Jet Propulsion Laboratory
California Institute of Technology

iSAT Proposed Description of Activity 2b:

Detailed Cost Estimate and Risk Assessment

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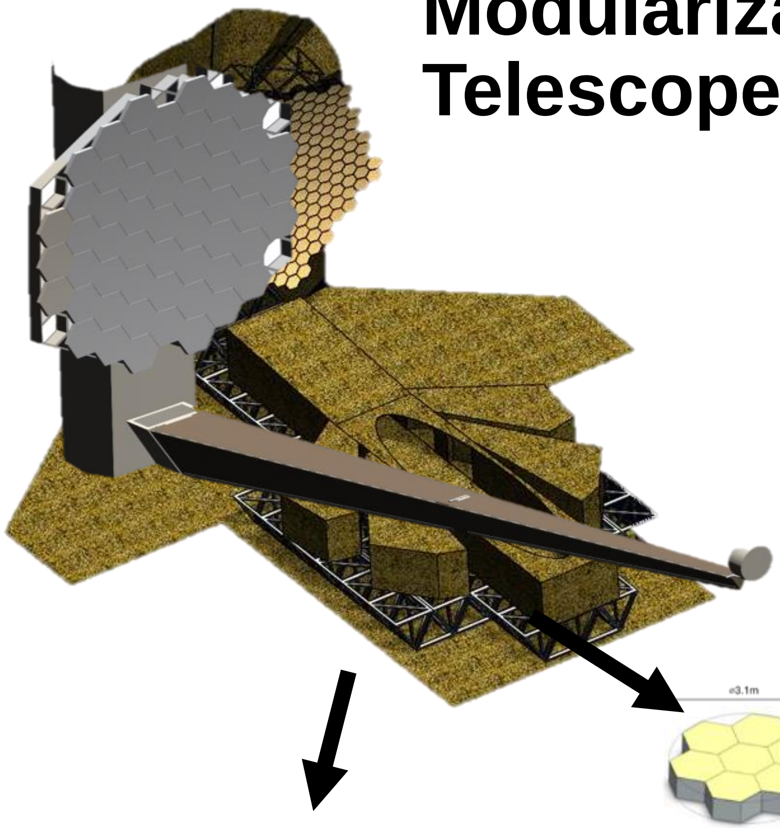
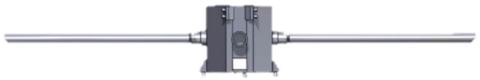
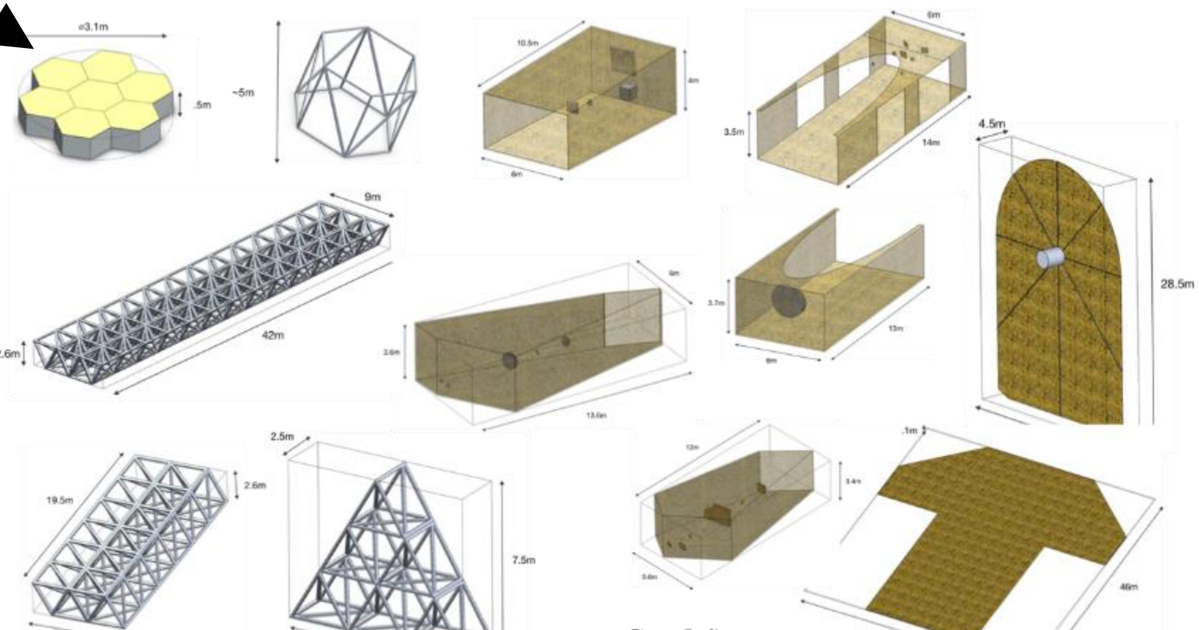
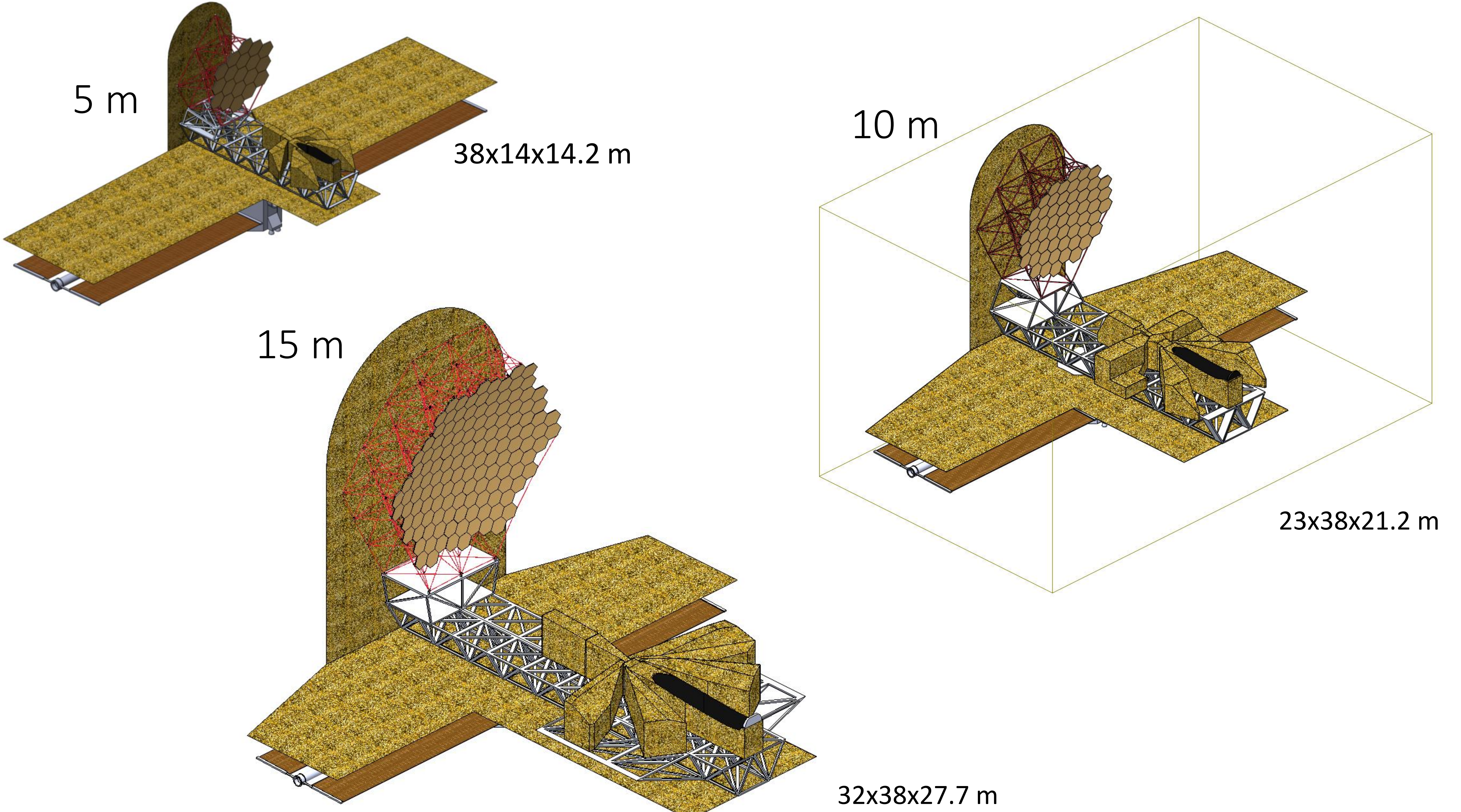
Modularization of a 20 m Space Telescope





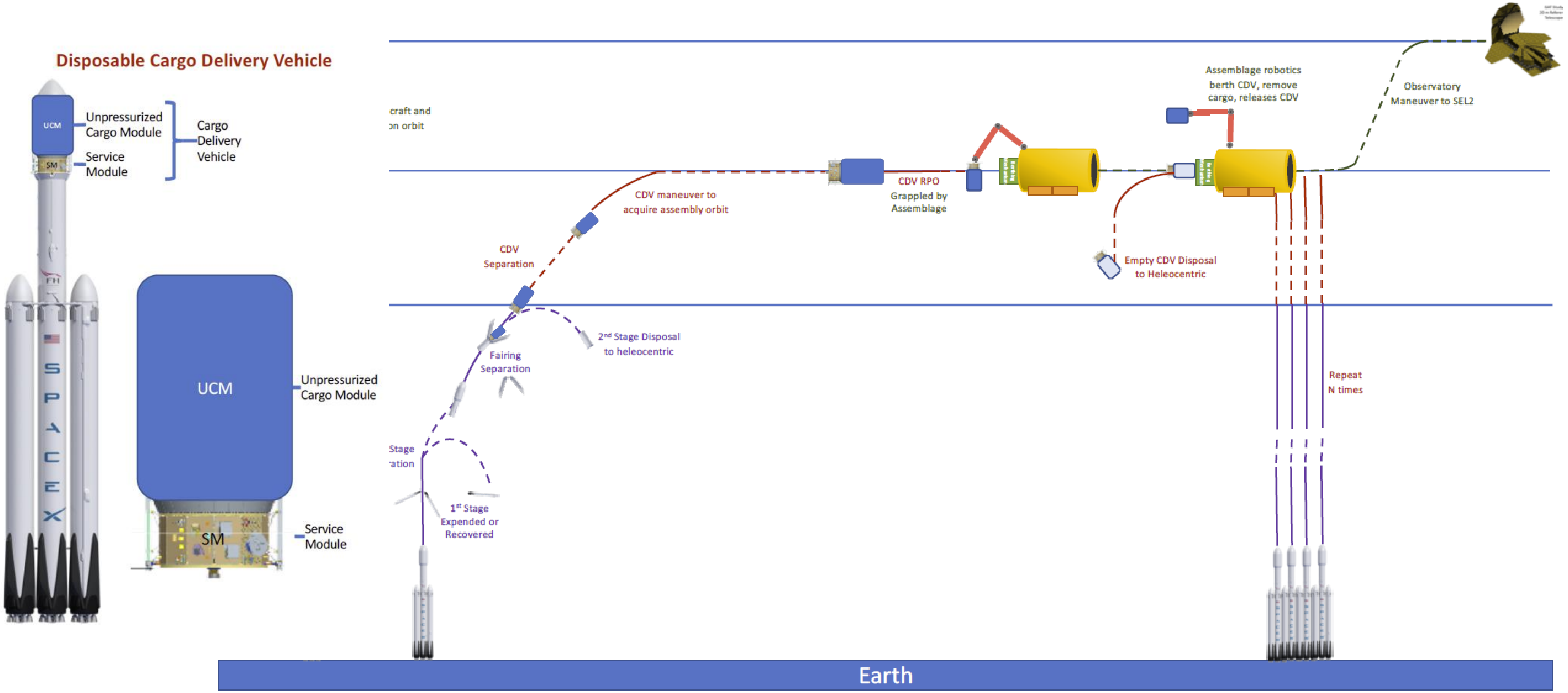


Picture Credit:
R. Mukherjee et. al., 2018


5 m
38x14x14.2 m
10 m
23x38x21.2 m
15 m
32x38x27.7 m

Delivery Via Disposable Cargo Delivery Vehicle

Preliminary Concept



Credit: Bo Naasz (NASA GSFC)

The Three Steps: Mutual Verification

(Activity 2a) The Subjective Effort: Non-quantitative, seeking insights by understanding parametric relations and interactions, creating high level “thesis and support” nuggets (6-8 weeks, 10-12 people)

(Activity 2b) The Detailed Effort: Grass-roots, high level planning and estimation exercise to develop, quantitatively, a cost estimate and development plan (16 weeks, 25-30 people)

The Concurrent Engineering Study: 3 half day sessions to review and update the findings of the detailed effort. Expectation of formalization of wrap factors and margins based on legacy data (3 half day sessions, 8-15 people)

If the findings of the three are mutually conflicting, we have a problem. If they converge, ballpark, then we can claim some verification of our plan and estimates

Overall Comments

This is not written in stone – it is due diligence planning

Prioritize completeness over fidelity – don't go more than one or two layers below your system definition

Ballpark and bound – don't sweat the third significant digit (may be even the second)

Think of it as a rapid fire session – project to your experience and your team members
    Be thorough and realistically frugal

Write early and write often – if it is not documented it did not exist

#1: How to describe the module?

Define your module scope and interfaces clearly

Create high level MEL at the level of next level of sub-systems within your module
    Estimate mass

Create high level PEL based on experience and estimation

Identify what "**must-do**" analyses are needed (e.g. FEA for structures) and communicate early to us

Interface with analyses team as needed

#2: What we need to do?

Create a high-level list of activities (10-15) that have to be done to develop and deliver your module

Consider including how many prototypes, breadboards, brassboards, EDU, EM and FM units

Consider NRE vs RE

#3: What is the V&V plan?

Note that there is no “full” system test and V&V on the ground

Create a list of various V&V activities that would be needed

- Identify additional ones, if any, needed due to the absence of “system” level V&V
- Consider MGSE and EGSE needed for these
- Consider facilities needed
- Consider need for robotics towards the V&V steps

State assumptions of interface elements needed for V&V and their expected schedule

Consider NRE Vs RE

#4 What resources are needed?

Refer to high level list of activities and create a high level workforce plan – ballpark

- Create the skinny, good and Xmas estimates
- Focus on your module only

Consider what fabrication, testing, legacy elements and other facilities may be needed

Consider NRE vs RE

How would you put a dollar value on resources needed?

#5 What is the schedule?

Considering the activities and resources, create estimates of time needed for the different activities, how they may be phased and what ”new” reviews may be needed

Create a notional schedule with KDPs

- Clearly show assumptions of deliverables from interface elements
- Clearly state assumptions of resource availability

Develop the skinny, good and Xmas schedules

- Consider NRE vs RE

#1: How to describe the module/scope?

#2: What are the activities in Phase A-E?

#3: What is the V&V plan?

#4 What resources are needed?

#5 What is the schedule?

Work Products:

a) List of activities in phases A-E
b) Corresponding schedule for Phase A-E
c) Resource plan including MGSE, ESGE, Labor etc.
d) MEL, PEL
e) Identify NRE and RE

Alternate Approach

Week Of	Objective
Nov 26	Team Formation, Study Definition
Dec 3	Kick off – Initial team meetings
Dec 10	Interface Definition and Scope Discussions
Dec 17	Interface Definition and Scope Finalization
Jan 7	First Iteration on Phase A-E Plan begins (for 6 weeks)
Feb 11	Conclude first iteration: Deliverable: Initial Phase A-E Plan on Feb 15
Feb 18	Systems level plan development
Feb 25	End System level plan: Deliverable: Overall Phase A-E plan due March 1st
Mar 4	Second iteration of Phase A-E (for 3 weeks)
Mar 18	Conclude Phase A-E plans: Deliverable: Overall plan due Mar 22nd
Mar 25	System level finalization of Phase A-E plan
Apr 1	Schedule Margin 1
Apr 8	Schedule Margin 2: **Last Day: April 12**

Writing Schedule

#	Week Of	Objective
1	Apr 15	Start Draft: PPTX and Doc of team findings
2	Apr 22	Deliverable: Above, end of week
3	Apr 29	Start first “Formal” draft of DSP – based on continual absorption draft
4	May 6	WIP
5	May 13	**Deliverable:** First formal draft of DSP at week’s end
6	May 20	Reviews, Edits and Iterations
7	May 27	**Deliverable:** First draft to Sponsor at Week’s end
8	Jun 3	Inputs and Iterations
9	Jun 10	Inputs and Iterations: **Deliverable:** Submission to Decadal Survey

Optical Elements

Name	Org
Keith Havey	Harris
David Redding	JPL
Allison Barto	Ball
Alison Nordt	LM
Alireza Azizi	JPL
Raymond Ohl	GSFC

Robotics

Name	Org
John Lymer	SSL
Glen Henshaw	NRL
Paul Backes	JPL
Brian Roberts	GSFC
Ken Ruta	JSC

Launch and Rendezvous

Name	Org
Mike Fuller	NG
Bo Naasz	GSFC
Dave Folta	GSFC
Diane Davis	JSC
Ryan Whitley	JSC
Diana Calera	KSC
John Ringelberg	LM

Systems Engineering

Name	Org
Allison Barto	Ball
Paul Lightsey	Ball
Doug McGuffee	GSFC
Al Nash	JPL

Spacecraft

Name	Org
Al Tadros	SSL
Stu Wiens	LM

Structures and Joining Means

Name	Org
Kevin Patton	NG
Bill Doggett	LaRC
Bob Hellekson	NG
John Dorsey	LaRC

Sunshade and Thermal Eng.

Name	Org
Kim Mehalick	GSFC
Jon Arenberg	NG

Optical Elements - Scope

The Team is responsible for **delivering to the launch vehicle**:

- Rafts that make the primary mirror
- The secondary mirror
- Any tertiary mirrors that are not part of other instruments
- All avionics needed, actuators and sensors
- Metrology for optical performance (separate from metrology from structural performance)
- Harnesses
- Structure for the elements
- Robotic grappling fixture
- Interface(s) for robotic assembly to structure: assume power, comm and fluidic (thermal) interface
- Software for these elements and optical performance
- Compute element
- Heaters or heat dissipation (fluid loop?)
- Launch locks
- Contamination mitigators
- Any other?

Interfaces

- Robotics team for grapple
- Structures team for assembly interface (joint)
- Sunshade and thermal team for thermal management approach
- Any other?

Structures and Joining - Scope

The Team is responsible for **delivering to the launch vehicle**:

- Deployable truss modules for the backplane
- Metering truss(es)
- Trusses for the instruments
- Interface between metering and backplane truss
- Interface to spacecraft including any vibration or thermal isolation
- Grappling fixtures for robot interface
- Joining interfaces for assembly that pass through power, comm and fluids
- Assume harnesses are intrinsic to modules and no external explicit harness
- Structural metrology to show accuracy of assembly
- Soft goods to hard goods interfaces for any blanketing or stray light blockage – interface with sunshade team
- Launch locks
- Contamination mitigators
- Any other?

Interfaces

- Robotics team for grapple
- Optical element team for assembly interface (joint)
- Sunshade and thermal team for thermal management approach
- Any other?

Sunshade and Thermal Management - Scope

The Team is responsible for **delivering to the launch vehicle**:

- Stowed sunshade elements in boxes for deployment in space
- All relevant hardware for in-space autonomous deployment
- Interface(s) for robotic grapple
- Interfaces(s) for robotic assembly to structure
- Any and all subsystems needed for the system level thermal management (e.g. pumps, radiators, heaters etc)
- Any other?

Interfaces

- Optical team
- Structures team
- Any other?

Robotics - Scope

The Team is responsible for **delivering to the launch vehicle**:

- Robotic arm(s) and end effectors, and relevant components (e.g. harness etc.)
- Perception sensors and any illuminators etc.
- Avionics for the robots
- Autonomy and motion control software for robotics
- Launch locks

The Team is responsible for **delivering MGSE and EGSE**:

- Test beds needed for any of the other subsystem teams
- Test beds to include hardware and software

The Team is responsible for **in-space, autonomous (low bandwidth) robotics:**

- Assembly of structure to desired performance, including nominal behaviors and adjustments
- Assembly of sunshade elements (boxes, not soft goods)
- Assembly of mirror rafts
- Assembly of secondary and instruments (treat instruments akin to secondary)
- Ground System

Interfaces

- Structure team for interface
- Optical element team for assembly interface (joint)
- Sunshade team for interface
- Any other?

Launch and Rendezvous - Scope

The Team is responsible for:

- Launch vehicles
- Launch vehicle integration of all subsystems
- Fairing and magazines
- All process costs for launches
- Rendezvous and proximity sensors
- Delivery vehicle: Intelligent upper stage or space tug
- Interfaces for autonomous robotic berthing
- Interfaces for autonomous docking
- Software for autonomous RPO for delivery vehicle
- Ground systems and related software
- Any other?

Interfaces

- All other teams for launch delivery
- Robotics team for in-space activities

Spacecraft - Scope

The Team is responsible for:
- The spacecraft bus with usual apps (ACS, pointing, comm, compute etc.)
- Power system for the observatory
- Interface to the structure
- Stack control with delivery vehicle and moving robot + modules
- RPO sensor suite
- RPO software
- Refueling interface
- Transfer from cis-Lunar orbit to ES-L2
- Robot control interface
- Communications between all subsystems of observatory
- On-board computer and software for OTA assembly, operations and servicing
- Interface to ground and on-board sequencing etc.
- Any other

Interfaces
- All other teams
- Robotics team for in-space activities

Systems Engineering - Scope

The Team is responsible for:

- Flight system engineering activities from Phase A-D
- In-space integration and test activities, V&V
- Schedule, MEL, PEL
- Interface tracking and completeness
- All other?

Interfaces

- All other teams

Action Items

Hold a team meeting - **before Dec 14th**

Complete scope definition chart(s) - **before Dec 14th**

Identify interfaces and create a list - **before Dec 20th**

Team leads formulate process of how they will facilitate the activity – **update thoughts in next telecon**

Send Nick and Rudra two time slots for 1hr weekly team meeting based on team availability - **by Dec 10th**

- Weekly team meetings to begin Jan 7th

Would like to move to one meeting for the team next two weeks. Could we do Wednesday?