Cost Estimation

ISA will incur additional cost compared to a conventional, single launch observatory. These include:

- Modularity, multiple launches, cargo delivery vehicles, rendezvous and proximity operations, assembly robotics

ISA will likely offer opportunities for cost savings in the development of flight system elements such as the telescope, instruments, spacecraft

- These elements typically represent 60-70% of mission costs. Hence, this can be a source of significant savings.
- Flight system assembly, I&T are other areas of potential savings.

→ What is the net effect?

Relative cost comparison between single-launch vehicle observatory and iSAT. Green represents WBS elements where ISA may provide cost benefits while red represents elements where ISA may have a cost increase in comparison to a conventional, single-launch approach

WBS 1-3 Mng. SE. SMA	WBS 4 SCI	WBS 5.1 Telescope Structure	WBS 5.2 Telescope Optics	WBS 5.3 Sunshade	WBS 5.4 Inst	WBS 5.5 Robotics	WBS 6 SC	WBS 7-9 MOS/GDS	LV	CDV	Ops	WBS 10 SI&T

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

CL#19-4130

These cost estimates and approaches are from the iSAT Study and have not been reviewed by JPL for institutional approval.

Cost Estimation

Developed and compared estimates of conventional single-launch vs ISA same architecture but 3 different aperture size (5, 10, 15m).

Used current cost models for conventionally developed observatories

- an architectural study undertaken by JPL's A-Team
- Same MEL as ISA
- CERs using established models
- and scaling laws

Our Study conducted a grass roots cost estimation for ISA

- detailed phase A-E plan,
- schedule,
- MEL, PEL,
- launch manifest
- resource plans

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

These cost estimates and approaches are from the iSAT Study and have not been reviewed by JPL for institutional approval.

Estimating Conventional Single Launch Costs

Using Traditional Cost Models

WBS/Element	Title	Calculation Method (Inputs)
1	Project Management (PM)	% (of 5A, 5B, 6A, 6B, 6C costs) – w/ % stretched operations for ISATs
2	Project Systems Engineering (PSE)	% (of 5A, 5B, 6A, 6B, 6C costs) – w/ % stretched operations for ISATs
3	Safety & Mission Assurance (SMA)	% (of 5A, 5B, 6A, 6B, 6C costs) – w/ % stretched operations for ISATs
4	Science (SCI)	% (of 5B Costs Only)
5A	Optical Telescope Element (OTE)	Phil Stahl Model (Dia., Temp., Diffraction wavelength, Segment Size) 15% reduction for ISAT (no full scale I&T on the ground)
5B	Instrument(s) Element (IE)	NASA Instrument Cost Model aka NICM (mass, power, type)
6A	Spacecraft Element (SCE)	$/kg (SCE mass) SCE mass as % of (mass of : OTE, IE, & RAE) OTE mass scaled as a power of the aperture from JWST mass
6B	Robotic Assembly Element (RAE)	Weighted $/kg Structure Cost Estimating Relationship from SMAD for Structure Spacecraft Cost Estimating Relationship from SMAD for "Smart Mass"
6C	Cargo Delivery Element (CDE)	$/kg (mass scaled from CYGNUS by cargo carrying capacity) 85% learning curve assumed for multiple units
7	Mission Operations System (MOS)	% (of 5A, 5B, 6A, 6B, 6C costs) – w/ % stretched operations for ISATs
8	Launch Vehicle Services (LVS)	LSP Catalog. # of launches based on Mass Only [no volume considerations]
9A	Ground Data System (GDS)	% (of 5A, 5B, 6A, 6B, 6C costs) – w/ % stretched operations for ISATs
9B	Science Data System (SDS)	% (of 5B costs Only) – w/ % stretched operations for ISATs
10	Systems Integration & Test (SI&T)	% of costs of elements integrated on the ground 5A, 5B, 6A, & 6B for GOATs 6A, & 6B only for ISATs
	Reserves	% of everything above EXCEPT WBS 8 Launch Vehicle Services
	TOTAL	Total of everything above

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

These cost estimates and approaches are from the iSAT Study and have not been reviewed by JPL for institutional approval.

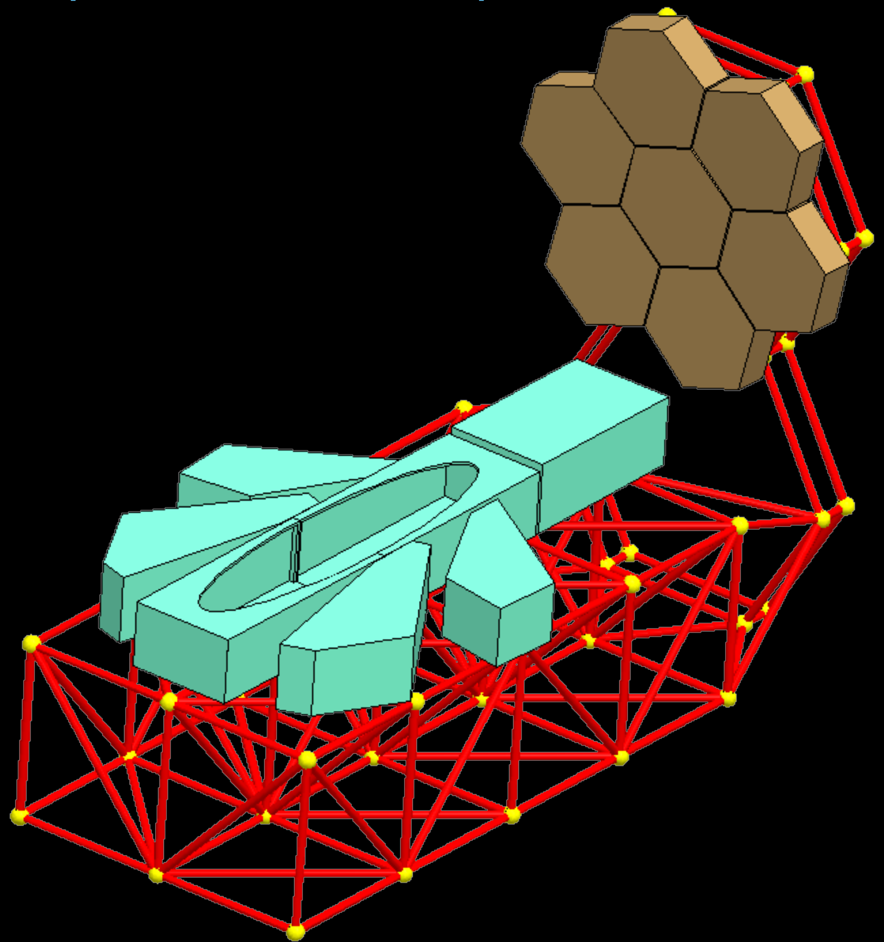
iSAT Grass Roots Estimation

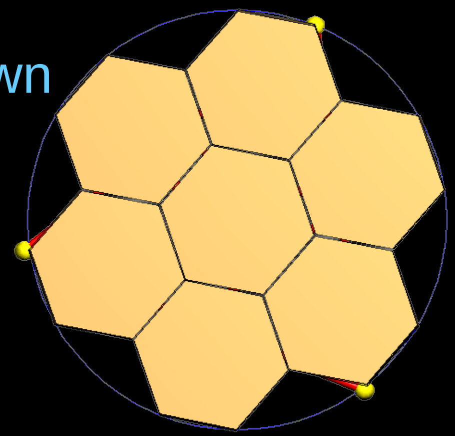
WBS Element	Basis of Estimate
WBS 1-3: Proj. Mgmt, Sys Eng (incl. Mission Design), SMA	Cost-to-Cost Ratio Based on Flagship class missions
WBS 4: Science	Cost-to-Cost Ratio Based on Flagship class missions
WBS 5.1 Telescope Structure	Grass roots for labor, per unit non-labor estimates:**$10M**
WBS 5.2 Telescope Optics	Grass roots for labor, per unit non-labor estimates: **$100M**
WBS 5.3 Telescope Sunshade	Grass roots for labor, per unit non-labor estimates: **30%** of labor
WBS 5.4 Instruments	CADRe based on analogues (HDI, ECLIPS, LUMOS, Pollux)
WBS 5.5 Robotics (2 arms)	Labor: Grass roots for labor, analogues (Gateway, Restore-L, RSGS, Mars), Non-Labor: estimate of **$100M** per arm
WBS 6: Spacecraft	Grass roots estimate, **$1B, $1.5B** and **$2B** for 3 sizes
WBS 7 & 9: MOS/GDS	Cost-to-Cost Ratio Based on Flagship class missions
Reserves	Consistent with A-Team (30%). Does not include LV and CDS,
WBS 8.1 Launch Systems	Input from NASA Launch Service Program (NLSII PPBE input)
WBS8.2 Cargo Delivery Vehicle	Grass roots estimate from analogues (Cygnus, Dragon)
Operations	$80M/year assembly ops cost added to mission operations
Servicer	From Analogues (DARPA RSGS and Restore-L)
Tech Dev and Pre-Phase A	**Did Not Estimate**

- Used $500k per person per year for labor; unit modules for truss and optics shown in next slide
- Multiplied labor estimates by factor of 2 to account for optimism in grass roots i.e. 100% margin for all three sizes
- Includes scaling effect with aperture size on non-labor costs, including materials
- Does not include learning curve for repeat modules

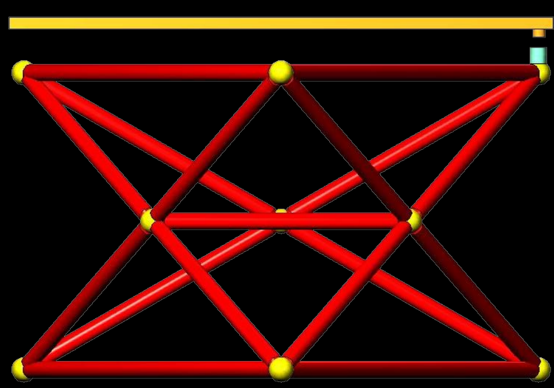
What is a unit module?

Example of truss and optical unit module are shown





Unit Module for Optical Raft



Unit Module for Truss

Grass Roots Costing
Creating List of Representative Activities

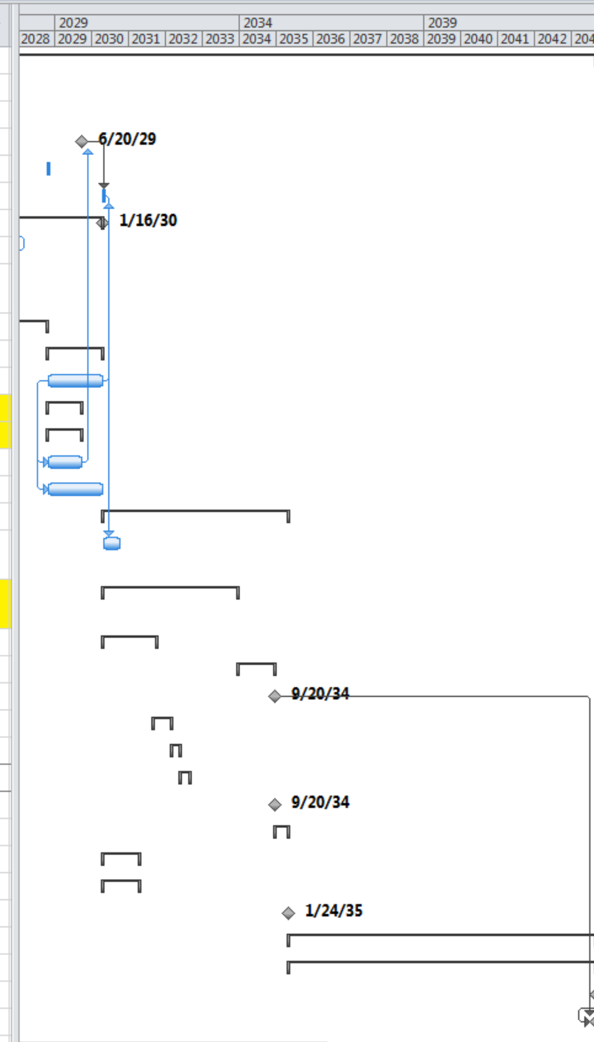
Example of Activities Per Phase shown for Thermal Subsystem

Thermal ICD, thermal specification finalization
Thermal Subsystem Risks, waivers and/or deviation status
Technology development tested and completed
Detailed Spacecraft Thermal Design/Architecture
Thermal model including simplified components with corresponding power
Finalized trade studies and outcomes for Spacecraft/Observatory
Thermal Analyses for Observatory utilizing flight orbit for full complement of cases including Launch, ascent, early operations and/or transition orbits
Thermal Predictions for Spacecraft and Observatory (temperature, heater power, gradients, etc.)
Integrated Modeling (STOP) Thermal inputs for bounding cases
Early delivery of Spacecraft model/boundaries for OTE and Instrument Analyses
Preliminary Thermal Vacuum and Balance Tests configurations and concepts identified including required GSE and facilities
Thermal Hardware identified (MLI, heaters, sensors, heat pipes, etc.) including installation process and testing identified
Mass estimates

Grass Roots Estimation: Creating a Notional Payload Schedule

Example of a Schedule per Payload Element

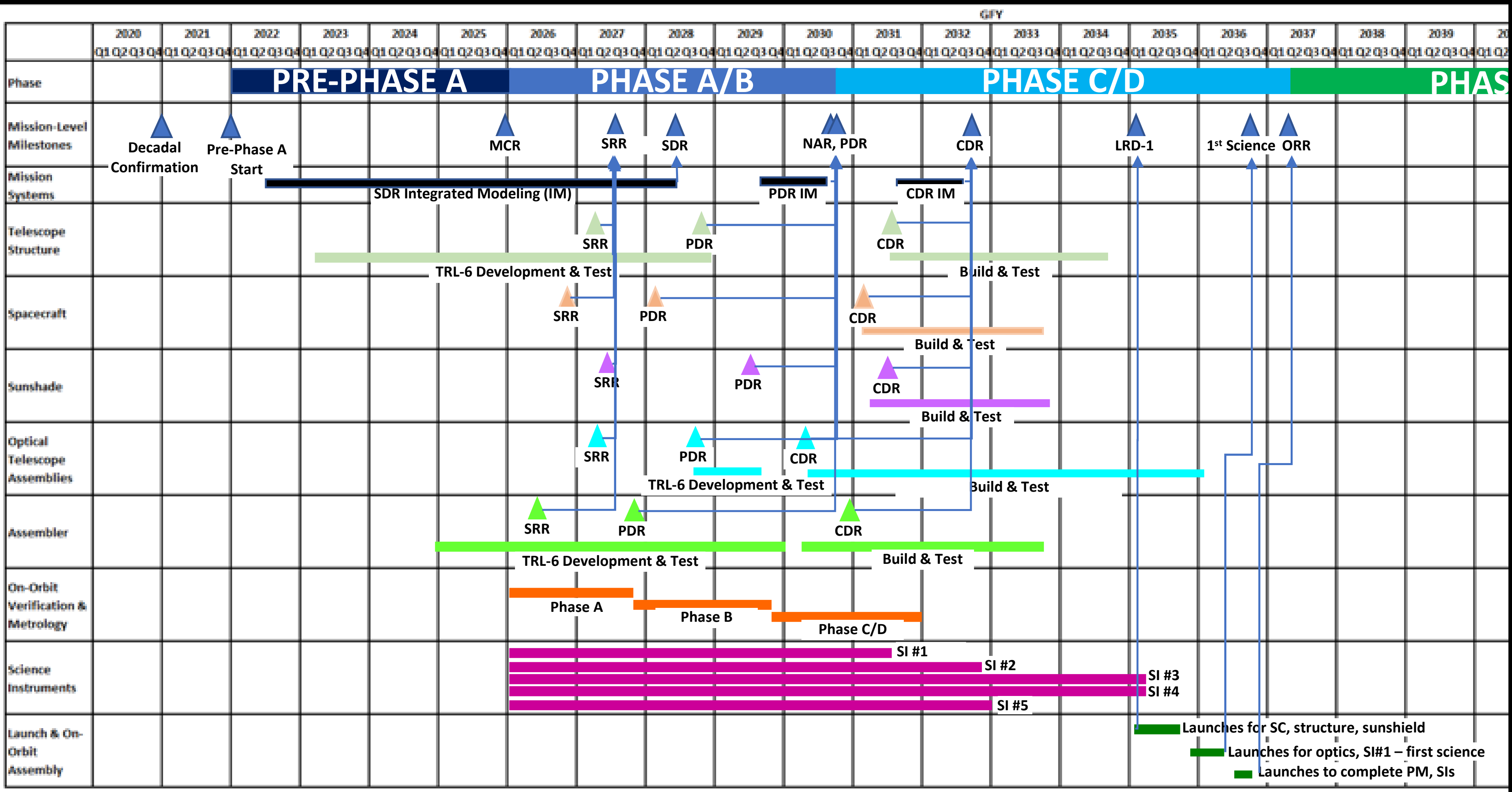
WBS	Task Name	Duration	Total Slack	Start	Finish
1.5	**iSAT Optical Telescope Assemblies**	**4607 days**	**528 days**	**Wed 10/1/25**	**Thu 5/28/43**
1.5.1	OTE Program Start	0 days	761 days	Wed 10/1/25	Wed 10/1/25
1.5.2	OTE SRR	1 day	761 days	Wed 1/20/27	Wed 1/20/27
1.5.3	OTE TRL-6 Demo Complete	0 days	911 days	Wed 6/20/29	Wed 6/20/29
1.5.4	OTE PDR	1 day	1893 days	Thu 7/20/28	Thu 7/20/28
1.5.5	OTE CDR	1 day	761 days	Thu 1/17/30	Thu 1/17/30
1.5.6	**OTE Phase A/B**	**1121 days**	**761 days**	**Wed 10/1/25**	**Wed 1/16/30**
1.5.6.1	Level 1 > 2 > 3 OTE Concept & Requirements	520 days	761 days	Wed 10/1/25	Tue 9/28/27
1.5.6.2	Risk Reduction Studies (Latches, metrology, RBA, production)	520 days	972 days	Wed 10/1/25	Tue 9/28/27
1.5.6.3	**PDR Phase**	**390 days**	**761 days**	**Thu 1/21/27**	**Wed 7/19/28**
1.5.6.4	**CDR Phase**	**390 days**	**761 days**	**Thu 7/20/28**	**Wed 1/16/30**
1.5.6.4.1	Final OTE Subsystems Design	390 days	761 days	Thu 7/20/28	Wed 1/16/30
1.5.6.4.2	**EM Technology Demonstrations**	**240 days**	**911 days**	**Thu 7/20/28**	**Wed 6/20/29**
1.5.6.4.2.1	**PMSA**	**240 days**	**911 days**	**Thu 7/20/28**	**Wed 6/20/29**
1.5.6.4.2.2	EM Latches, System Metrology	240 days	911 days	Thu 7/20/28	Wed 6/20/29
1.5.6.4.3	Production Lines Design and Long Lead Procure	390 days	4014 days	Thu 7/20/28	Wed 1/16/30
1.5.7	**OTE Production (Rafts 1-3, SMA, Aft Optics)**	**1309 days**	**761 days**	**Thu 1/17/30**	**Wed 1/24/35**
1.5.7.1	Complete parallel production lines (single line is ready)	120 days	810 days	Fri 1/18/30	Thu 7/4/30
1.5.7.2	**Multi-RAFT Assembly & Handling Pathfinder (1 EM raft, 2 simulators)**	**953 days**	**168 days**	**Thu 1/17/30**	**Tue 9/13/33**
1.5.7.3	**Raft #1 Subassemblies**	**381 days**	**761 days**	**Fri 1/18/30**	**Fri 7/4/31**
1.5.7.4	**Raft #1 Assembly Integration & Test**	**266 days**	**168 days**	**Wed 9/14/33**	**Wed 9/20/34**
1.5.7.5	End of 5m Program	0 days	2794 days	Wed 9/20/34	Wed 9/20/34
1.5.7.6	**Raft #2 Subassemblies**	**126 days**	**767 days**	**Fri 6/6/31**	**Fri 11/28/31**
1.5.7.7	**Raft #2 Assembly Integration & Test**	**64 days**	**767 days**	**Mon 12/1/31**	**Thu 2/26/32**
1.5.7.8	**Raft #3 All Elements**	**70 days**	**767 days**	**Fri 2/27/32**	**Thu 6/3/32**
1.5.7.9	Completion of RAFTS 1-3 I&T (milestone)	0 days	168 days	Wed 9/20/34	Wed 9/20/34
1.5.7.10	**Multi-Raft Assembly Demonstrations**	**90 days**	**168 days**	**Thu 9/21/34**	**Wed 1/24/35**
1.5.7.11	**Secondary Mirror Assembly**	**260 days**	**1217 days**	**Fri 1/18/30**	**Thu 1/16/31**
1.5.7.12	**Aft Optics & Instrument Interface**	**260 days**	**1217 days**	**Fri 1/18/30**	**Thu 1/16/31**
1.5.8	Initial Phase Complete (Rafts 1-3, SMA, Aft Optics)	0 days	168 days	Wed 1/24/35	Wed 1/24/35
1.5.9	**OTE Final Production (10m , 15m, 20m)**	**2176 days**	**168 days**	**Thu 1/25/35**	**Thu 5/28/43**
1.5.9.1	**Final Production Phase (20m / rafts 4-37)**	**2176 days**	**168 days**	**Thu 1/25/35**	**Thu 5/28/43**
1.5.9.2	20m OTE Production Complete	0 days	528 days	Thu 5/28/43	Thu 5/28/43
1.5.10	OTE Program Complete	0 days	528 days	Thu 5/28/43	Thu 5/28/43
1.6	**iSAT Assemblies**	**3740 days**	**1036 days**	**Fri 10/1/31**	**Thu 1/21/36**



The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.
These cost estimates and approaches are from the iSAT Study and have not been reviewed by JPL for institutional approval.

Grass Roots Estimation: Creating a Notional Overall Schedule

Example of a Schedule per Payload Element



Grass Roots Estimation:
Creating a Notional MEL