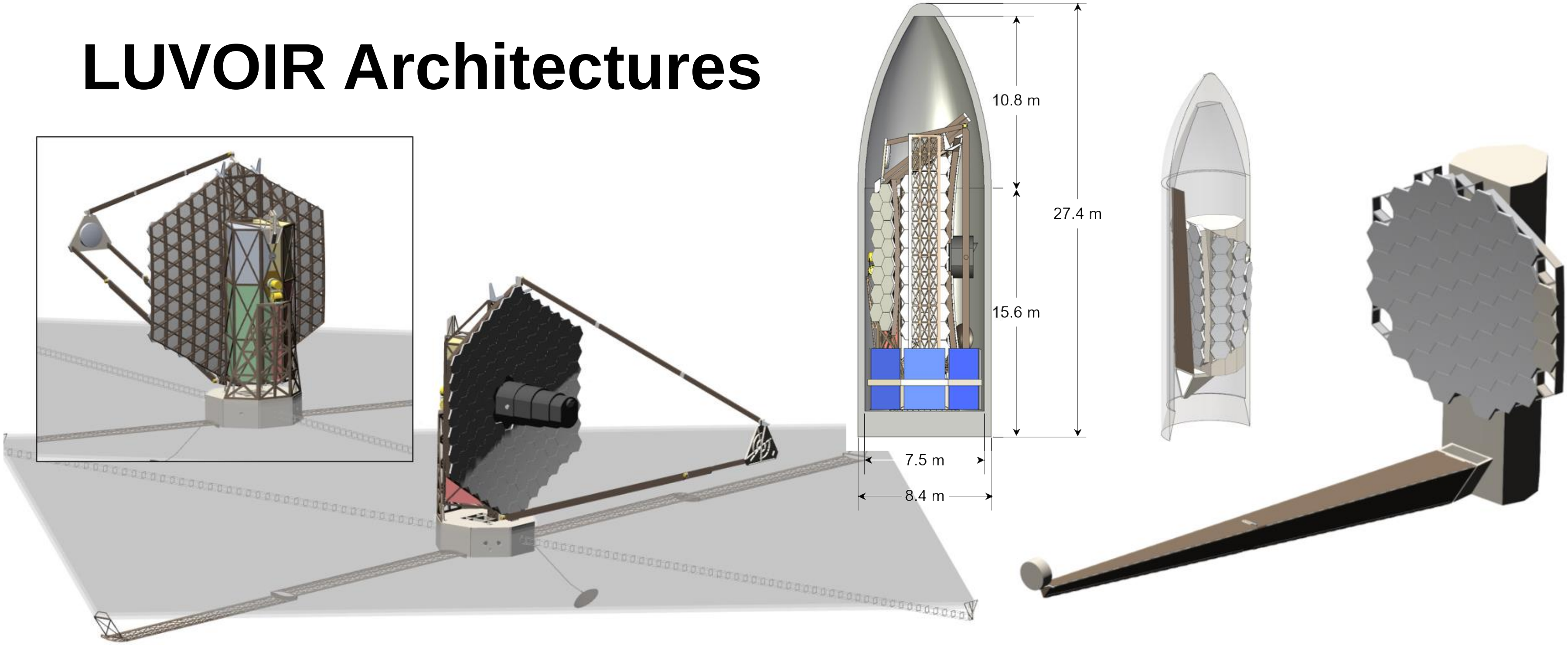
- **Telescopes for direct imaging of ExoPlanets have:**
    - Large aperture, for high resolution and high sensitivity in UV through NIR wavelengths... **D = 20 m**
    - A coronagraph or starshade to suppress the starlight from the system being observed... **Coronagraph**

- **Coronagraphic telescopes have:**
    - **Active optics**, to phase segments and shape the Wavefront (WF)
    - **Ultra-stable optics**, combining passive and active methods...
        - Stable materials, L2 environment, passive and active thermal control
        - WF Sensing and Control, metrology, actuators, DMs

- **Space telescopes in general have:**
    - **Vacuum** environment, with **sun** and **deep space** exposure

- **LUVOIR provides 2 architectural touchpoints...**

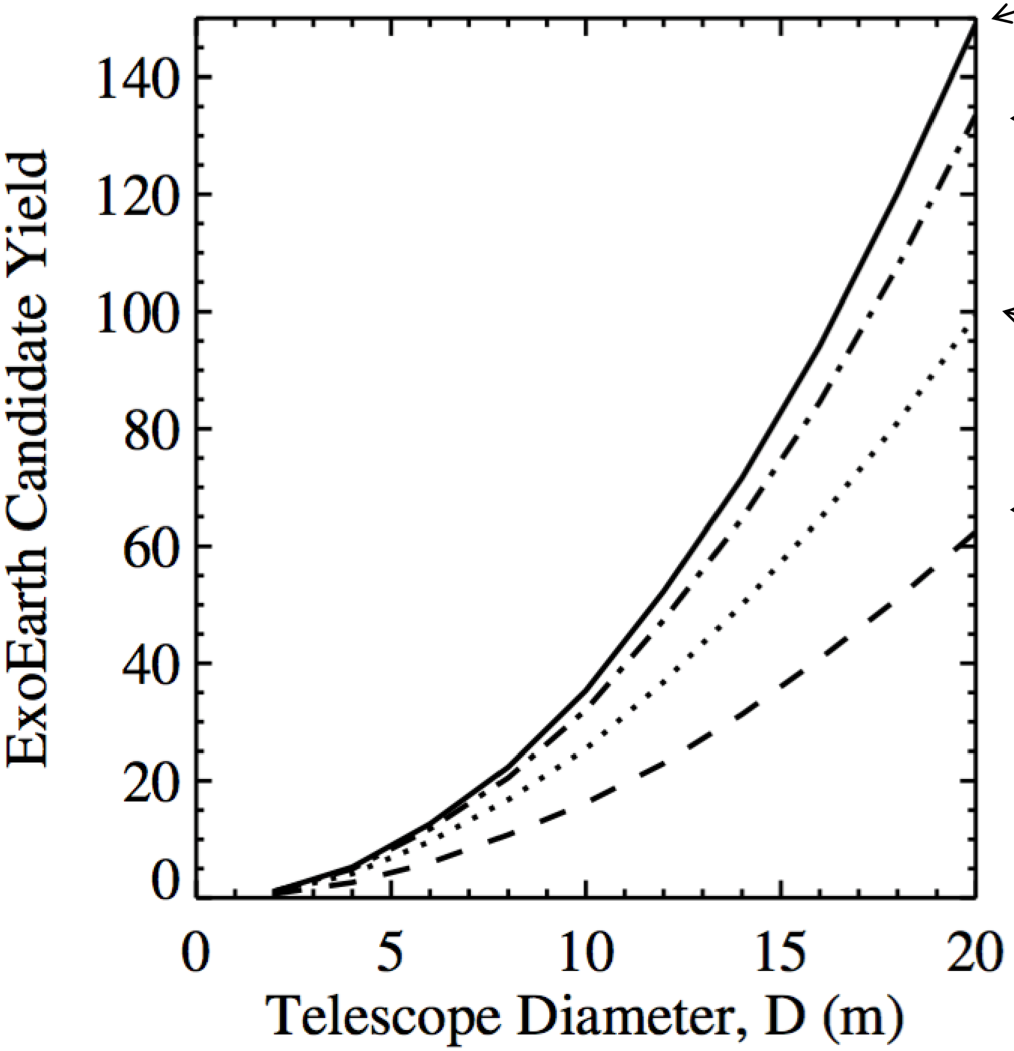
LUVOIR Architectures



- **LUVOIR A: 15 m on-axis**
  - On-axis JWST-derived configuration
  - Shielded from the Sun, then optics heated to 270K
  - Gimballed telescope
- **LUVOIR B: 8 m off-axis** (*preliminary*)
  - Off-axis config is better for coronagraphy
  - Primary mirror f/2.7: 20 m PM-SM separation

Exo-Earth Yields

(Stark et al, 2017 SPIE)



Detection Only

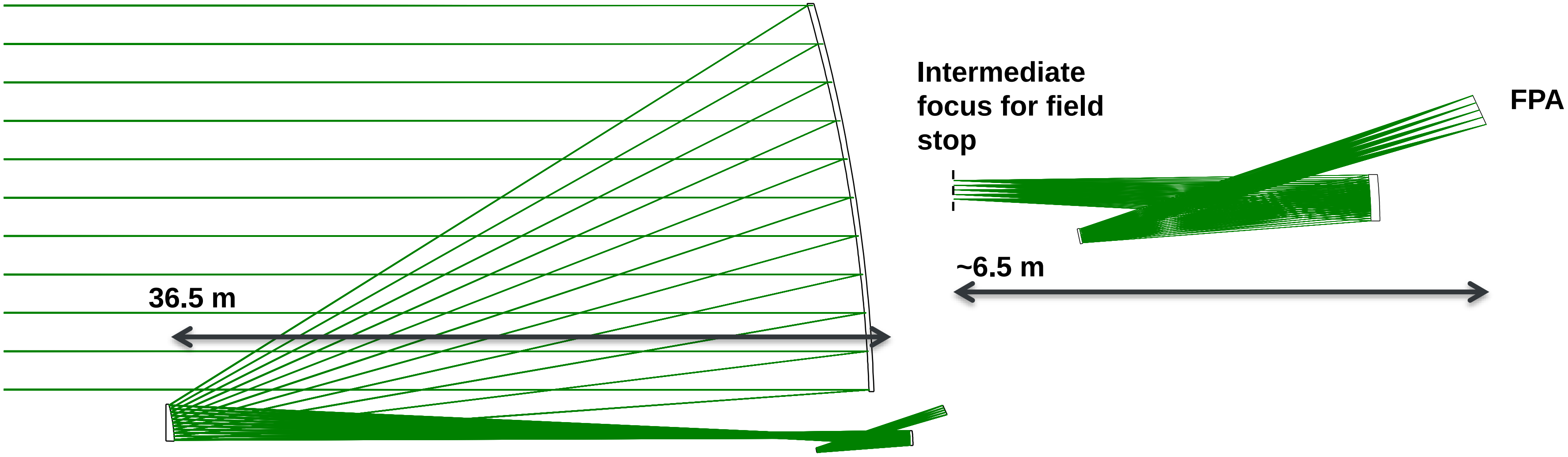
Detection + Orbit determination -> spectra of exoEarth candidates

2 Color Detection + Spectra on just the exoEarth candidates

Detection + Spectra after every observation

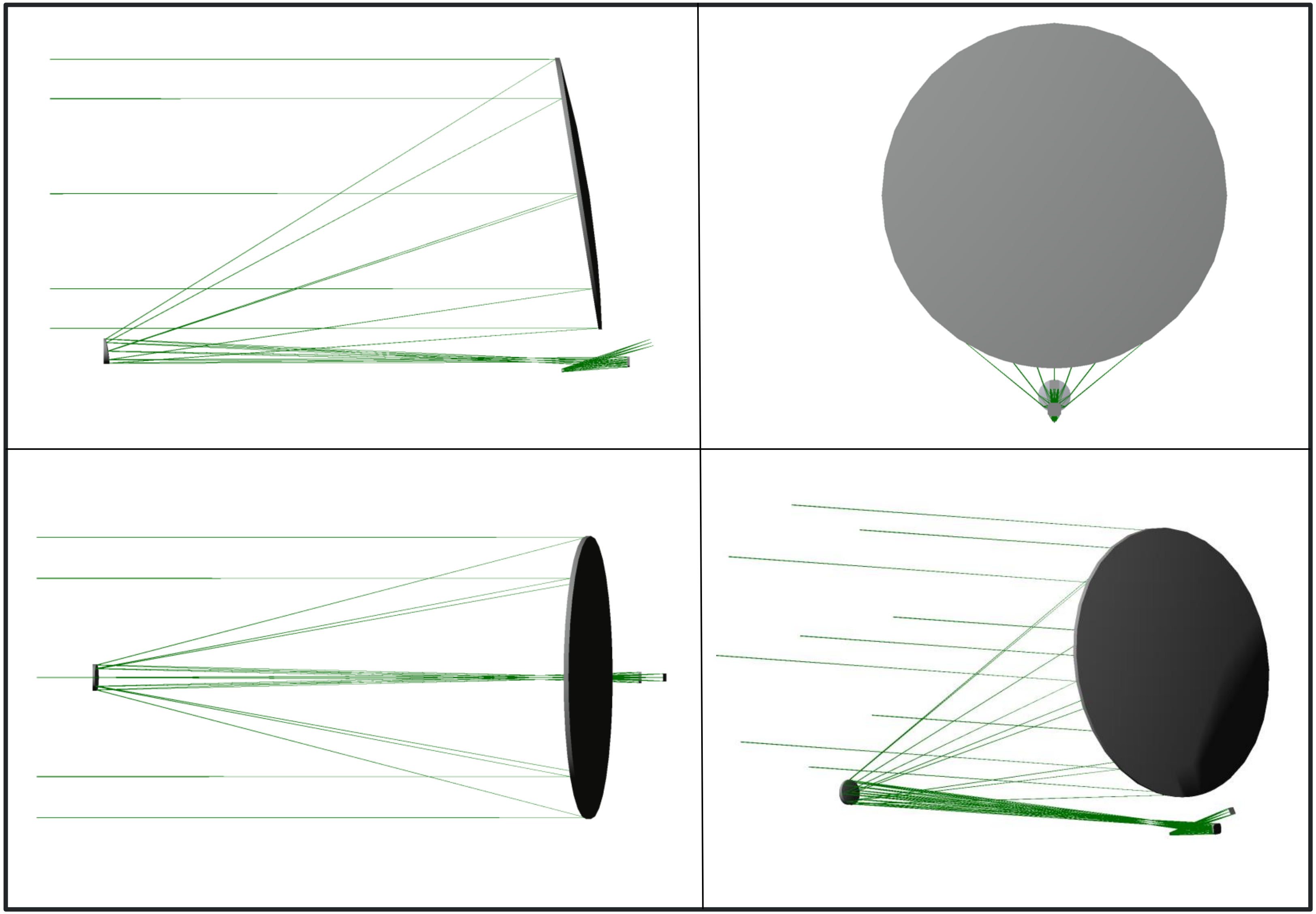
Off-Axis 20-Meter Optical Layout

.Candidate conceptual design



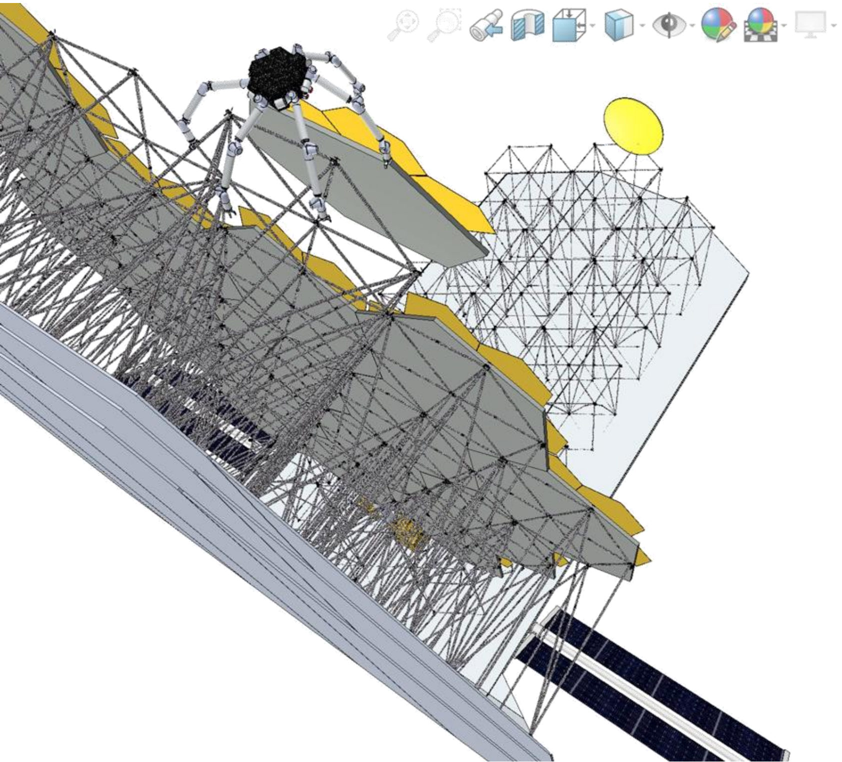
Parameter	Assumption
Entrance pupil diameter	20 meter
Field of View	3x3 arc-minute
Final F/#	F/30
Image size	530 x 530 mm (implied by EPD, F/#, and FOV)
Primary mirror ROC and F number	80 meter ; F/2.0
Primary-secondary spacing	36.5 meter
AOI, maximum on each mirror	16.0° primary; 17.5° secondary; 5.6°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

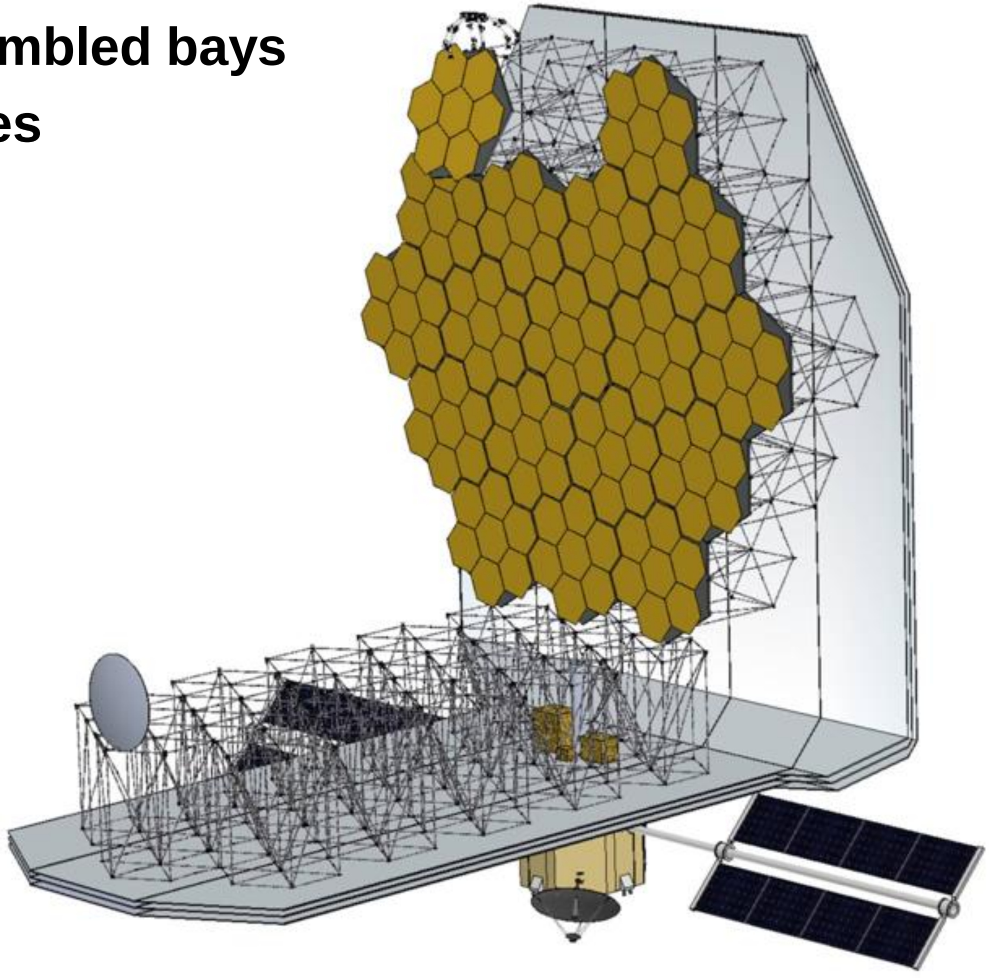
Different Views: Off-Axis 20-Meter Concept



Off-Axis Assembly Concept

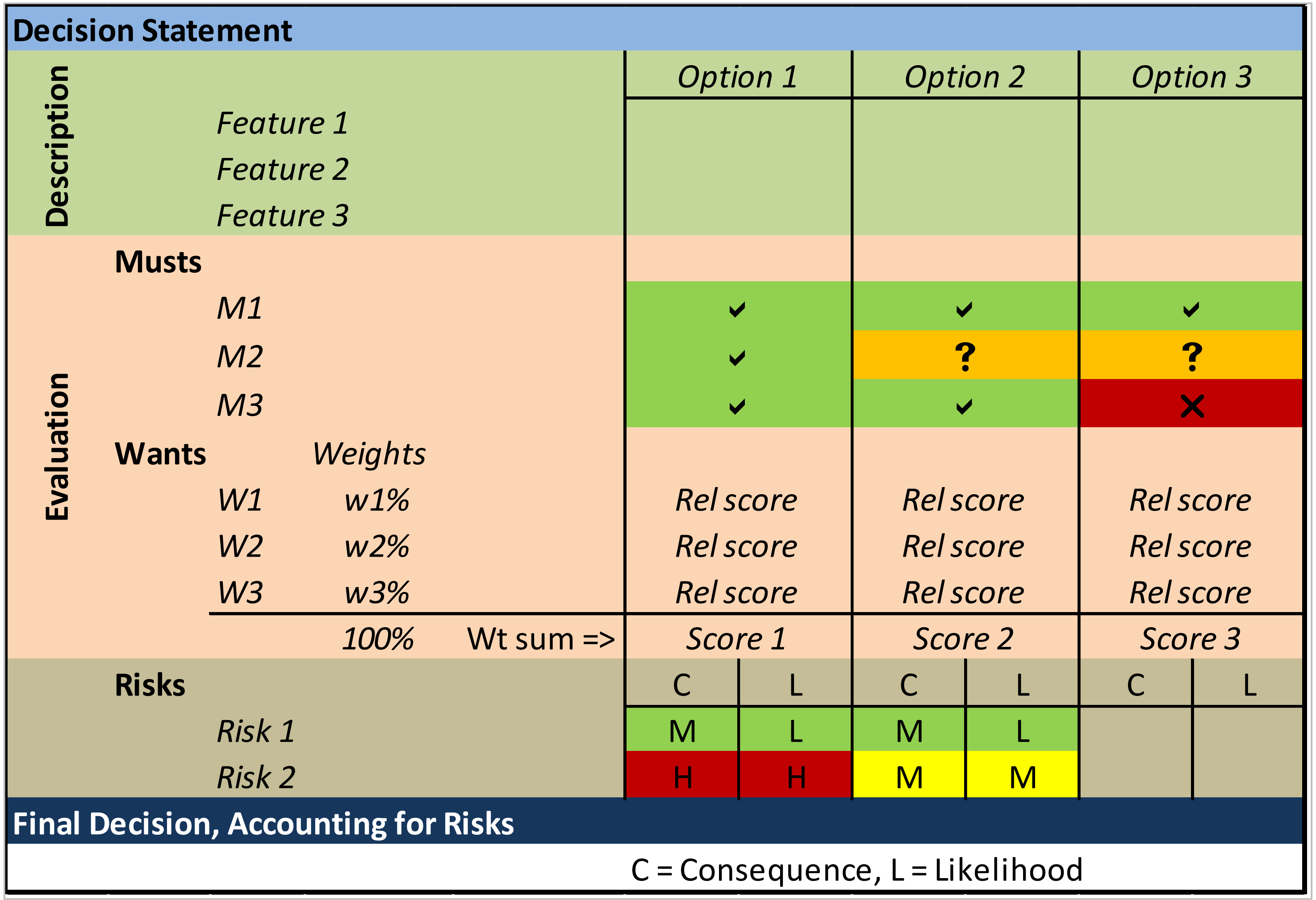
- PM optics in 6-segment modules
- Truss structure in pre-assembled bays
- Spider robot places modules





Very Short Tutorial on the Decision-Making Process

Features of Kepner-Tregoe Decision Process



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					

Begin Selection Criteria Brainstorming

(switch to Excel)

Next Steps

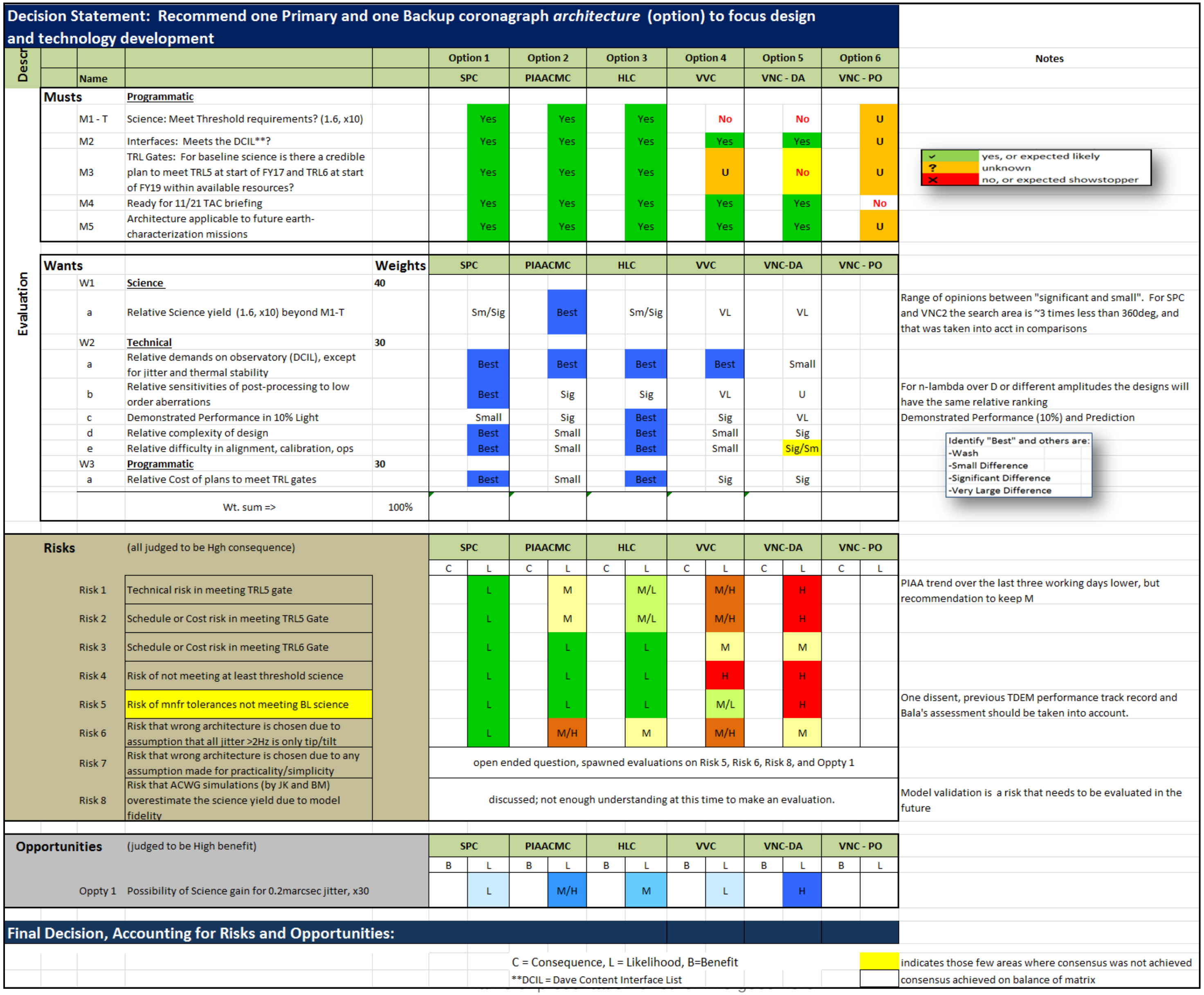
Next Steps

- **Telecon next week with the entire Working Group**
  - 5/22 and 5/24
  - Advance work on Selection Criteria

- **First Face-to-Face Workshop for the Working Group**
  - June 5-7 at Caltech
  - Focus is on Activity 1a: Designing and Architecting a Modularized Telescope
  - Draft Agenda completed
  - Breakout sessions

Additional Slides

Example of a Completed Trade Matrix



Decision Statement: Recommend one Primary and one Backup coronagraph *architecture* (option) to focus design and technology development

Descr	Name			Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Notes
				SPC	PIAACMC	HLC	VVC	VNC - DA	VNC - PO	
Musts		**Programmatic**								
	M1 - T	Science: Meet Threshold requirements? (1.6, x10)		Yes	Yes	Yes	No	No	U	
	M2	Interfaces: Meets the DCIL**?		Yes	Yes	Yes	Yes	Yes	U	
	M3	TRL Gates: For baseline science is there a credible plan to meet TRL5 at start of FY17 and TRL6 at start of FY19 within available resources?		Yes	Yes	Yes	U	No	U	
	M4	Ready for 11/21 TAC briefing		Yes	Yes	Yes	Yes	Yes	No	
	M5	Architecture applicable to future earth-characterization missions		Yes	Yes	Yes	Yes	Yes	U	

✓	yes, or expected likely
?	unknown
✕	no, or expected showstopper

Evaluation			Weights	SPC	PIAACMC	HLC	VVC	VNC-DA	VNC - PO	Notes
Wants										
	W1	**Science**	40							
	a	Relative Science yield (1.6, x10) beyond M1-T		Sm/Sig	Best	Sm/Sig	VL	VL		Range of opinions between "significant and small". For SPC and VNC2 the search area is ~3 times less than 360deg, and that was taken into acct in comparisons
	W2	**Technical**	30							
	a	Relative demands on observatory (DCIL), except for jitter and thermal stability		Best	Best	Best	Best	Small		
	b	Relative sensitivities of post-processing to low order aberrations		Best	Sig	Sig	VL	U		For n-lambda over D or different amplitudes the designs will have the same relative ranking
	c	Demonstrated Performance in 10% Light		Small	Sig	Best	Sig	VL		Demonstrated Performance (10%) and Prediction
	d	Relative complexity of design		Best	Small	Best	Small	Sig		
	e	Relative difficulty in alignment, calibration, ops		Best	Small	Best	Small	Sig/Sm		
	W3	**Programmatic**	30							
	a	Relative Cost of plans to meet TRL gates		Best	Small	Best	Sig	Sig		
		Wt. sum =>	100%							

Identify "Best" and others are:
-Wash
-Small Difference
-Significant Difference
-Very Large Difference

Risks	(all judged to be Hgh consequence)	SPC		PIAACMC		HLC		VVC		VNC-DA		VNC - PO		Notes
		C	L	C	L	C	L	C	L	C	L	C	L	
Risk 1	Technical risk in meeting TRL5 gate		L		M		M/L		M/H		H			PIAA trend over the last three working days lower, but recommendation to keep M
Risk 2	Schedule or Cost risk in meeting TRL5 Gate		L		M		M/L		M/H		H			
Risk 3	Schedule or Cost risk in meeting TRL6 Gate		L		L		L		M		M			
Risk 4	Risk of not meeting at least threshold science		L		L		L		H		H			
Risk 5	Risk of mnfr tolerances not meeting BL science		L		L		L		M/L		H			One dissent, previous TDEM performance track record and Bala's assessment should be taken into account.
Risk 6	Risk that wrong architecture is chosen due to assumption that all jitter >2Hz is only tip/tilt		L		M/H		M		M/H		M			
Risk 7	Risk that wrong architecture is chosen due to any assumption made for practicality/simplicity	open ended question, spawned evaluations on Risk 5, Risk 6, Risk 8, and Oppty 1												
Risk 8	Risk that ACWG simulations (by JK and BM) overestimate the science yield due to model fidelity	discussed; not enough understanding at this time to make an evaluation.												Model validation is a risk that needs to be evaluated in the future

Opportunities	(judged to be High benefit)	SPC		PIAACMC		HLC		VVC		VNC-DA		VNC - PO	
		B	L	B	L	B	L	B	L	B	L	B	L
Oppty 1	Possibility of Science gain for 0.2marcsec jitter, x30		L		M/H		M		L		H		

Final Decision, Accounting for Risks and Opportunities:

C = Consequence, L = Likelihood, B=Benefit

**DCIL = Dave Content Interface List

🟨	indicates those few areas where consensus was not achieved
☐	consensus achieved on balance of matrix

Comments on Reference Telescope

- **We need to select a reference telescope that we can use to explore the benefits of iSA (cost, risk, opportunities enabled).**
    - *Size, operating wavelength, aperture, operational temperature, etc.*
    - *“Parameterizable”*
- **So it doesn’t matter which telescope is selected as long as we don’t select one that is very unlikely or atypical.**
- **And we don’t want to design the telescope in this Study.**
- **Hence the need for a reference telescope**

Proposed Study Reference Telescope

1. **Operational destination is Sun-Earth L2**

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. **A high-contrast coronagraph will be the observatory instrument tasked to directly image and spectrally characterize Earth-sized planets.**
   - *The coronagraph will have the capability to actively sense and control input light wavefront errors due to all reasonable disturbance sources.*

4. **f/(>2) to reduce polarization effects to coronagraph performance**

5. **Off-axis secondary mirror (to assist coronagraph throughput and performance)**

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