



PACE 2012

Price - H Cost Modeling

10 June, 2012

"If all the economists were laid end to end, they'd never reach a conclusion."
George Bernard Shaw

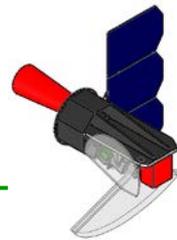


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Parametric Cost Estimating Tools

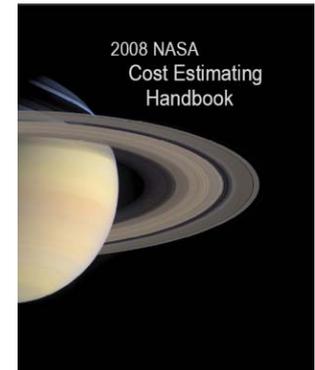


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- **NASA Cost Estimating Handbook 2008 describes two commercial tools**

- **PRICE: Parametric Review of Information for Costing and Evaluation**

- Separate modules for Hardware, Software, Integrated Circuits, and Life Cycle
- PRICE H (Hardware) approaches cost estimates by parametrically defining:
 - Hardware to be built
 - Development and manufacturing environments
 - Operational environment
 - Schedule
- PRICE H model is built from key engineering data (e.g., MEL: Master Equipment List)
- Tool Heritage: Developed by RCA in the 1960's for the U.S. NAVY, Air force & NASA; Commercialized by PRICE Systems, L.L.C.
- NASA-wide site license for PRICE H managed by Langley Research Center (GSFC Contact: Dedra Billings, Code 305.0, e-mail: Dedra.S.Billings@nasa.gov)
- PRICE H use at GSFC:
 - MDL (and former IMDC), 10+ years experience and 100+ S/C Bus models
 - Instrument Design Lab (and former ISAL), 6+ years experience and 70+ Instrument models
 - Code 600, 10+ years experience, 50+ S/C Bus and 50+ Instrument models

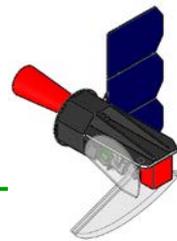


- **SEER: System Evaluation & Estimation of Resources**

- Separate modules for Hardware, Software, Integrated Circuits, Manufacturability and Life Cycle
- NASA-wide site license for SEER managed by Langley Research Center
- Application-specific use of SEER-H at GSFC (e.g., detectors, cryocoolers, etc.)



Cost Methodology Selection



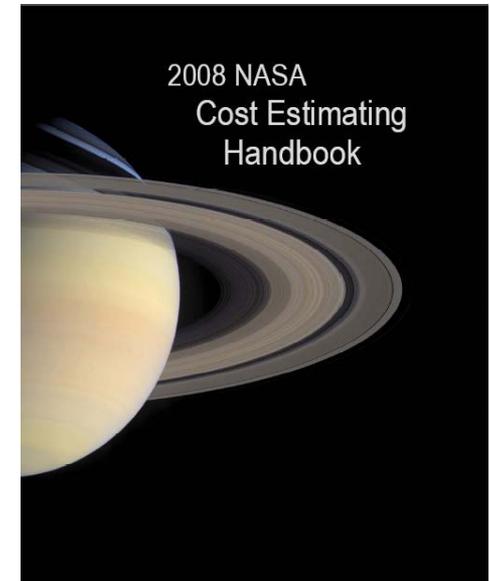
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- **NASA Cost Estimating Handbook 2008 provides Cost Estimating Methodology Selection during S/C development, manufacturing, Integration and test and launch .**

Table 1-3. Cost Estimating Methodology Selection Chart

	Pre-Phase A	Phase A	Phase B	Phase C/D	Phase E
Parametric	●	●	◐	◐	○
Analogy	●	◐	◐	◐	○
Engineering Build Up	◐	◐	●	●	●

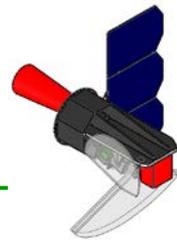
Legend: ● Primary ◐ Applicable ○ Not Applicable



The 2008 NASA Cost Estimating Handbook (CEH) is a reorganized and updated handbook that has been streamlined and consolidated into useful volumes based on input from the NASA Cost Estimating Community. The primary goal of the 2008 NASA CEH is to incorporate the survey feedback from the NASA Cost Estimating Community, implement comments collected through ceh_comments@nasa.gov, provide interim updates from the prior CEH tasks, and include data on new cost initiatives.



PRICE H: (Typical Contractor Rates) Key Input Parameters



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- **Global Parameters:**

- **Labor Rates** (set as appropriate)

Used in
this study



- **Typical Contractor Rates - FY12 \$ (PACE 2012 S/C Bus)**

- **G&A: 10%; Fee: 14%, Cost of Money (CoM): 0.0%**

- PRICE H Industry Labor Rates (default labor rates provided by Price Systems, Inc.)

- G&A: X%; Fee: Y%; CoM: Z%

- **Inflation** (NASA escalation rates)

- **Engineering Environment** (Defined for NASA by PRICE Systems, Inc. calibration study)

- Emphasizes: System Engineering, Project Management, Automated design capabilities

- **Individual Cost Component Parameters:**

- **Complexity Factors** (Table driven, defined by Price Systems from industry experience)

- **Modification Level/Remaining Design Factor** (Heritage)

- **Quantity and Design Repeat** (Learning Curve)

- **Composition** (Structure, Electronic, Purchased, Cost Pass-through)

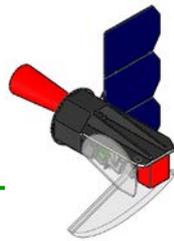
- **Mass**

- **Operating Platform** (Uncrewed Space – High Reliability)





MDL PRICE-H Cost Modeling



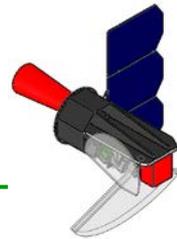
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- **PACE 2012 study began with MDL PRICE H cost model template**
 - S/C Bus cost model based on template developed over 10 years
 - Multiple proposal efforts and prior MDL/IDC studies have contributed to template development
 - New knowledge and experience gained from prior studies incorporated in cost model template
 - PACE 2012 cost model inherits knowledge and experience gained from over 10+ years of cost modeling.
- **Key Assumptions**
- Class C Mission – Selective redundancy design approach to be used see NPR 8705.4 Risk Classification for NASA Payloads
 - No existing Manufacturing Process and Assembly Line
 - Detailed assumptions are tagged CME (Cost Modeler Engineered) in model.
- **MDL study output products:**
 - Power-point presentation
 - PRICE H model exported to Summary Excel Spreadsheet
 - PRICE model file (requires PRICE H software)





PACE 2012 Mission Summary – (Final Version)



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Orbit parameters – Near-noon sun-synchronous polar:

- 700 ± 10 km circular, Sun-synchronous
- Orbit Inclination: 98.1928°
- Descending node crossing time: 12 PM ± 10 minutes
- Orbit Period: 98.77 minutes

LV – Antares 120 or Falcon 9

Launch date – October 1, 2019

Mission Lifetime – 3 year minimum, 5 desired (size consumables for 5 years)

Mass estimate –

payload: OCE CBE: 301 kg (1 assembly)
Polarimeter CBE: 60 kg total (in 2 assemblies)

mission: TBD

Power estimate –

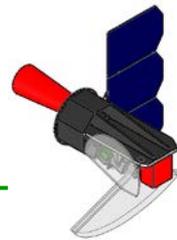
payload: OCE CBE: 515 W avg., 648W peak
OCE Survival Heater Power CBE: 244 W avg., 349 W peak
Polarimeter CBE: 70 W observing plus 15 W operational heater;
15 W when not imaging plus 15 W op. heater 100 W peak

Mission class – C

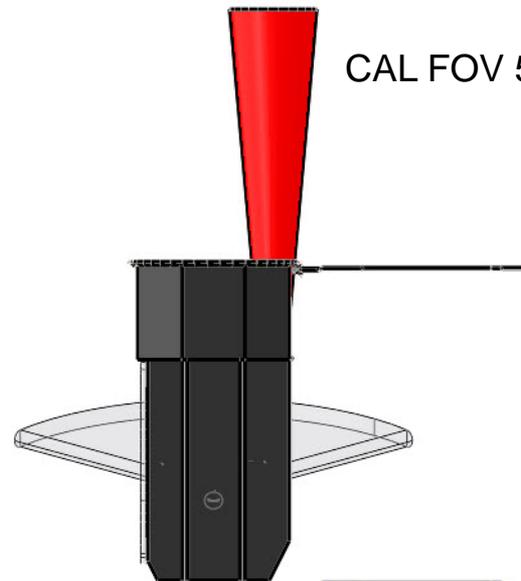
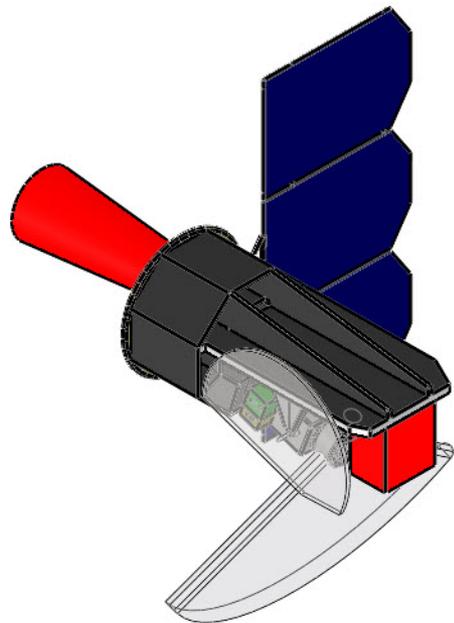




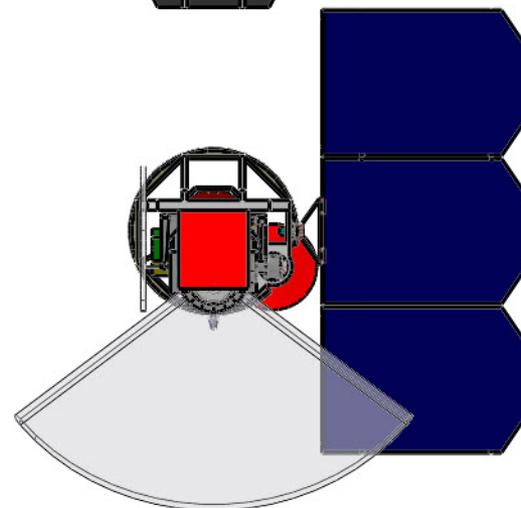
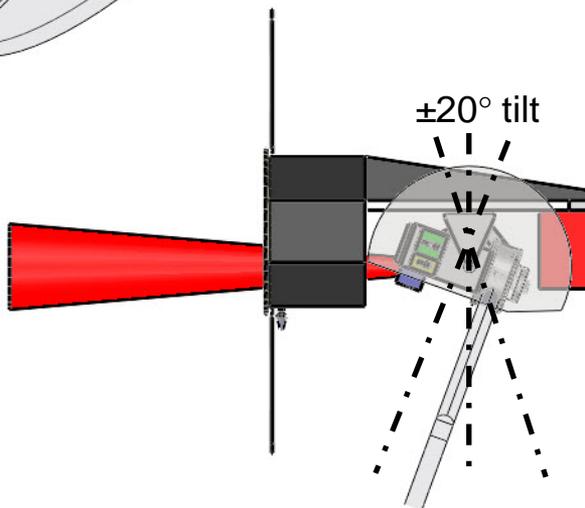
PACE 2012 Deployed Configuration



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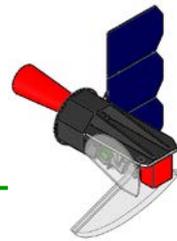


CAL FOV 5° half angle





Top-Level Price-H PACE 2012 (Contractor Bid Rates) S/C Model



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PRICE Estimating Suite 2010 - [w:\pace, 2012\disciplines\parametric_cost_analysis\pace 2012 pricecost 052412 .hpr]

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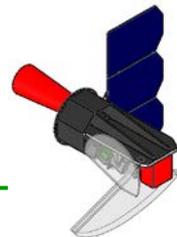
Category	Item	Weight (kg)	Cost
0	PACE 2012 Spacecraft Bus (PriceCost Modler Mr. Larry Phillips)		
1	PACE 2012 Spacecraft Bus (Vendor Rates, 10% G&A, 14% Fee)	462.77	
2	PACE 2012 Structure and Mechanisms Assembly	104.25	
3+	Core Structure Assembly		
12	Structure and Mechanisms Integration & Test		
13+	Power	167.676	
45+	Attitude Control System (ACS)	73.67	
55+	Propulsion	29.02	
68	Command and Data Handling (C&DH) Assembly	22.40	
69+	Avionics (IAU / Integrated Avionics Unit (1 Flight Unit Total= 12.1 kg)		
82+	Solid State Digital Recorder (SSDR)	12.1	
92	C&DH Assembly Integration & Test		
93+	Communications Assembly (TRL 7)	22.40	
104+	Thermal	19.18	
116+	S/C Harness Assembly	22.394	
128	Spacecraft Bus Integration & Test (TRL 6)		

PRICE Estimating Suite 2010 Met H





Expanded Price-H PACE 2012 (Contractor Bid Rates) S/C Model



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PRICE Estimating Suite 2010 - [w:\pace, 2012\disciplines\parametric_cost_analysis\pace 2012 pricecost 052412 .hpr]

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Item	Description	Weight	TRL	Cost
0	PACE 2012 Spacecraft Bus (PriceCost Modler Mr. Larry Phillips)		H/L	
1	PACE 2012 Spacecraft Bus (Vendor Rates, 10% G&A, 14% Fee) (462.77 kg)		H/L	
2	PACE 2012 Structure and Mechanisms Assembly (104.25 kg)		H/L	
3	Core Structure Assembly		H/L	
4	Strong Back Inst. Deck (Al Honeycomb core, Composite facesheet) (TRL 7)		H/L	
5	Deck Braces (2) (Al Honeycomb core, Composite facesheet) (TRL 7)		H/L	
6	Panels (8) (Al Honeycomb core, Composite facesheet) (TRL 7)		H/L	
7	Cross Supports (3) (Al Honeycomb core, Composite facesheet) (TRL 7)		H/L	
8	(Optional) Launch Vehicle Interface Ring (TRL 7)		H/L	
9	(Optional) Secondary Structure (TRL 7)		H/L	
10	Misc Clips, Fasteners, etc. (TRL 8)		H/L	
11	Core Structure Integration & Test		H/L	
12	Structure and Mechanisms Integration & Test		H/L	
13	Power (167.676 kg)		H/L	
14	Power System Electronics (PSE) Assembly (27.69 kg)		H/L	
15	PSE Housing (TRL 8) (28vDC Housing)		H/L	
16	Battery Module (power) (TRL 7)		H/L	
17	Output Module (power) (3) (TRL 7)		H/L	
18	Low Voltage Power Converter (LVPC) (power) (TRL 7)		H/L	
19	Control Module (digital/analog) (TRL 7)		H/L	
20	Solar Array Module (power) (TRL 7)		H/L	
21	Backplane (analog/power) (TRL 7)		H/L	
22	Conformal Coatings Etc. (TRL 9)		H/L	
23	PSE Integration & Test		H/L	
24+	Lithium Ion Battery Assembly (38.06 kg)		H/L	
28+	Solar Array Assembly (Fit. units = 3) (95.66 kg) (CME)		H/L	
34+	Solar Array Deployment Mechanism (Fit. Units = 1) (6.25 kg) (CME)		H/L	
44	Power Assembly Integration & Test		H/L	
45	Attitude Control System (ACS) (73.67 kg)		H/L	
46	Gyro (NGES SIRU) (Est PurPrice: \$1.0M ea.)		H/L	
47	Star Tracker (2) (Ball Aerospace CT-631) (Est PurPrice: \$600K ea)		H/L	
48	Coarse Sun Sensors (8) (Adcole CSS) (Est PurPrice: \$80K ea)		H/L	
49	Magnetic Torquers (3) (Goodrich TR60CFR) (Est PurPrice: \$33K ea)		H/L	
50	Reaction Wheels (4) (Goodrich TW-26E300) (Est PurPrice: \$170K ea)		H/L	
51	Magnetometer (Goodrich IM-103) (Est PurPrice: \$52K ea)		H/L	
52	Earth Sensors (3) (Barnes 13-470 SS Horizon Sensor)(Est PurPrice: \$100K ea)		H/L	
53	ACS Design		H/L	

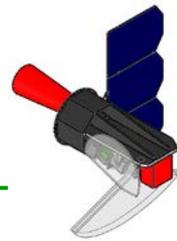
PRICE Estimating Suite 2010

Met H





PRICE H PACE 2012 S/C Summary Report (Contractor Bid Rates) Cost Estimate



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Basic Estimate (Metric)			
Cost Summary	LM Totals	LM Production	LM Development
PAGE 2012 Spacecraft Bus (PriceCost Modler Mr. Larry Phillip Tue June 12 2012 12:28 PM (PRICE Estimating Suite 2010) System Cost Summary Costs in (\$1000 Constant 2012)			
Program Cost	Development	Production	Total Cost
Engineering			
Draft	3115.6	707.9	3823.5
Design	13332.2	3536.6	16868.8
System	5328.5	-	5328.5
Proj. Mgmt.	5672.8	8955.3	14628.1
Data	85.9	162.1	248.0
SubTotal(ENG)	27535.0	13361.8	40896.8
Des Int Cost	[7550.9]		
Manufacturing			
Production	-	16183.9	16183.9
Prototype	375.2	-	375.2
Tool Test Eq.	199.5	277.0	476.5
Purchased	0.0	15013.3	15013.3
SubTotal(MFG)	574.7	31474.2	32048.8
G & A / CoM	2788.4	2716.1	5504.5
Fee / Profit	4325.7	6657.3	10983.0
Total Cost	35223.9	54209.4	89433.3
System Total	35223.9	54209.4	89433.3
Schedule Start	Jun 14 [12]	Sep 16 [15]	
First Item	May 15	Nov 17 [15]	
Finish	May 15 [12]	Feb 19 [30]	
System Weight	462.77	System WS	417.33
System Series MTBF Hrs	922.054	Unit Sys Cost	36888.72
System Quantity	1	Avg System Cost	53787.78

Labor/Material

Engineering

Project Management

Manufacturing

G&A, Fee

Dry Mass
Bus Total:
462.77 kg

Cost Element
(Summary Report
Available for each
cost element)

Year Dollars
(\$2012)

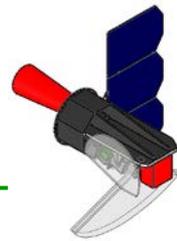
Production

Development

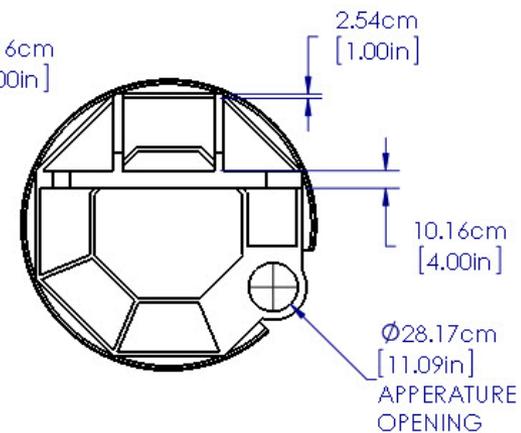
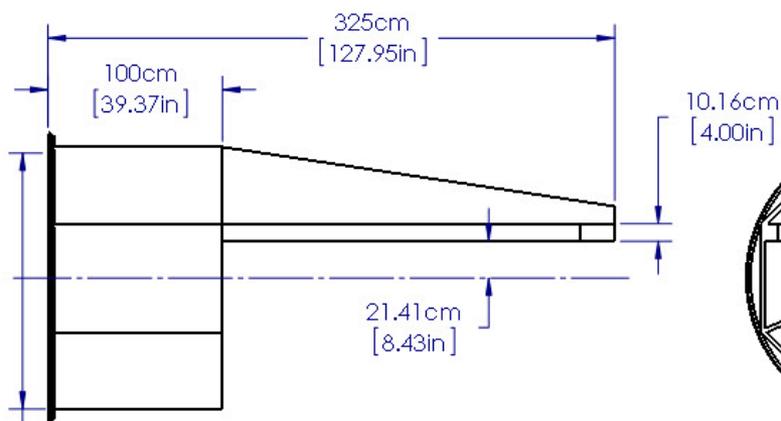
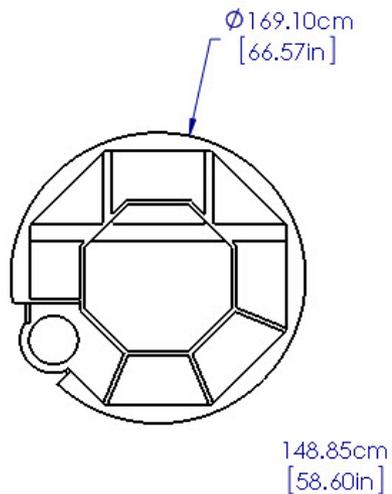
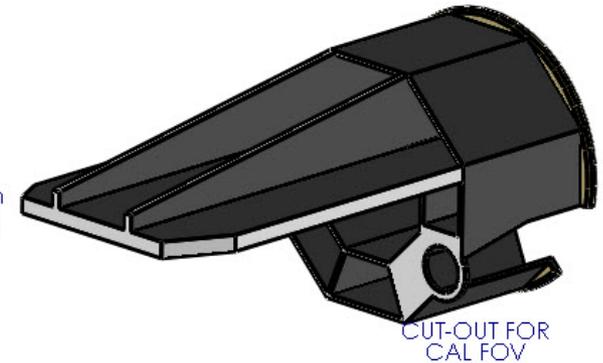
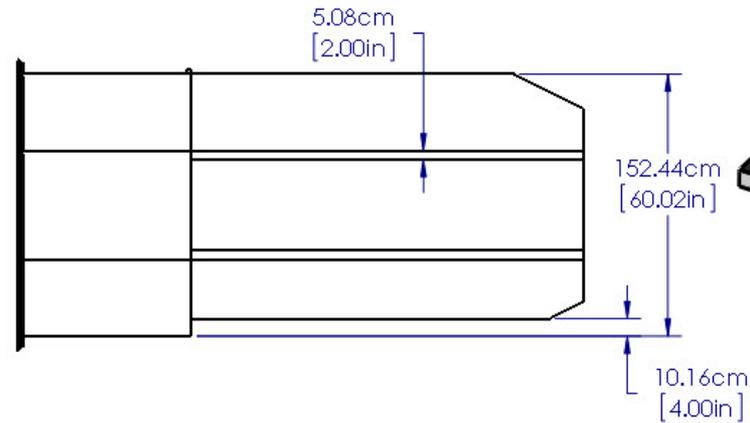
Cost Estimate
~\$89 M



PACE 2012 Bus Structure

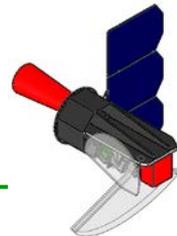


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PACE 2012 PRICEcost.xls Summary (Contractor Bid Rates) Stack Cost Estimate



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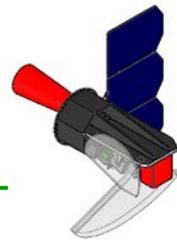
MDL Parametric Cost Estimate (MDL = Mission Design Lab) (Development and Production Costs)	Flight Units = 1 Eng Design Units = 1 Cost Estimate (FY\$012)
PRICE-H Cost Model Summary 12-Jun-12	
PACE 2012 Spacecraft Bus (Vendor Rates, 10% G&A, 14% Fee) (462.77 kg) PACE 2012 Structure and Mechanisms Assembly (104.25 kg) Power (167.676 kg) Attitude Control System (ACS) (73.67 kg) Propulsion (29.02 kg) Command and Data Handling (C&DH) Assembly (22.40 kg) Communications Assembly (TRL 7) (22.40 kg) Thermal (19.18 kg) S/C Harness Assembly (22.394 kg) Spacecraft Bus Integration & Test (TRL 6)	\$89,433,251 \$12,161,400 \$26,236,364 \$12,721,089 \$5,582,139 \$13,309,653 \$9,910,223 \$1,752,315 \$4,558,663 \$3,201,404
PRICE-H Spacecraft Bus Estimate	<u>\$89,433,251</u>
The Following are NOT PRICE-H estimates but are derived from PRICE-H estimates. These are included for completeness and are considered ROM 'Grass-roots' estimates. Consult the Grass-roots estimating organization for a more accurate estimate.	
Flight Software (10% of S/C Bus Cost Estimate) FPGA Development (0 Unique FPGAs @ \$400K ea & 0 Unique Algorithms @ \$400K ea identified) Ground Support Equipment (GSE) (5% of S/C Bus Cost Estimate) Environmental Testing (5% of S/C Bus Cost Estimate) Flight Spares (10% of S/C Bus Cost Estimate) Engineering Test Unit (ETU) (10% of S/C Bus Cost Estimate) Launch Vehicle I&T (5% of S/C Bus Cost Estimate, Typically Included in WBS 10.0)	\$8,943,325 \$0 \$4,471,663 \$4,471,663 \$8,943,325 \$8,943,325 \$4,471,663
Spacecraft Bus Subtotal	\$129,678,213
Institutional Charges (Basis of Estimate: 0% GSFC CM&O)	N/A
Spacecraft Bus Total	<u>\$129,678,213</u>

\$129M

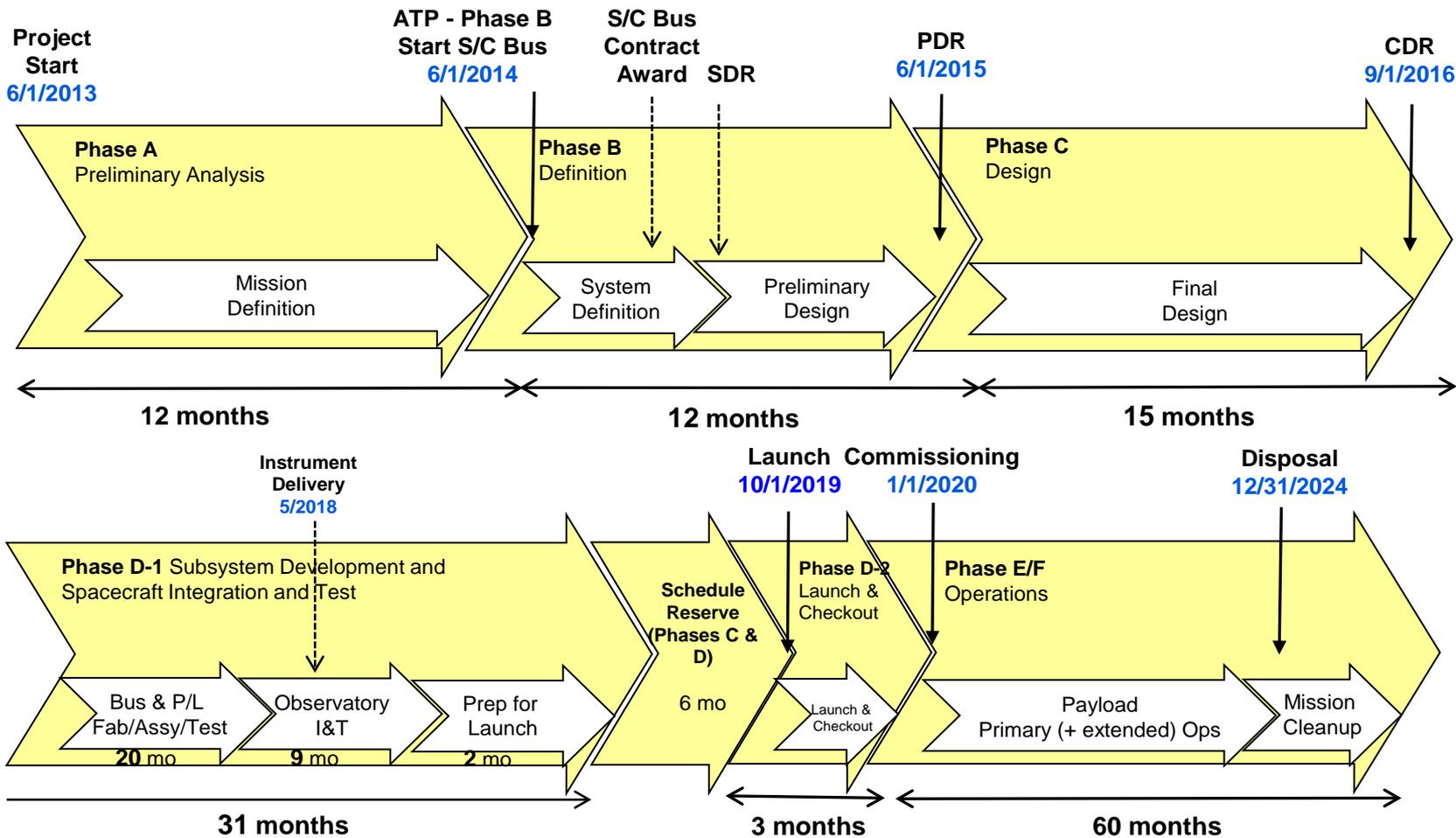




PACE Mission Level Schedule

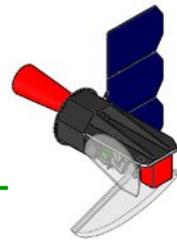


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PACE Mission Timeline (up to launch)



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Mission Phase (or other event)	Start Date	Duration			End Date
		days	months	years	
Mission Phase A (preliminary analysis)	6/1/2013	365	12.00		6/1/2014
Mission Phase B (system definition & preliminary design)	6/1/2014	365	12.00		6/1/2015
Mission PDR	6/1/2015				
Mission Phase C (final design)	6/1/2015	456	15.00		9/1/2016
Mission CDR	9/1/2016				
Mission Phase D1 (S/C fabrication, assembly, I&T and pre-launch operations)	9/1/2016	943	31.00		4/2/2019
Fabrication of bus (and instruments, more or less in parallel)	9/1/2016	426	14.00		11/1/2017
Bus I&T	11/1/2017	183	6.00		5/1/2018
Observatory: Integration of instruments with bus; functional testing	5/1/2018	122	4.00		9/1/2018
Observatory: Environmental testing	9/1/2018	152	5.00		2/1/2019
Launch site operations	2/1/2019	61	2.00		4/1/2019
6 months Observatory slack	4/1/2019	183	6.00		10/1/2019
Launch date	10/1/2019				

