Space Missions Cost Estimation in TruePlanning®

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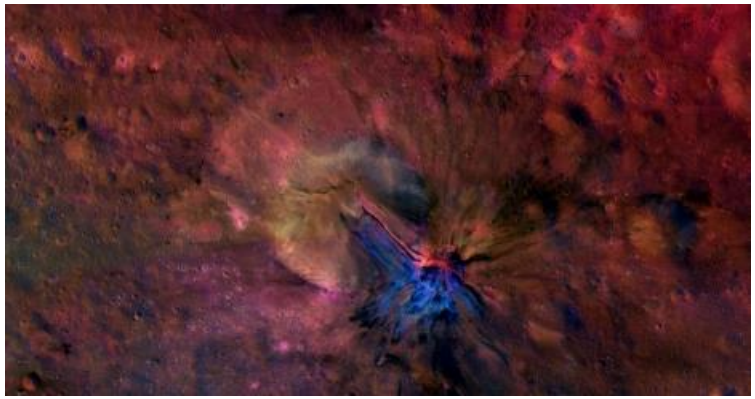
Agenda

- Space Missions Model Overview
- Introduction to TruePlanning®
- Framework Orientation
- Space Mission Cost Objects
- Space Missions Model in Use



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Space Missions Model Overview

- Cost estimating for Formulation through Implementation for robotic Earth and Space Science Missions
- Methodology used in supporting NASA mission analyses for 25 years.
  - 1989: initially developed to support NASA's Discovery Program
  - Applied to Mars Pathfinder and NEAR
  - 1991: Major modification to incorporate PRICE H
  - Used for NASA's first Discovery AO (Announcement of Opportunity) evaluation in 1994
  - Periodic updates from 1994-2014
  - Updated regularly with data from missions such as Lunar Atmosphere and Dust Environment Explorer(LADEE), Mars Science Laboratory (MSL), Gravity Recovery and Interior Laboratory (GRAIL), etc.

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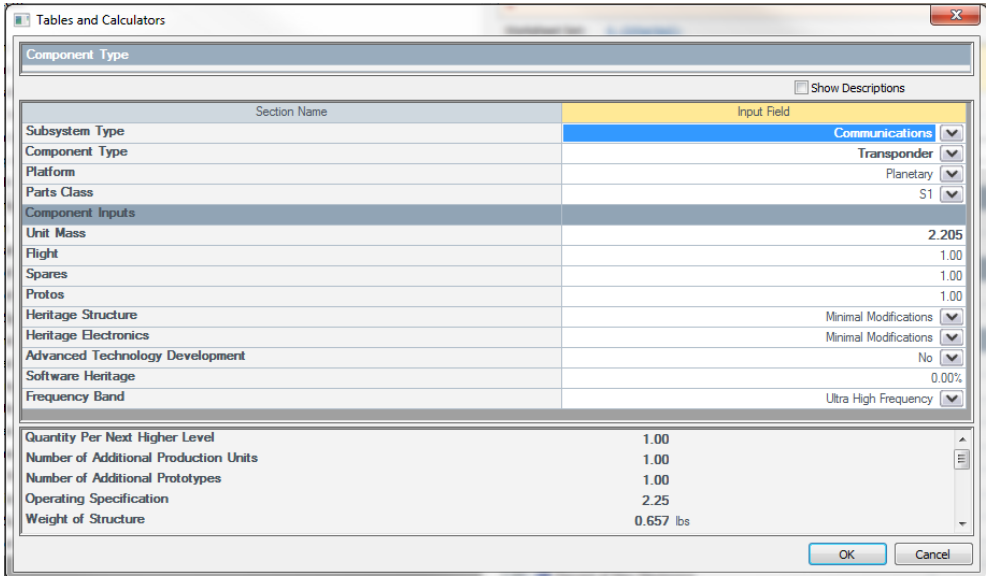
Space Missions Overview

- Implementation of PRICE TruePlanning® for Hardware specifically tailored for estimation of Space Missions



Subsystem / Component	Subsystem / Component	Subsystem / Component
STRUCTURE & MECHANISMS	**GUIDANCE, NAVIGATION, & CONTROL**	**ENTRY & DESCENT**
Primary Structure	Star Tracker	Themal Protection System *
Secondary Structure	Sun Sensor	Parachute *
Shielding	Reaction Wheel	
Solar Array Substrate/Structure	Torque Rod	**OPTICS**
HGA Structure	Gimbals	Optical Bench
Electronics Boxes	IMU-Gyro	Optics
Mechanisms	Actuators	Gratings
Motor/Actuator	Radar Altimeter *	Filter Wheel
Booms		Optics Filters/Misc
	COMMUNICATIONS	
ROBOTIC ARM	Transponder	**SENSOR SYSTEMS**
Robotic Arm - Limb	Transmitter	Laser *
Robotic Arm - Joint/Actuator	Amplifier	Sensors-Detectors
	Misc RF Electronics	CCD Detectors
THERMAL CONTROL	HGA	Magnetometer
MLI, Paints, Coatings	MGA/LGA	TOF Spectrometer
Heaters, RHUs, Thermostats	Waveguide/Comm Cabling	ESA sensor
Radiators/Louvers		Photodiode
Heat Pipes	**COMMAND & DATA HANDLING**	Bolometer
Cryocooler	Command/Data Processing	Ion Source
	Solid State Memory	Gamma Sensor
PROPULSION		Neutron Sensor
Propulsion Lines/Valves/Fittings	**POWER**	Dust Detector
Pressure Regulator	Power Management and Distribution	Readout Electronics
Tanks	Solar Cells/Electrical	
Thrusters	Pyrotechnics	
	Batteries	
ELECTRIC PROPULSION	Harness	
Ion Thruster *		
Power Processing Unit *		

- Component-Level Cost Estimating Methodology
  - Spacecraft/Instrument component types cover all space subsystem functions
  - Flight Element (Spacecraft) and Instrument Estimates are built up from a user-defined combination of subsystem and component-level estimates
  - Space Mission Component level inputs drive the inputs for the PRICE TruePlanning® model for Hardware

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Space Missions Overview

- Development Phases:
  - **Design:** these costs come directly from the TruePlanning ®Hardware model
  - **Fabrication:** these costs come directly from the TruePlanning ® Hardware Model
  - **Assembly Integration and Test:** these costs are a function of the Design & Fabrication costs
  - **Launch Operations:** these costs are a function of Design and Fabrication costs
- Project Support Functions:
  - Project Management
  - Mission Analysis
  - System Engineering
  - Safety and Mission Assurance
  - Science/Technology
  - Mission Operation System (MOS)
  - Assembly and Integration Support
  - System Test
  - Ground Support Equipment

These costs apply to all phases

Milestones: ATP → CDR→SIR→ Ship

WBS	Design	Fab	I&T	Launch Ops
1) Project Management				
2) Systems Engineering (w/ Mission Analysis)				
3) Mission Assurance				
4) Science/ Technology				
5) Payload (w/ details by subsystem)				
6) Spacecraft (w/ details by subsystem)				
7&9) MOS/GDS Dev				
10) System I&T (w/ Ground Support Equip)				

Space Missions estimated costs align with the NASA WBS and provide phasing details

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TruePlanning® Methodology

- TruePlanning® is a set of Parametric Models executed using an Activity-Based Costing approach

- Parametric Modeling is:
  - An Operations Research Discipline
  - Relies on …
    - *Mathematical models of real life situations*
    - *The application of these models to new projects and technologies*
  - Relies heavily on historical data
    - *Data is reviewed and important cost drivers are identified*
    - *Regression analysis is used to determine cost estimating relationships*
    - *Results can then be refined with additional data and extrapolated to new projects, technologies and processes*

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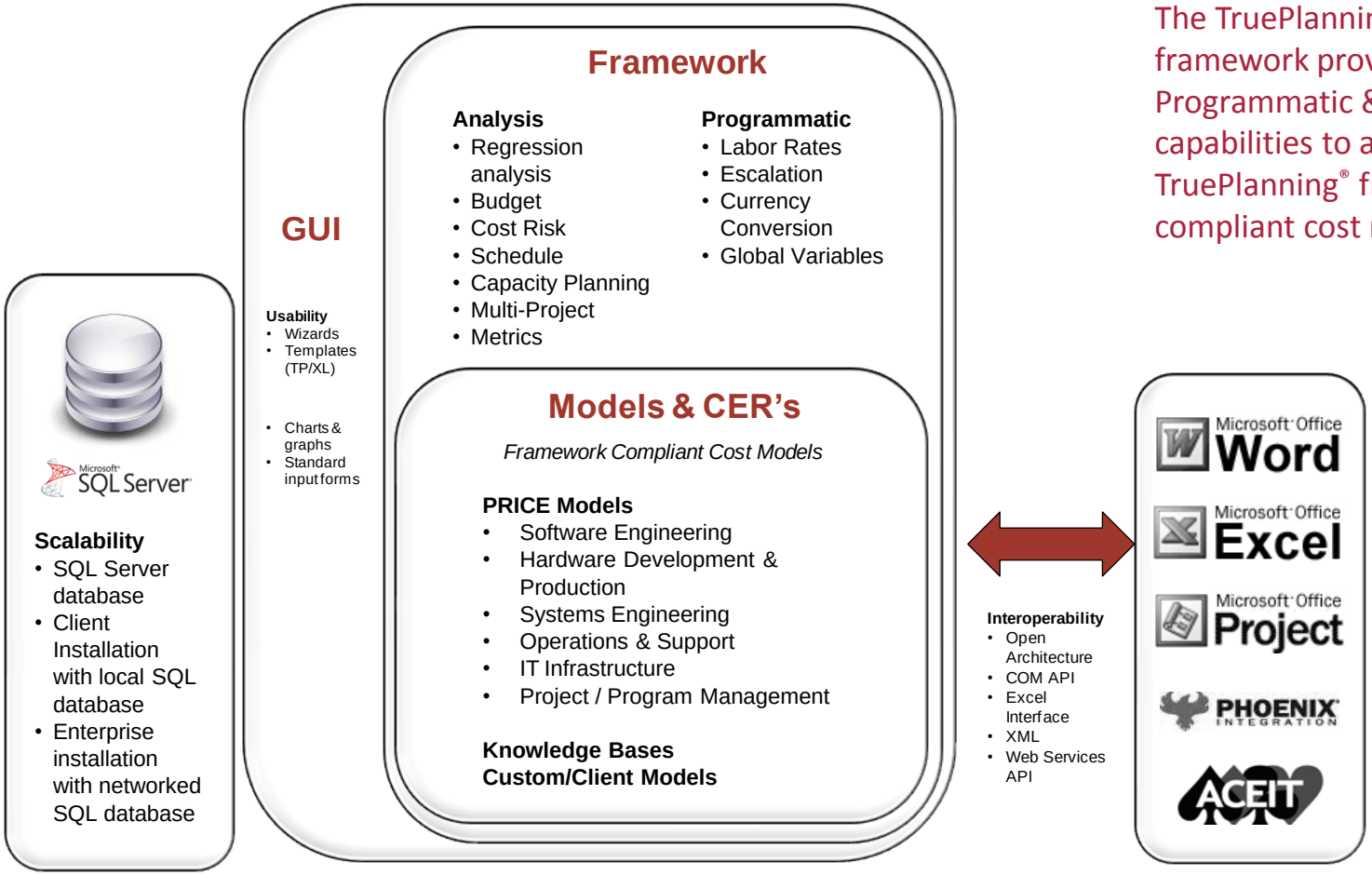
What is the TruePlanning® Framework?



The TruePlanning® framework provides Programmatic & Analysis capabilities to any TruePlanning® framework, compliant cost model.

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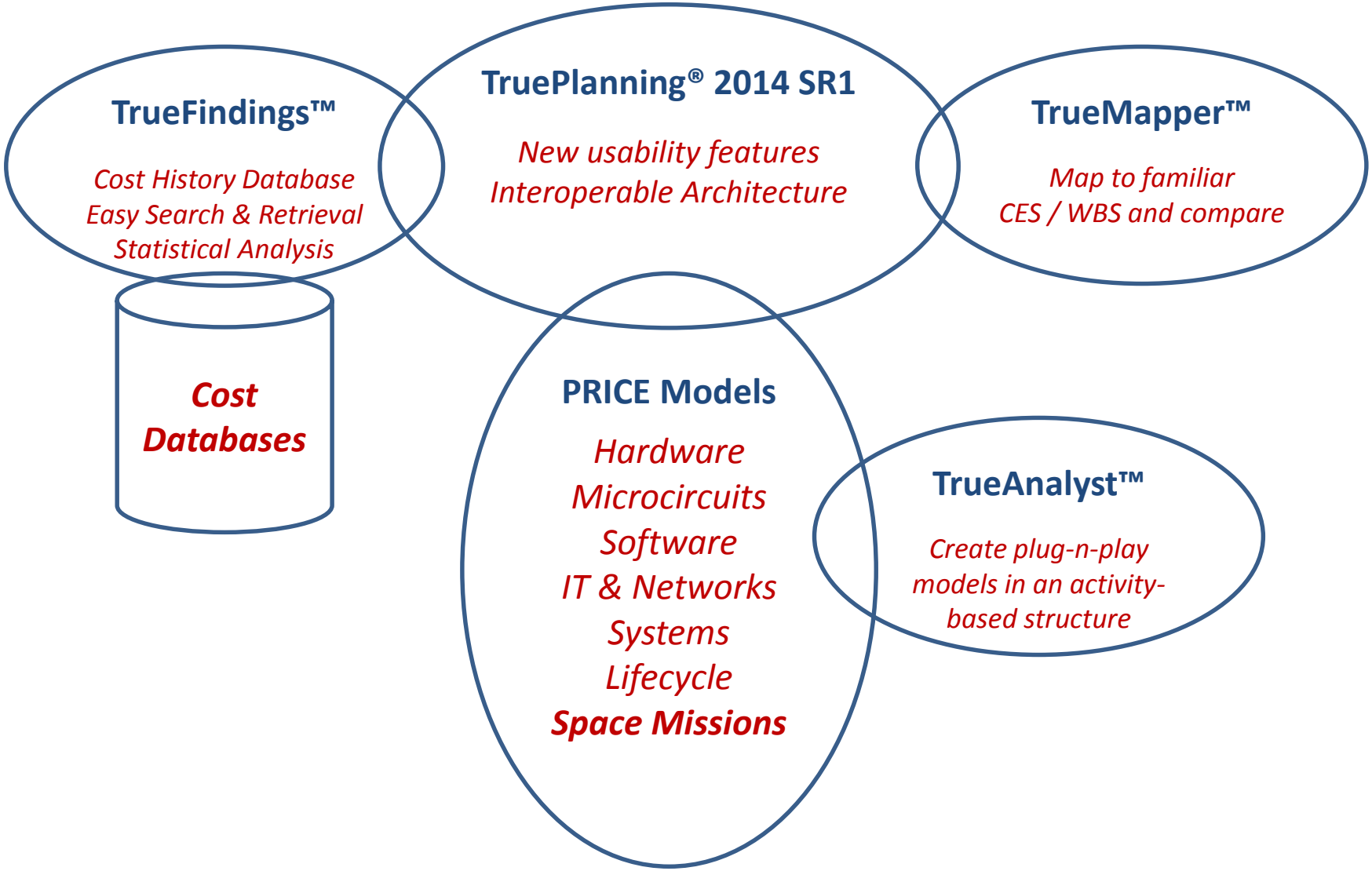
Space Missions Estimating Environment



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ABC's of PRICE Parametric Estimation

TruePlanning® Is a parametric cost engineering solution which estimates costs in support of activity-based costing

Cost Object

- What is produced
- Inputs describe what is being produced - WBS
- Contains activities

Activities

The work that is done

- Each type of cost object has different set of activities
- Each activity contains one or more assigned resources

Resources

- Anything you spend money on when performing activities
- Labor hours and material dollars

Effort by Activity & Resource ✖ *Resource Rates & Activity Adjusters* = **Program Costs by Activity & Resource**

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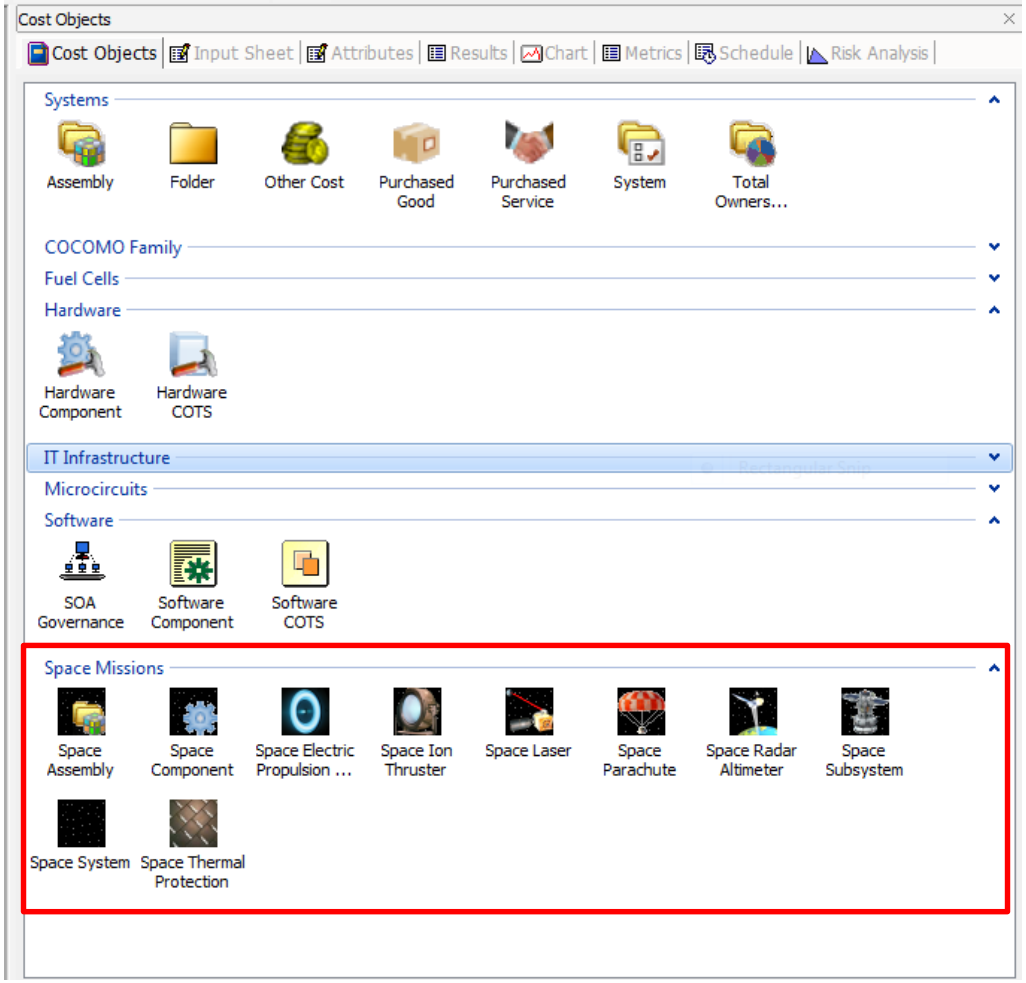
Cost Objects – PBS Building Blocks

- Cost Models are stored in “Catalogs”
- Each Cost Model contains a series of interrelated cost estimating relationships, an input sheet, activities and resources.



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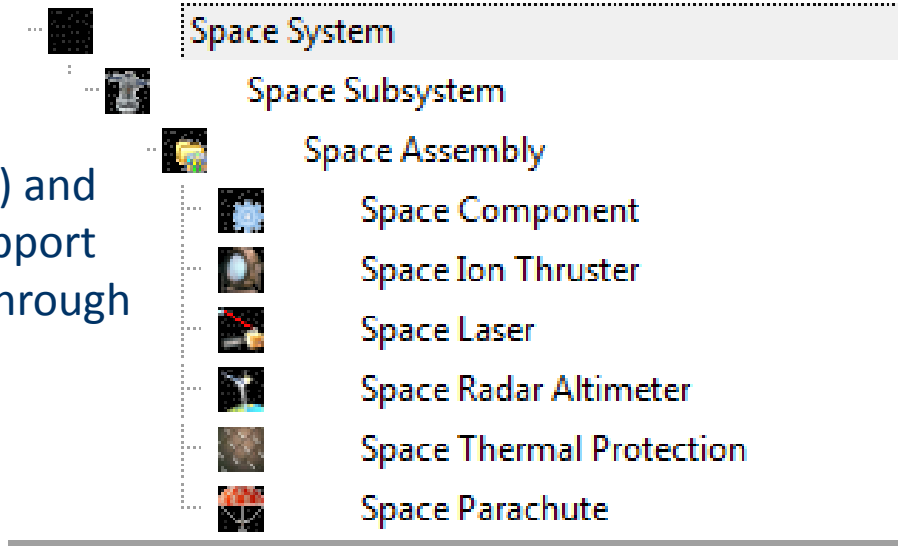
Space Mission Cost Objects

- Space System
  - Project Support Function Costs for Spacecraft and/or Payload
- Space Subsystem
  - Subsystem-level Integration & Test (I&T) and Spacecraft or Instrument subsystem support to System I&T and Launch Operations through On-Orbit Check-Out
- Space Assembly
  - Roll-up of Subsystem-level Design and Fabrication
- Space Component
  - Design and Fabrication via True Hardware Calculation
- Custom Components
  - Custom CER implementations



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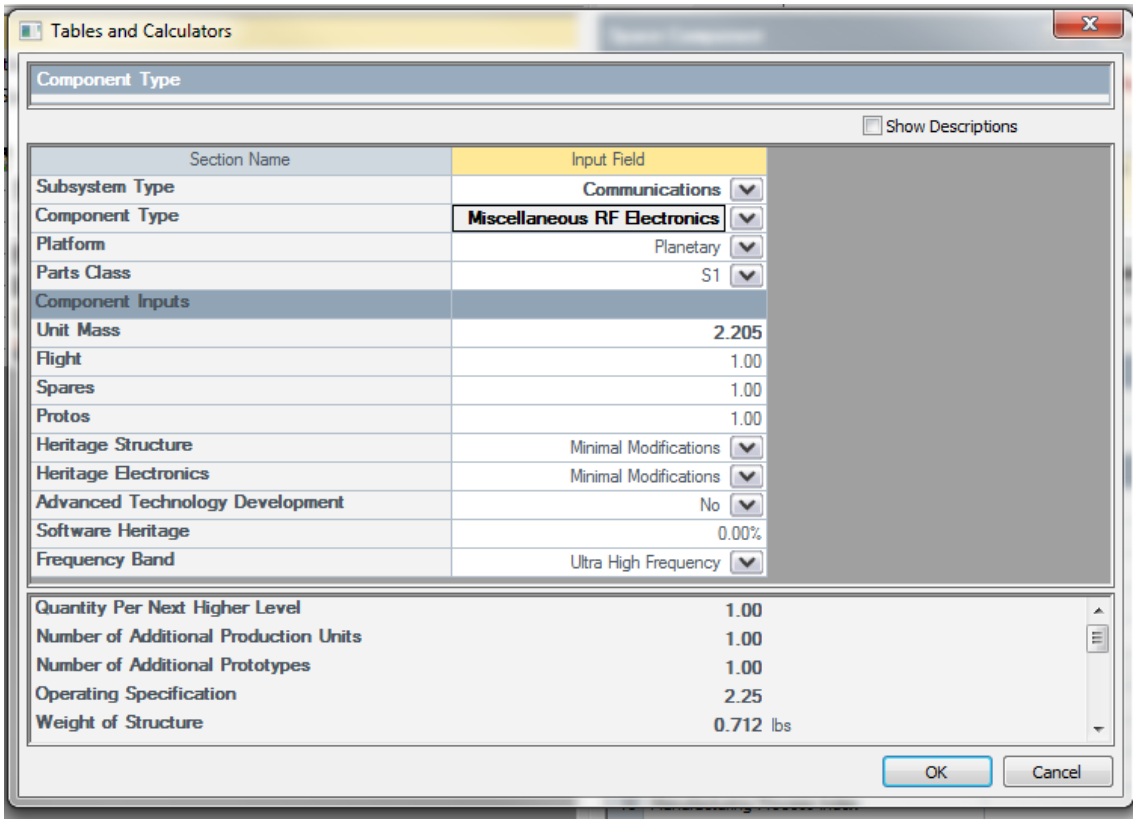
Space Component Cost Object

- Subsystems
  - Command and Control
  - Communications
  - Guidance, Navigation and Control
  - Optics
  - Power
  - Propulsion
  - Robotic Arm
  - Sensor System
  - Structure and Mechanisms
  - Thermal Control



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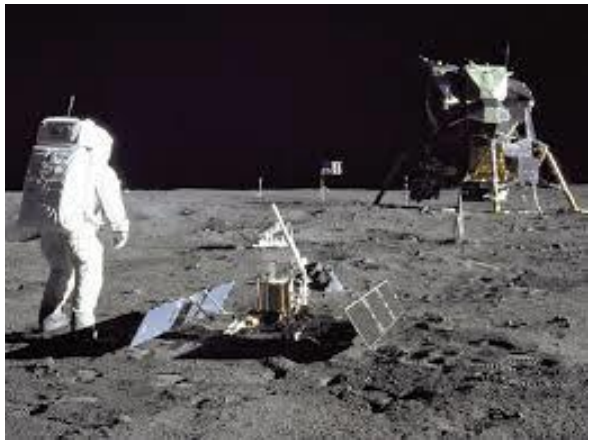
Space Component Cost Object

- Space Component Calculator inputs generate True H inputs for:
  - Quantity
  - Prototypes
  - Spares
  - Operating Specification (Platform)
  - Weight of Structure
  - Weight of Electronics
  - Manufacturing Complexity of Structure
  - Manufacturing Complexity for Electronics
  - Percent New Structure
  - Percent New Electronics
  - Engineering Complexity



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Space Component Cost Object

		Value	Unit
1	Start Date		
2	Subsystem Type	**Propulsion**	
3	Component Type	**Primary Structure**	
4	Quantity Per Next Higher Level	1.00	
5	**Additional Units**		
6	Number of Additional Production Units	0.00	
7	Number of Additional Prototypes	0.00	
8	**Cost Sharing Units**		
9	Total Number of Production Units Produced	0	
10	Total Number of Prototypes Produced	0.00	
11	**Technical Description**		
12	Equipment Type	None	
13	Operating Specification	**2.25**	
14	Weight of Structure	**12.130**	kg
15	Weight of Electronics	0.000	kg
16	Volume	**77.263**	
17	Manufacturing Complexity for Structure	**8.630**	
18	Percent of New Structure	**95%**	
19	Percent of Design Repeat for Structure	0%	
20	Manufacturing Complexity for Electronics		
21	Percent of New Electronics		
22	Percent of Design Repeat for Electronics		
23	Engineering Complexity		
24	Labor Learning Curve		
25	Material Learning Curve		
26	Manufacturing Process Index	0.000	
27	Technology Improvement Control	1.0	
28	Technology Obsolescence Control	0.0	
29	Year of Technology		
30	External Integration Complexity for Structure	**2.00**	
31	External Integration Complexity for Electronics	**2.00**	
32	Hardware Software Integration Factor	**0.50**	

Input values

Tables and Calculators

Component Type

Section Name	Input Field
Subsystem Type	Propulsion
Component Type	More Options
All Component Types	Primary Structure
Platform	Planetary
Parts Class	S1
Component Inputs	
Unit Mass	12.130
Flight	1.00
Spares	0.00
Protos	0.00
Heritage Structure	Major Modifications
Advanced Technology Development	No
Material	Composite

Quantity Per Next Higher Level	1.00
Number of Additional Production Units	0.00
Number of Additional Prototypes	0.00
Operating Specification	2.25
ight of Structure	12.130 kg
	77.263 l
cturing Complexity for Structure	8.630
t of New Structure	95.00 %
Engineering Complexity	0.665
External Integration for Structure	2.00

OK Cancel

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Space Missions in Use

- Estimate for Dawn Mission at Launch
- The Dawn Mission's goal is to investigate in detail two large protoplanets – Ceres and Vesta to learn their condition and history
- Estimate is based on technical and cost data collected from the CADRE and through interviews with Subject Matter Experts

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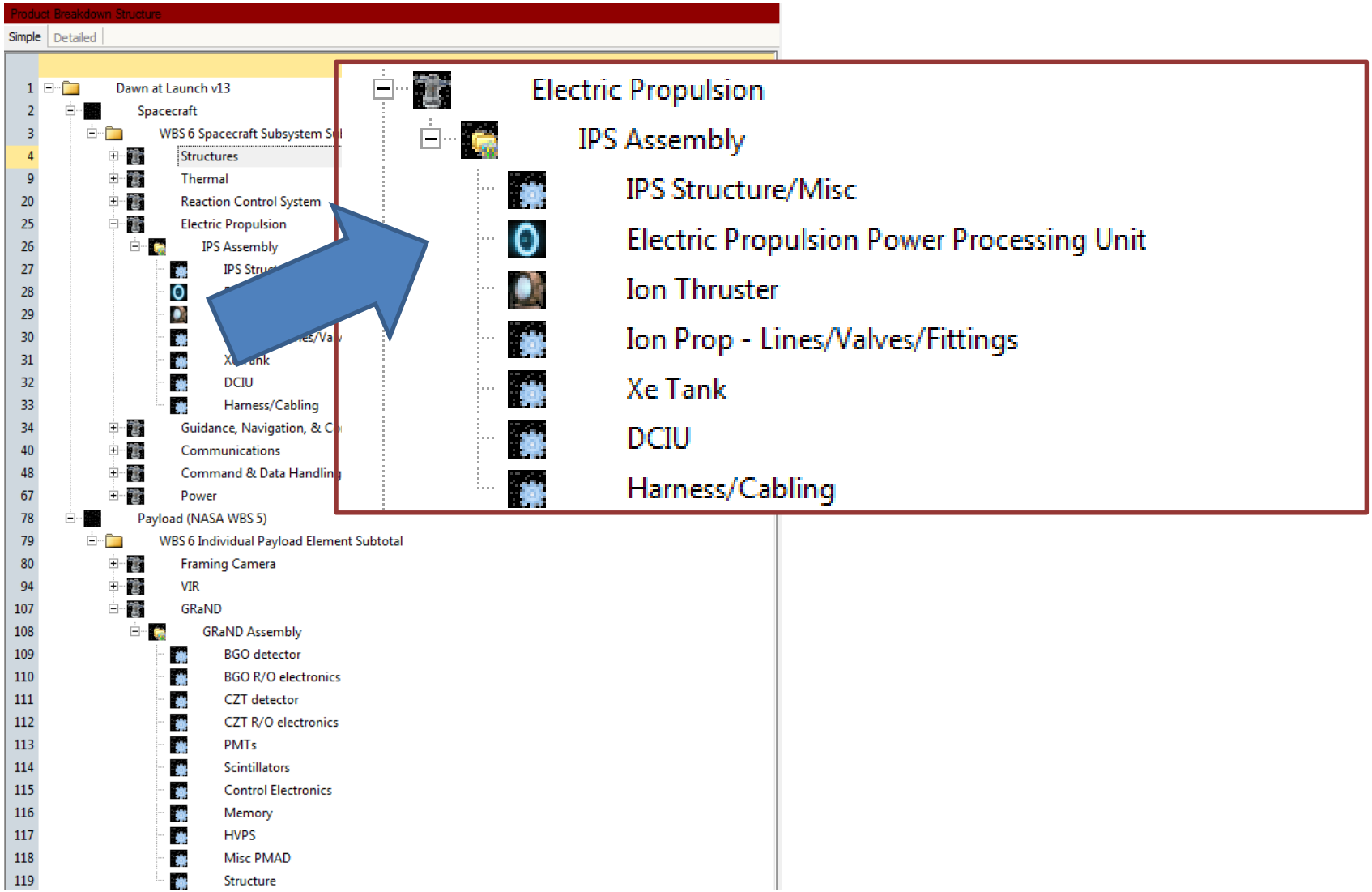
Space Missions in Use



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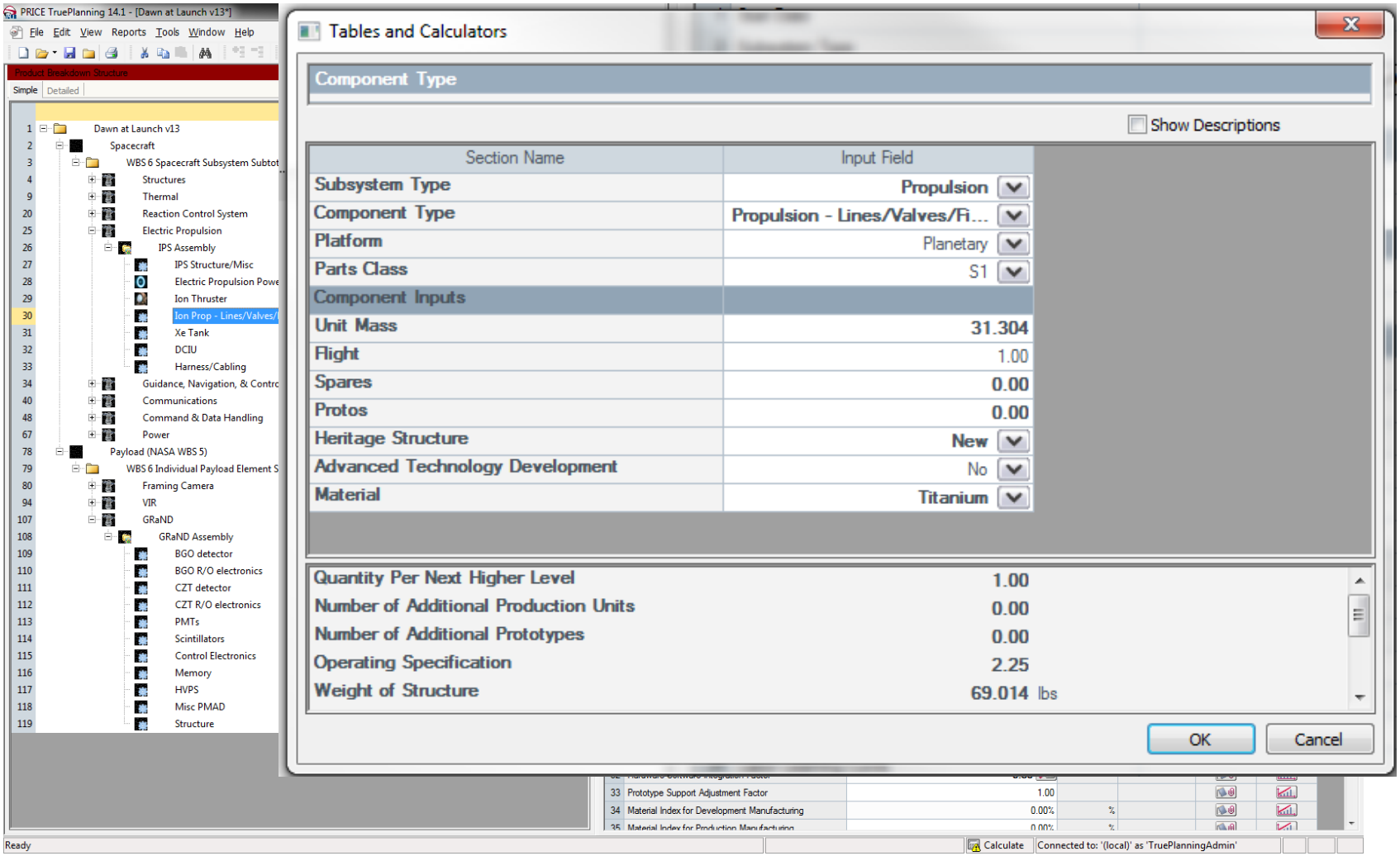
Space Missions in Use



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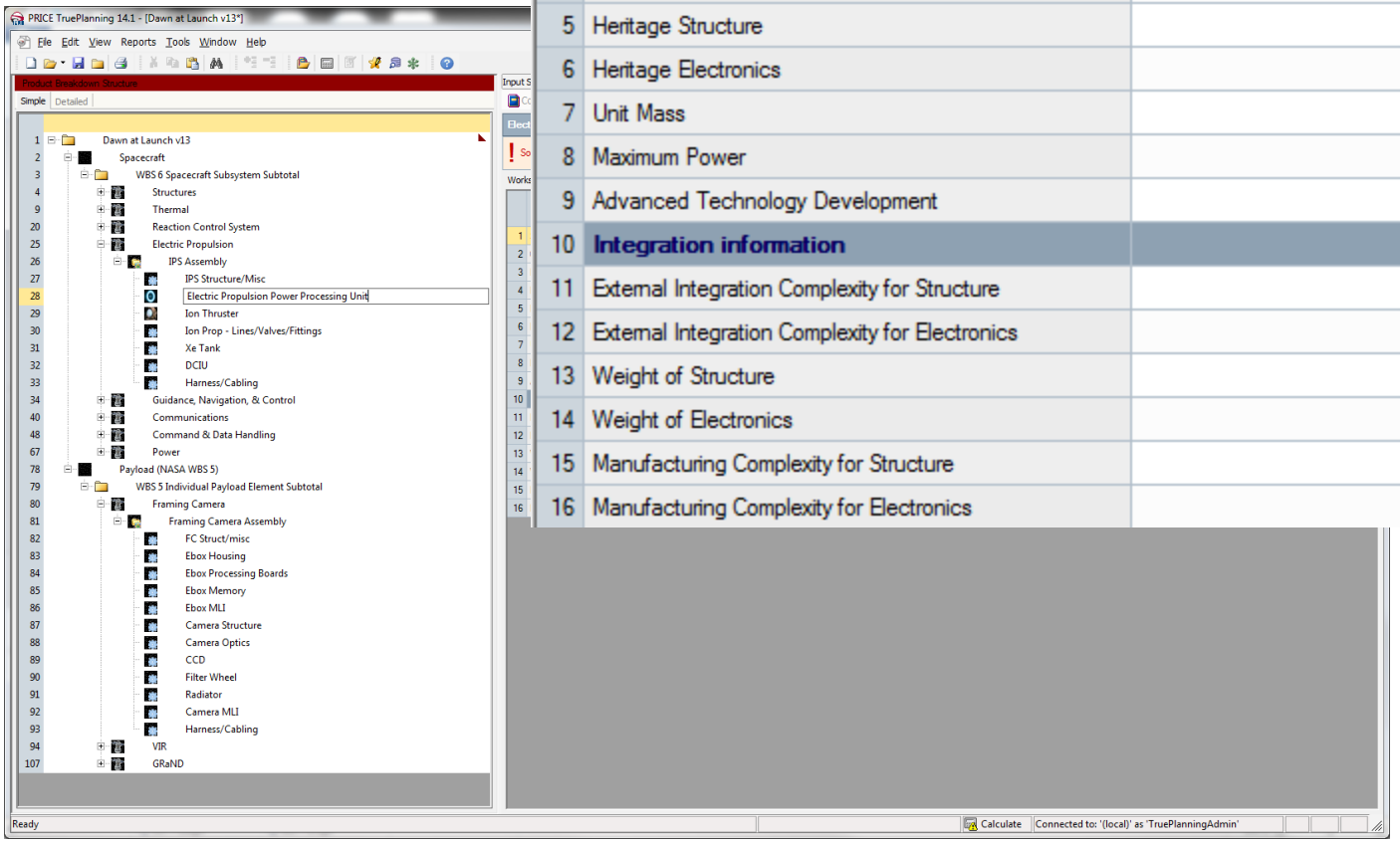
Space Missions in Use: Custom CERs



		Value	Units
1	Start Date	1/2/2003	
2	Quantity Per Next Higher Level	2.00	
3	Number of Additional Production Units	0.00	
4	Number of Additional Prototypes	0.00	
5	Heritage Structure	Copy	
6	Heritage Electronics	Copy	
7	Unit Mass	13.90	kg
8	Maximum Power	2.60	kW
9	Advanced Technology Development	No	
10	**Integration information**		
11	External Integration Complexity for Structure	2.00	
12	External Integration Complexity for Electronics	2.00	
13	Weight of Structure	4.200	kg
14	Weight of Electronics	9.700	kg
15	Manufacturing Complexity for Structure	9.210	
16	Manufacturing Complexity for Electronics	10.812	

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Space Missions in Use

Dawn at Launch v13

Cost:	$390,536,548	100.00%	Labor Requirement:	
Project Cost:	$390,536,548		Project Labor Requirement:	

	Costs : Dawn at Launch v13 - [System Folder] Currency in USD ($) (as spent)	Total	Design	Fabrication	Assembly Integration and Test	Launch Operations
1	01. Project Management	28,299,765	6,176,729	18,889,125	2,712,190	521,720
2	02a. Mission Analysis	4,912,504	2,879,336	1,022,582	643,059	367,526
3	02b. System Engineering	11,189,357	4,793,117	4,537,971	1,594,837	263,432
4	03. Safety & Mission Assurance	16,764,732	5,25			
5	04. Science/Technology	6,079,443	6			
6	07. Mission Operation System	14,47	1,3			
7	10a. Assembly and Integration Sup...	5,2				
8	10b. System Test	26,323,9				
9	10c. Ground Support	9,020,553	3,2			
10	Assembler	15,595,185	1,8			
11	Assembly Integration and Test	44,224,506				
12	Design Engineering	53,228,453	51,4			
13	Fabricator	8,884,251				
14	Launch Operation	7,161,229				
15	Manufacturing Engineering	20,595,168				
16	Material	24,836,224	5,2			
17	Non-Recurring Cost	3,876,541	3,8			
18	Recurring Cost	2,478,552				
19	Support Engineering	43,698,639	29,7			
20	System Engineering	4,349,083	4,3			
21	Test Engineering	17,656,271	2,4			

			Mass (kg)	COST				
				Design	Fabrication	AIT	Launch Operations	Total
01 Project Management				$6,176,729	$18,889,125	$2,712,190	$521,720	**$28,299,765**
02a Mission Analysis				$2,879,336	$1,022,582	$643,059	$367,526	**$4,912,504**
02b System Engineering				$4,793,117	$4,537,971	$1,594,837	$263,432	**$11,189,357**
03 Saftey and Mission Assurance				$5,256,690	$5,968,015	$4,670,624	$869,403	**$16,764,732**
07 Science/Technology				$606,507	$1,937,752	$2,950,772	$584,412	**$6,079,443**
10a Assembly and Integration Support				$1,313,551	$5,020,577	$6,904,756	$1,240,213	**$14,479,097**
10b System Test				$1,830,120	$2,040,194	$1,178,964	$174,677	**$5,223,956**
10c Ground Support				$4,507,513	$6,137,144	$14,801,032	$878,238	**$26,323,927**
And the rest of the Space System Resources similarly mapped				**$3,224,334**	**$3,714,245**	**$1,810,683**	**$271,291**	**$9,020,553**
05 Payload (Space System CO)			75.78	$22,391,180	$35,864,479	$20,067,930	$3,222,012	81545600.6
	Framing Camera		22.68	$26,869,416.20	$43,037,374.46	$24,081,515.91	$3,866,414.14	97854720.7
		FC Struct/Misc	1.33	$12,283,579.92	$13,247,447.62	$5,596,313.68	$980,273.28	32107614.5
		Ebox Housing	1.16	$2,919,207.37	$3,165,517.16			6084724.53
		Ebox Processing Boards	0.2					
		...	...					
	VIR		25.8	$10,236,317	$11,039,540	$4,663,595	$816,894	26756345.4
		Optics Module Struc	12.08	$2,432,673	$2,637,931			5070603.78
		Cryocooler	0.5	$184,994	$31,735			216728.216
		IR Detecter	0.75					
		...	...					
	...							
06 Spacecraft (Space System CO)			645.984	$21,271,621.16	$34,071,254.78	$19,064,533.43	$3,060,911.19	77468320.6
	Structure		132.7	$9,724,500.77	$10,487,562.70	$4,430,415.00	$776,049.68	25418528.1
		Primary Structure	72.85	$2,311,039.17	$2,506,034.42			4817073.59
		Secondary Structure	45.75	$175,743.94	$30,147.87			205891.806
		Balance Weight	14.1					
		....	...					
		....						

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Space Missions Model in Action

- PRICE consultants are currently using these models to perform estimates validating several space missions against actuals
  - Validating Space Mission Models vs actuals for 16 different programs
  - Modeled to Level III Breakdown, matching At-Launch Spacecraft and Payload configurations and weights
  - Calculator input values derived from Cost Analysis Data Requirement (CADRE) Part-B data
  - Outputs mapped to NASA WBS categories in alignment with CADRE Part C data
  - Error-bands determined for total, spacecraft, payload and payload instrument costs
  - Burdening and escalation normalized across programs

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Conclusions

- The Spacecraft Missions models combine the power of the TruePlanning® framework with a time-tested space specific application of the PRICE Hardware estimating methodology
- One-stop shopping for estimating entire missions including spacecraft and payload
- Models validated by their original creators and long-time users as well as by the PRICE team

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Questions & Answers

To submit a question, please use the **“Questions”** feature located in your control panel, which you can access by clicking on the orange arrow on the right hand side of your screen.

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Upcoming Events

12 Aug 2014, Herdon, VA | Industry Event

NASA Cost Symposium

17 Sep 2014 | Industry Event

ICEAA SoCal and San Diego Chapters - Workshop

More details at pricesystems.com/events

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Wrap-up: More Information

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Learn more about TruePlanning® 2014

pricesystems.com/en-us/offerings/trueplanningframework.aspx

Call 1-800-43-PRICE or email: robert.becker@pricesystems.com

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Introduction - TruePlanning®

- TruePlanning® (TP) is an activity-based Resource Consumption Accounting (*RCA*) and Cost Analysis Tool
- TruePlanning® Estimation Framework consists of:
  - ***TrueAnalyst®*** is the application used by PRICE personnel to construct reusable activity-based RCA cost estimating models
  - ***TruePlanner®*** is the application which integrates the TP cost models with schedule and financial information through a robust software architecture and implementation called the TP Framework
  - ***SQL Database*** contains cost models and saved projects

TruePlanning® is an integrated set of cause and effect models. It identifies the primary cost drivers through statistical relationships and applies cost effects through the use of mathematically sound algorithms.

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Activity-Based Costing Definition

- A special costing model that identifies activities in an organization and assigns the cost of each activity with resources to all products and services according to the actual consumption by each
- A method that measures the cost and performance of process-related activities and cost objects
- Assigns cost activities based on their use of resources, and assigns cost-to-cost objects, such as products or customers, based on their use of activities
- Recognizes the causal relationship of cost drivers to activities
- Measures the cost and performance of process-related activities and cost objects

Source: The CAM-I Glossary of Activity-Based Management, 1990

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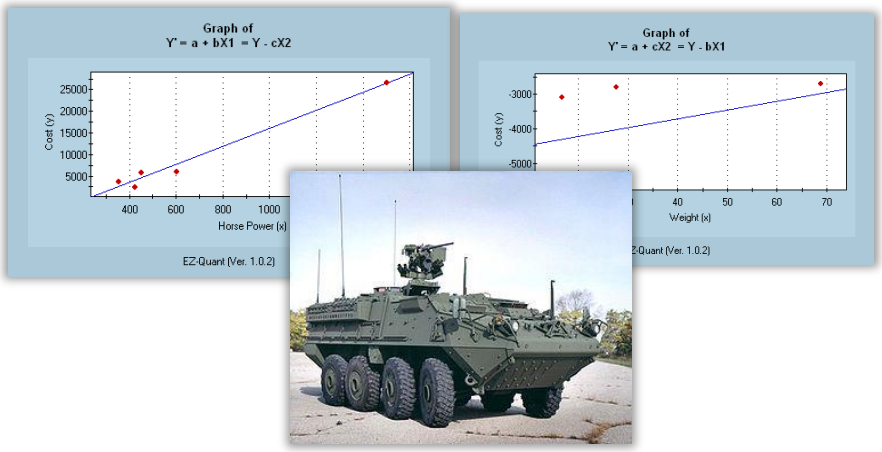
Estimating Approach Comparison

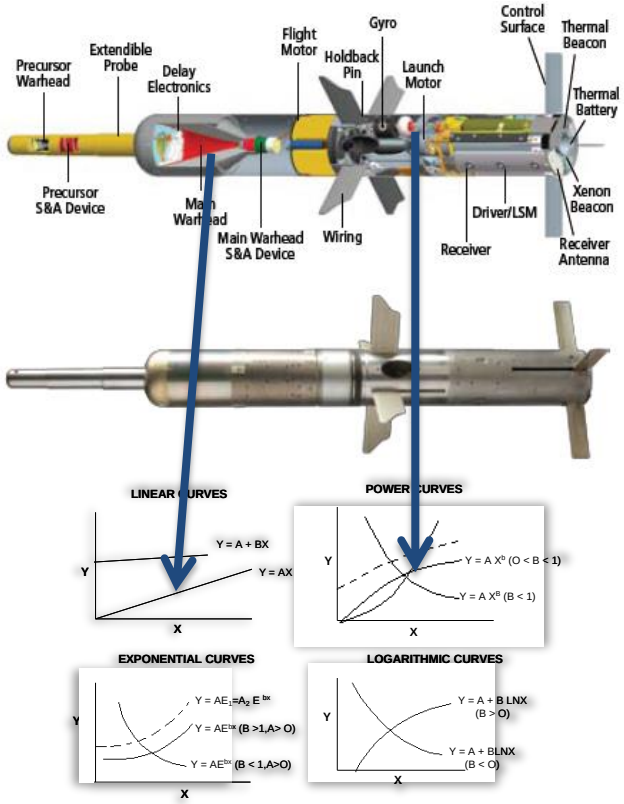
Traditional Approach

MDSNAME	Avg Annaul Class IX Cost	Horse Power	Weight
STRYKER	$4,191.54	350	16.47
PALADIN	$6,559.67	450	27.5
ABRAMS	$28,417.17	1500	68.7
BRADLEY	$6,955.52	600	27.6
FAASV	$3,342.55	420	26.1



CER: System to Class IX Parts Total Cost

TruePlanning® Approach



CER: Component Parts to Hours To Build

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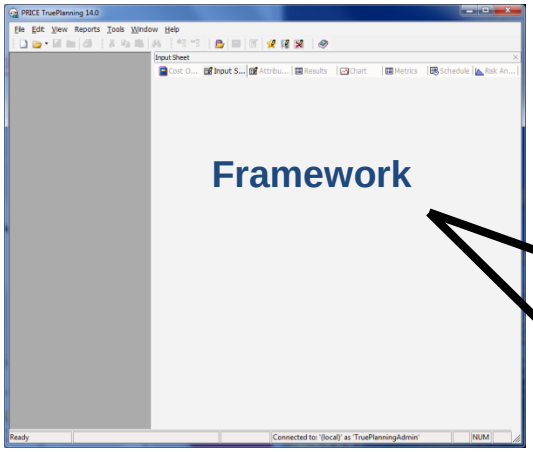
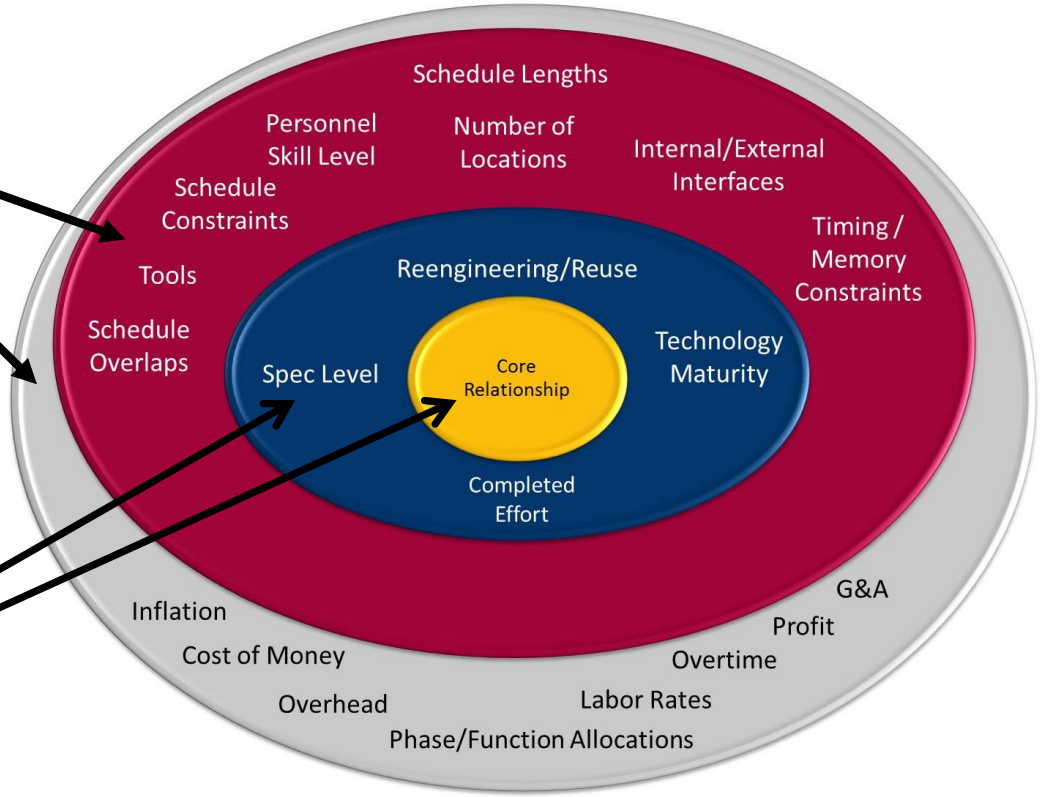
Framework Orientation

Cost Research Content Hosted In An Analysis Framework





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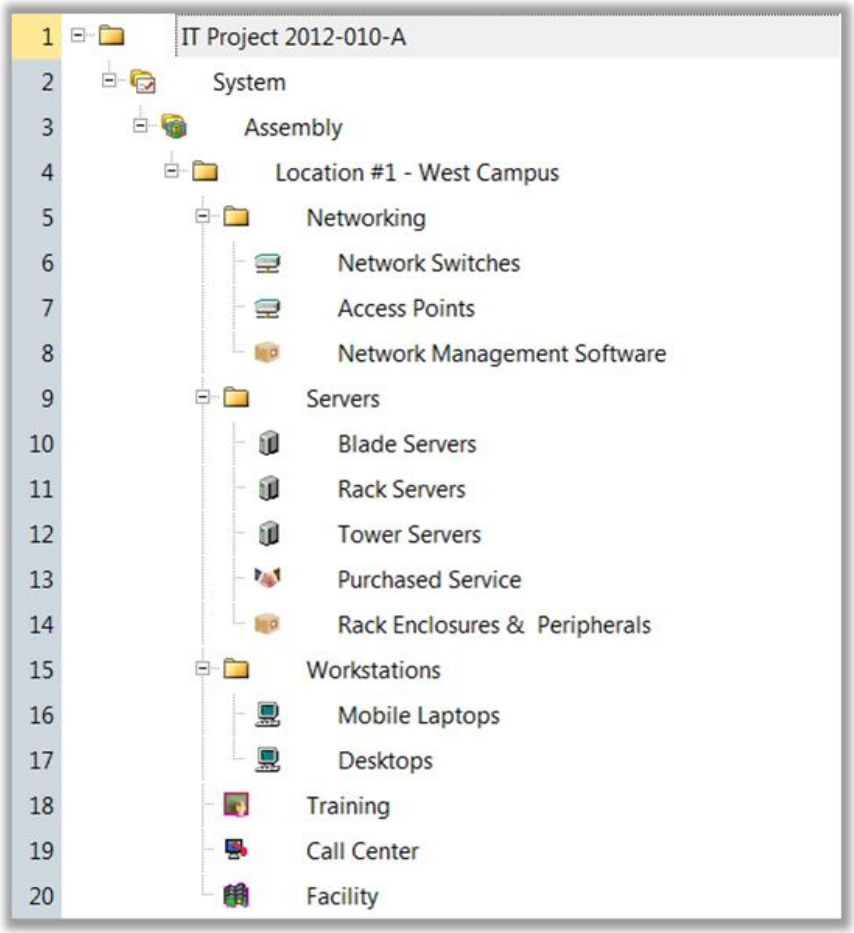
Hierarchical PBS and Integrated Models

- The PBS/WBS is a **hierarchical** method of representing a program with component models
- How the PBS Structure is modeled determines how cost, effort, schedule and risk are reported
- Models can be dragged into the PBS and **renamed** to be more useful or appropriate
- Objects have a Parent/Child relationship



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