Optimizing Data Driven Cost Estimating Models for Space Mission Analysis and Design

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TruePlanning® by PRICE® Systems

Introduction

- In today's data driven cost estimating environment, it is critical to understand the impact of design and systems engineering decisions on cost.
  - Important to leverage actual cost data in developing data-driven Cost Estimating Relationships (CERs) that relate engineering design and performance parameters to cost.
  - Critical in today's environment to have the ability to conduct sensitivity analysis on not only the CER, but on the entire system estimated to understand the full impact on Measures of Effectiveness and Measures of Performance.
  - Using the FireSat satellite example we will discuss how to create libraries of data-driven CERs for future projects. These CERs are "white box" and auditable both in terms of the trend line equation and underlying data points.
  - The presentation will also cover the benefits of implementing a data-driven methodology in the TruePlanning framework vs. maintaining CERs in EXCEL.
  - Using a new interface developed for TruePlanning, this presentation will also demonstrate how sensitivity analysis for custom developed CERs can easily be generated.

Data Driven Estimating

- What does it mean?
  - It means the kind of estimating envisioned by S. 454, Weapon Systems Acquisition Reform Act of 2009, signed into law by President Obama on May 22, 2009.

- Among the initiatives of the act are:
  - Getting things right from the start with sound systems engineering, cost-estimating;
  - Ensure that cost estimates for major defense acquisition programs are fair, reliable, and unbiased;
  - Ensure the consideration of trade-offs between cost, schedule, and performance early in the process of developing major weapon systems;
  - An infusion of highly skilled and capable acquisition specialists to carry out the requirements of this bill and address the problems in the defense acquisition system.

Parametric Estimating

- Parametric estimating represents the most widely adopted method in the integrated engineering and costing environment. Among the reasons:
  - Parametrics are faster to respond than conventional or bottoms-up cost estimating;
  - Parametrics, by amalgamating cost variables into a few cost drivers, require less information than other methods;
  - Parametric cost drivers often align to engineering drivers, allowing concurrent development of estimates and design alternatives; no other methods have demonstrated this ability;
  - Interfaces between Systems Engineering tools and parametric estimating tools, some commercial, are in use right now;
  - When properly calibrated, parametric estimating is at least as accurate as any other estimating method; parametrics is often better.

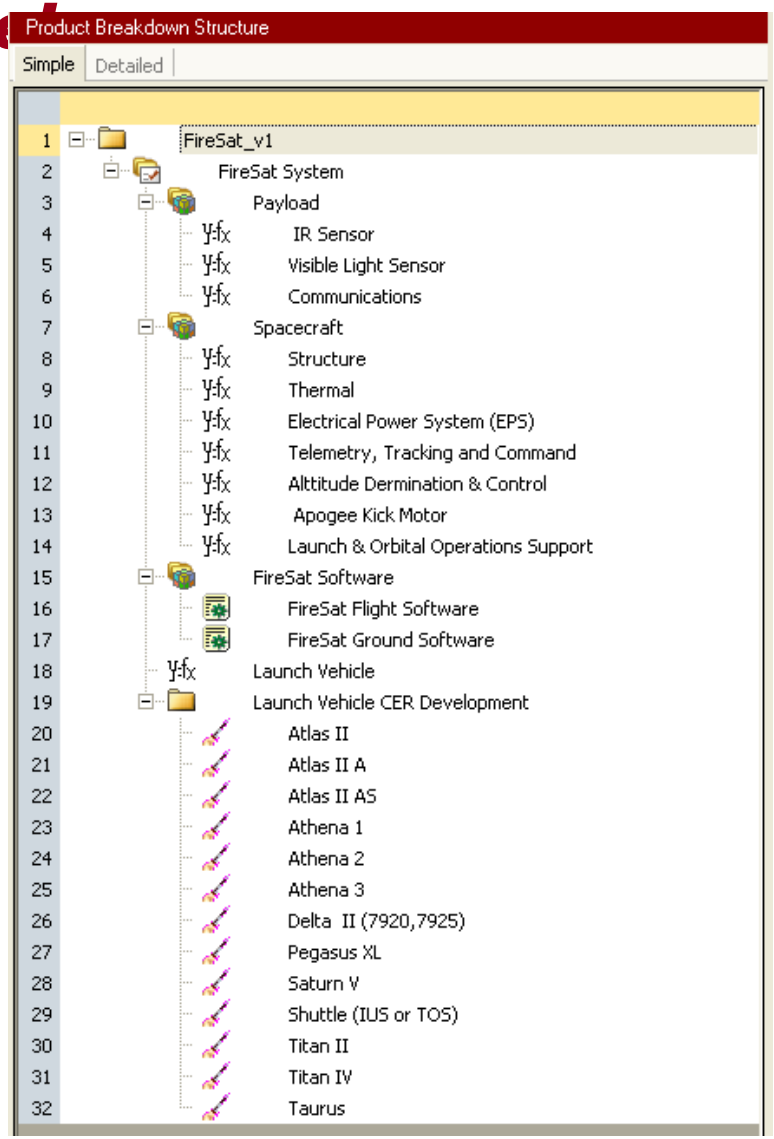
Case Study

Leveraging Data-Driven CERs and Sensitivity Analysis in Satellite Estimating

FireSat Case Study

- Using Space Mission Analysis Design FireSat equations , 3rd edition, and PRICE Systems cost research, the objectives of this case study are to:
  - Develop a data-driven estimating model.
  - Determine he “surface response” of the model (carpet plot analysis) to changes in design and design life parameters.
  - Understand which of the design variables drive cost – and to what extent (Design of Experiments).
  - Examine the trending within the cost estimating model.
  - Conduct and Independent Cost Estimate (ICE) as a cross-check against our “point” estimate.
- We begin by constructing a Work Breakdown Structure in the TruePlanning model and then integrating the results with Phoenix Integration ModelCenter 9.0.

"Data Driven" Example – FireSat TruePlanning Model



FireSat CER's from Space Mission Analysis and Design (SMAD) 3rd Edition

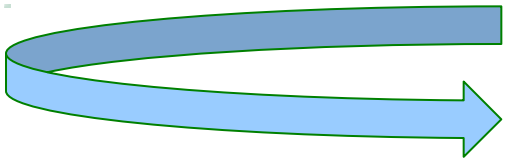
TruePlanning Software Cost Model

Launch Vehicle CER

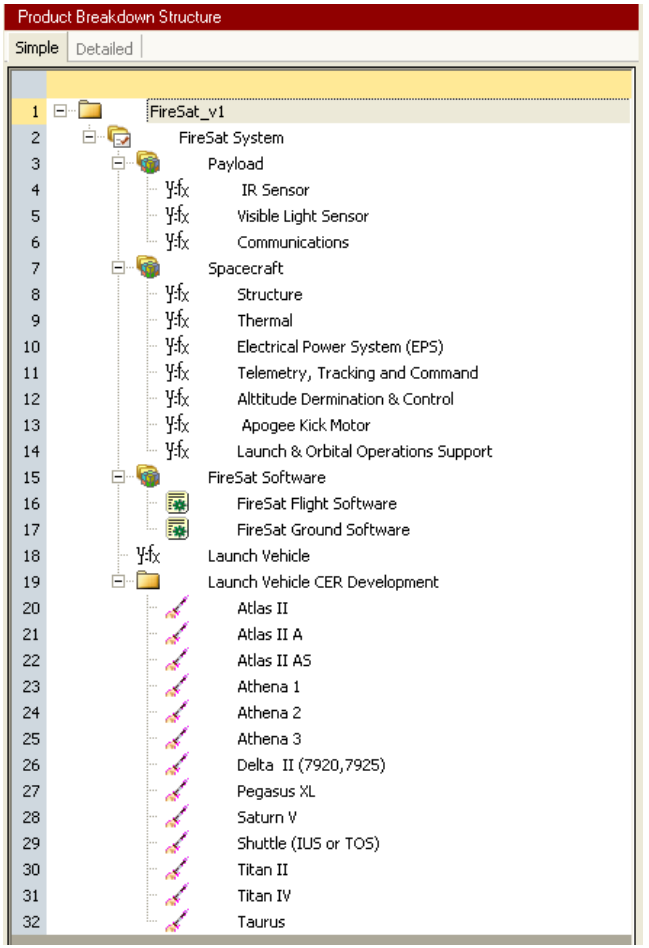
Launch Vehicle Database / CER Development

FireSat Cost Estimating Relationships

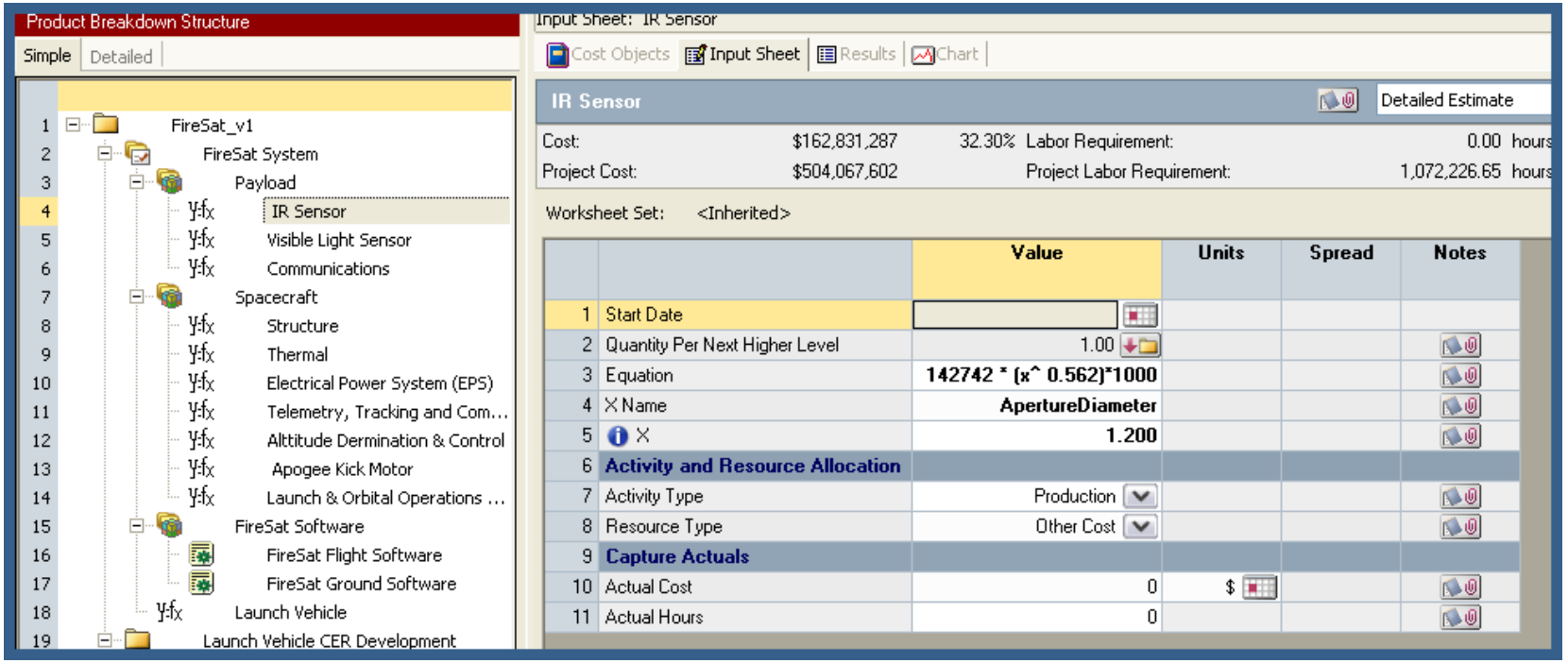
Level	Cost Object Name	Cost Object Custom Name	Equation	X Name	X
0	System	FireSat System			
1	Assembly	Payload			
2	Single Variable Equation	IR Sensor	142742 * (x^ 0.562)*1000	ApertureDiameter	1.2
2	Single Variable Equation	Visible Light Sensor	51469 * (x^ 0.562)*1000	ApertureDiameter	1.2
2	Single Variable Equation	Communications	(140*x)*1000	CommWtKG	395
1	Assembly	Spacecraft			
2	Single Variable Equation	Structure	13.1*x*1000	SpacecraftDryWtKG	560
2	Single Variable Equation	Thermal	50.6*x^.707*1000	Thermal_WT_KG	87
2	Single Variable Equation	Electrical Power System (EPS)	112*X^.763*1000	EPS_WT_KG	573
2	Single Variable Equation	Telemetry, Tracking and Command	635*X^.568*1000	TTC_WT_KG	79
2	Single Variable Equation	Alttitude Dermination & Control	293*x^.777*1000	ADCS_WT_KG	192
2	Single Variable Equation	Apogee Kick Motor	4.97*X^.826*1000	AKM_WT_KG	966
2	Single Variable Equation	Launch & Orbital Operations Support	4.9*X*1000	LOOS_WT_KG	1537



Space Mission Analysis Design FireSat equations imported directly from EXCEL into TruePlanning Equation Cost Object



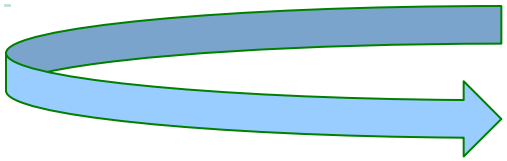
Example of FireSat CER imported into TruePlanning

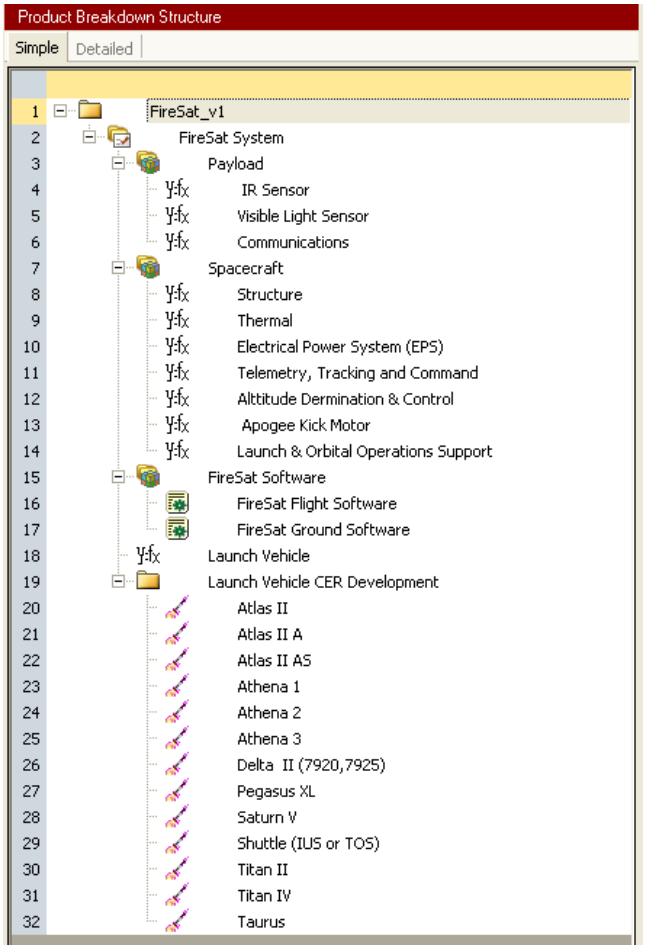


Once the CER is imported into TruePlanning it become an integral part of the framework co-existing with other CERs. The CER is not subject to breakage as in an EXCEL spreadsheet and leverages additional TruePlanning capability e.g, risk analysis.

FireSat Launch Vehicle CER Development

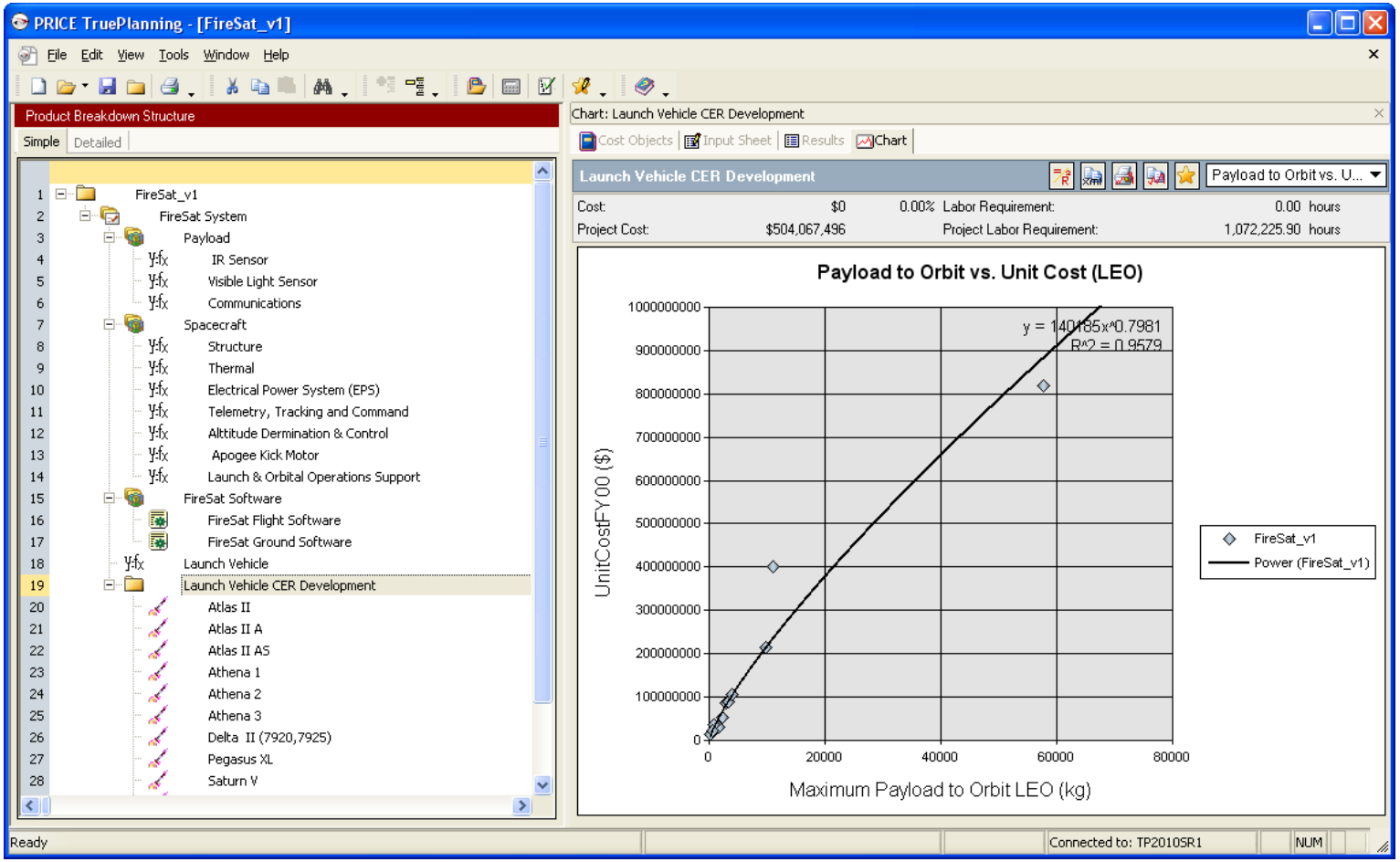
Level	Cost Object Name	Cost Object Custom Name	Unit Cost FY00	Cost per KG to LEO FY00	New Cod
1	Folder	Launch Vehicle CER Development			
2	Launch Vehicle Data	Atlas II	$85,000,000	$13,700	
2	Launch Vehicle Data	Atlas II A	$90,000,000	$13,000	
2	Launch Vehicle Data	Atlas II AS	$105,000,000	$12,700	
2	Launch Vehicle Data	Athena 1	$18,000,000	$22,500	
2	Launch Vehicle Data	Athena 2	$26,000,000	$13,300	
2	Launch Vehicle Data	Athena 3	$31,000,000	$8,500	
2	Launch Vehicle Data	Delta II (7920,7925)	$52,500,000	$10,800	
2	Launch Vehicle Data	Pegasus XL	$13,000,000	$28,300	
2	Launch Vehicle Data	Saturn V	$820,000,000	$6,500	
2	Launch Vehicle Data	Shuttle (IUS or TOS)	$400,000,000	$16,400	
2	Launch Vehicle Data	Titan II	$37,000,000	$19,400	
2	Launch Vehicle Data	Titan IV	$214,000,000	$9,900	
2	Launch Vehicle Data	Taurus	$21,500,000	$15,700	





Space Mission Analysis Design Launch Vehicle Data imported from EXCEL to TruePlanning for CER development

FireSat Launch Vehicle CER Development



Space Mission Analysis Design Launch Vehicle Data regression analysis and CER development in TruePlanning

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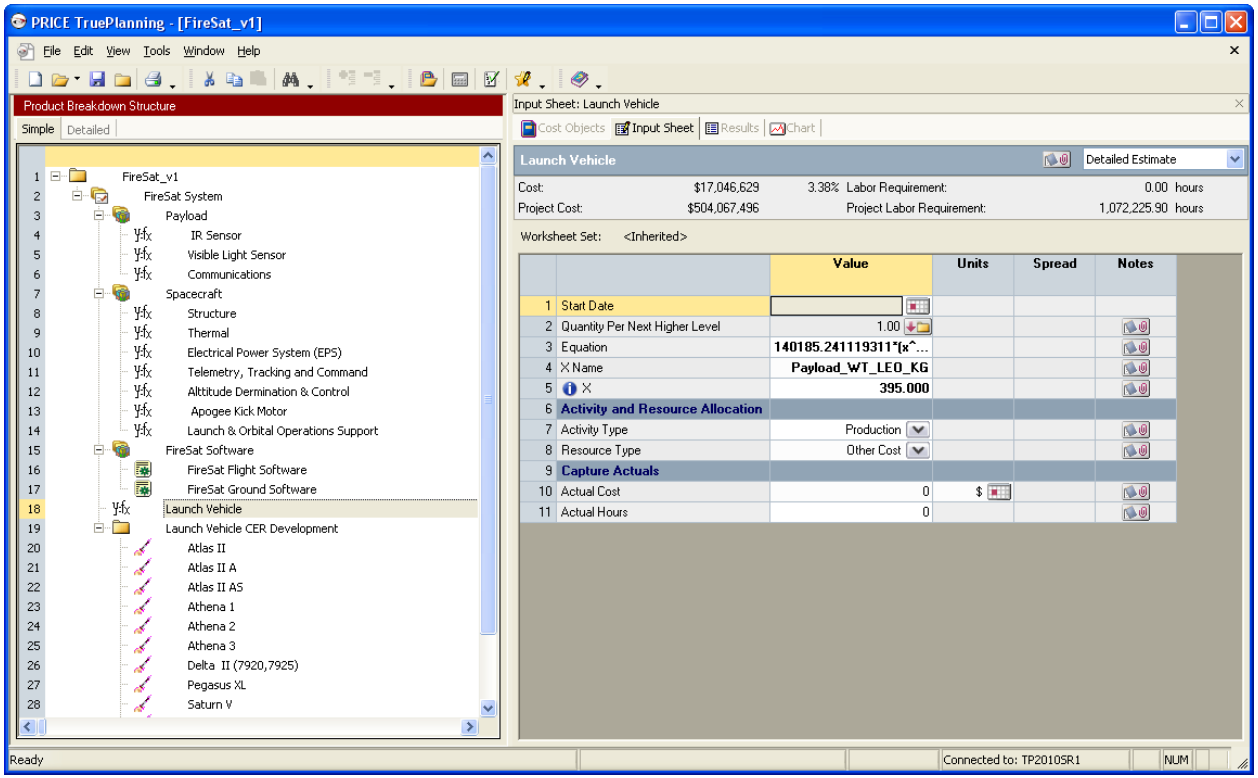
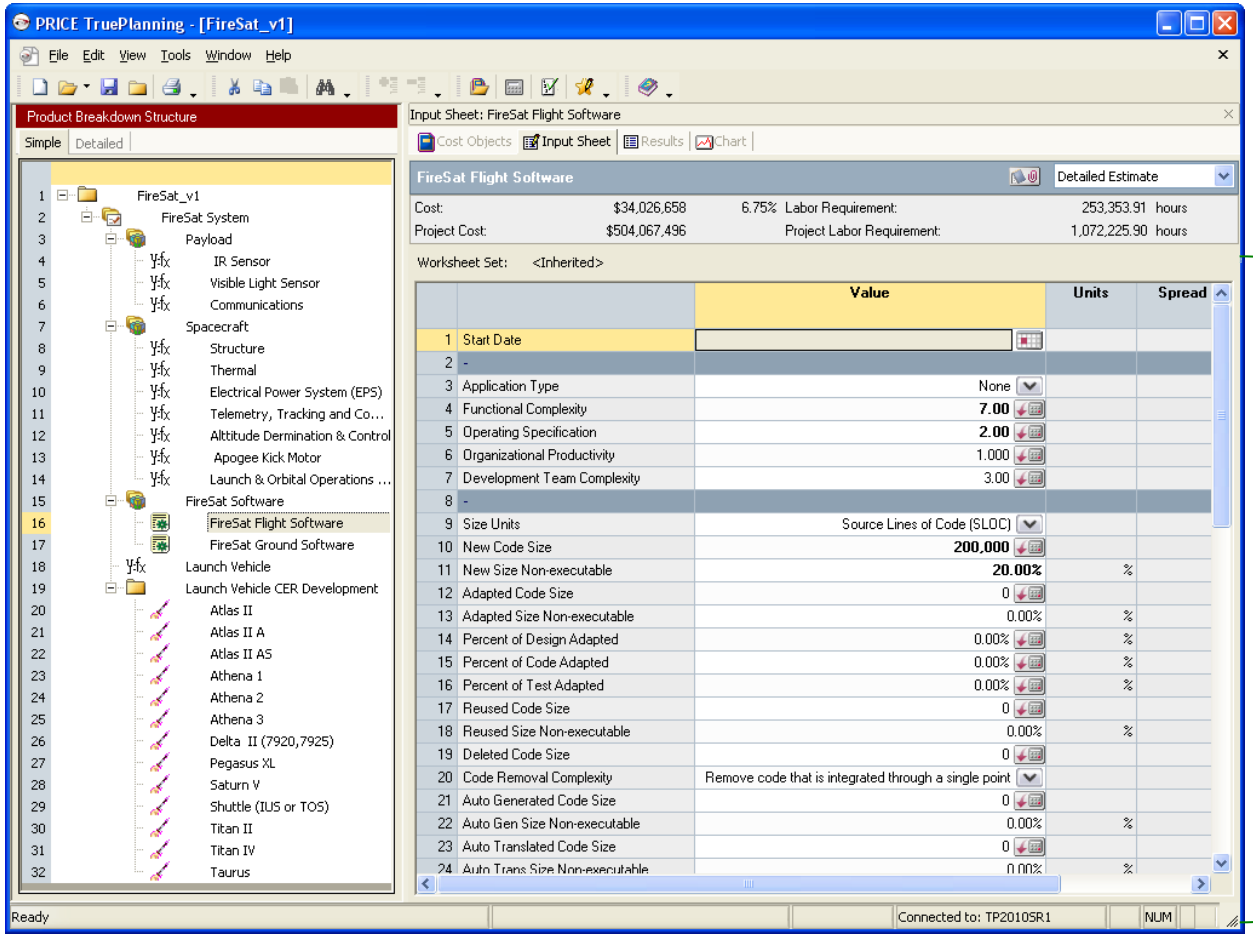
FireSat - Launch Vehicle CER



Resultant CER based on regression analysis of Launch Vehicle data is encapsulated into a Launch Vehicle CER cost object.

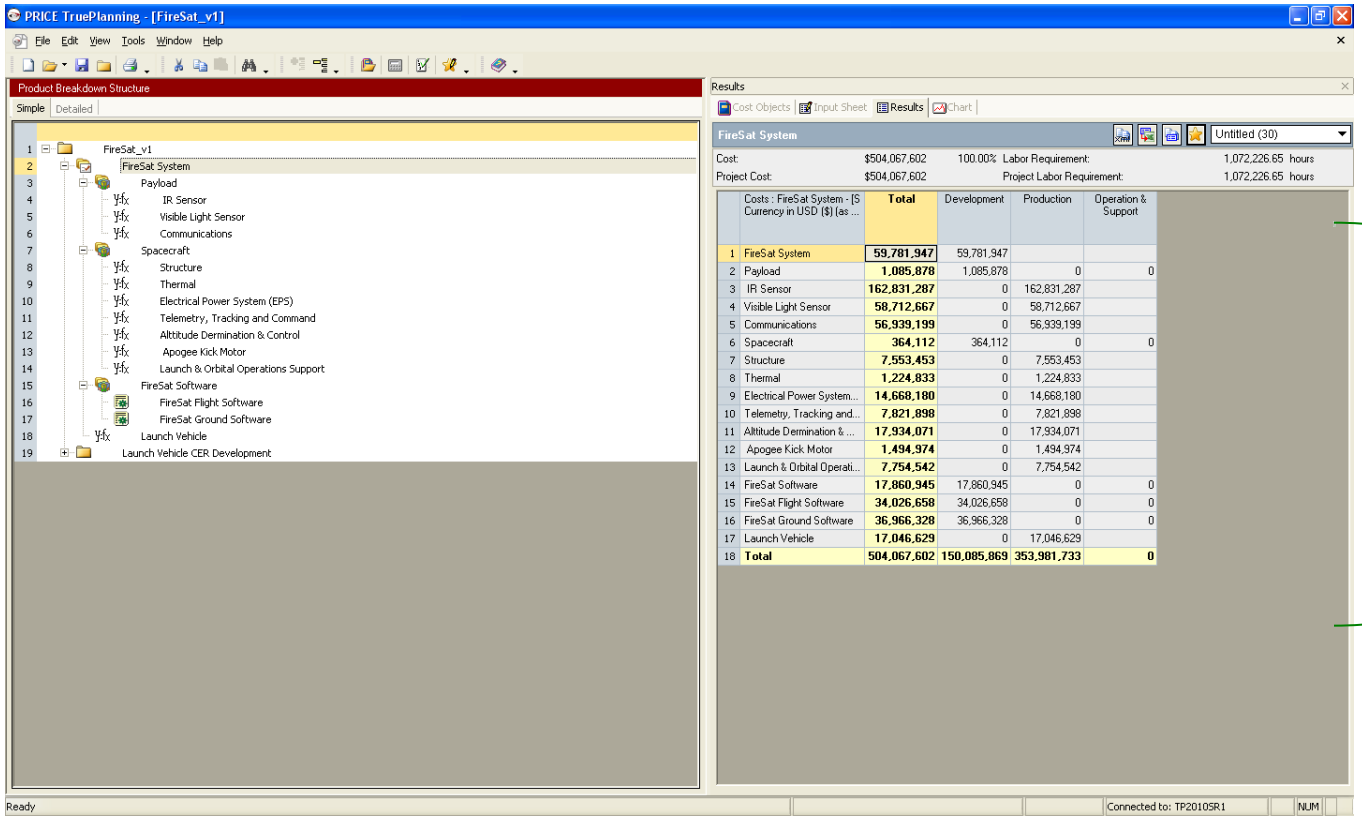
This can become part of a library of CER's including the source data

FireSat - TruePlanning Software Estimating Model



For software, we have augmented the SMAD CERs with TruePlanning for Software. This allows a much more robust modeling of the software estimate taking into account additional parameters software sizing, effective lines of code and team experience.

"FireSat Model Cost Estimate Model



Total System Estimate @ $504M

Based on:

SMAD CERs

Launch Vehicle CER Development

TruePlanning System of Systems Estimates

True Planning Software Estimates

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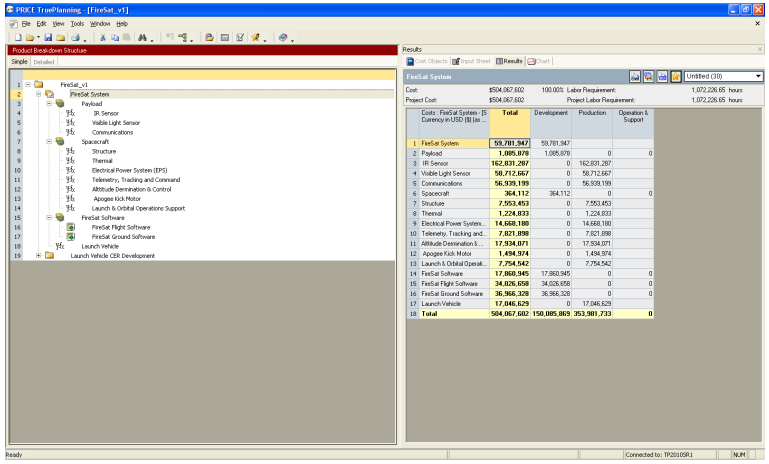
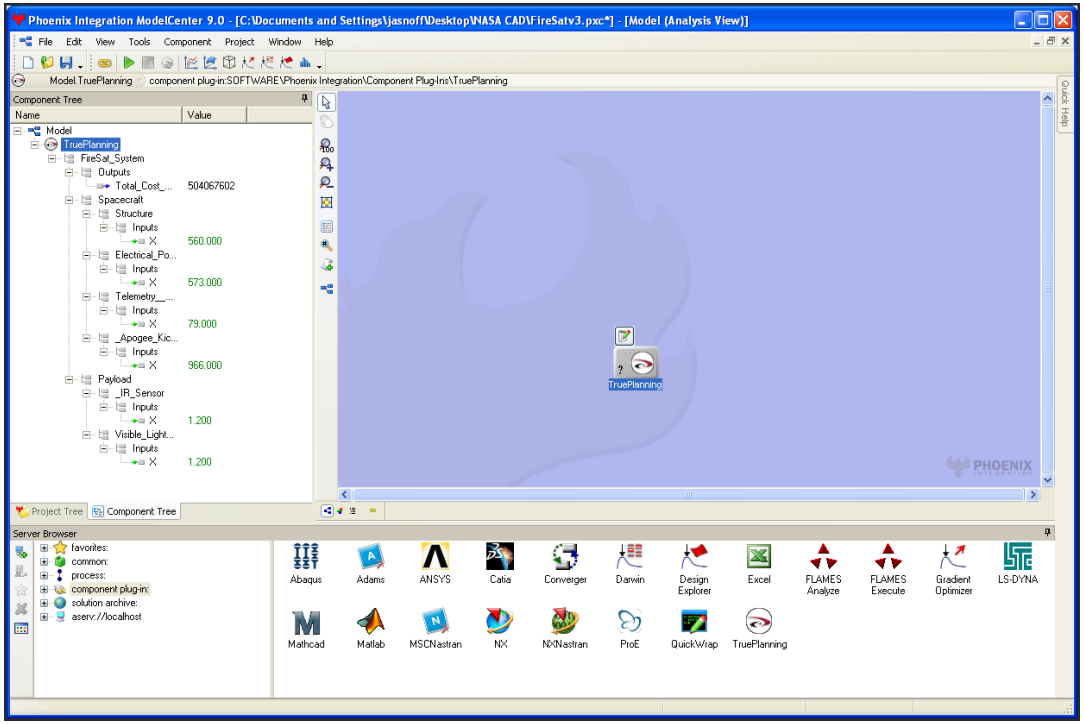
FireSat Sensitivity Modeling

- Our TruePlanning model provide a single “point estimate”. However, we want to understand:
  - Sensitivity of the model to changes in CER parameters.
  - The response surface or “Carpet Plot” of the model to parameter changes
  - Which of the design variables drive cost – and to what extent (Design of Experiments)
- Using ModelCenter 9.0 from Phoenix Integration, we can conduct these (and many other) system engineering studies.
- This allows us to determine the sensitivies of FireSat CERs within the TruePlanning model

FireSat Sensitivity Modeling



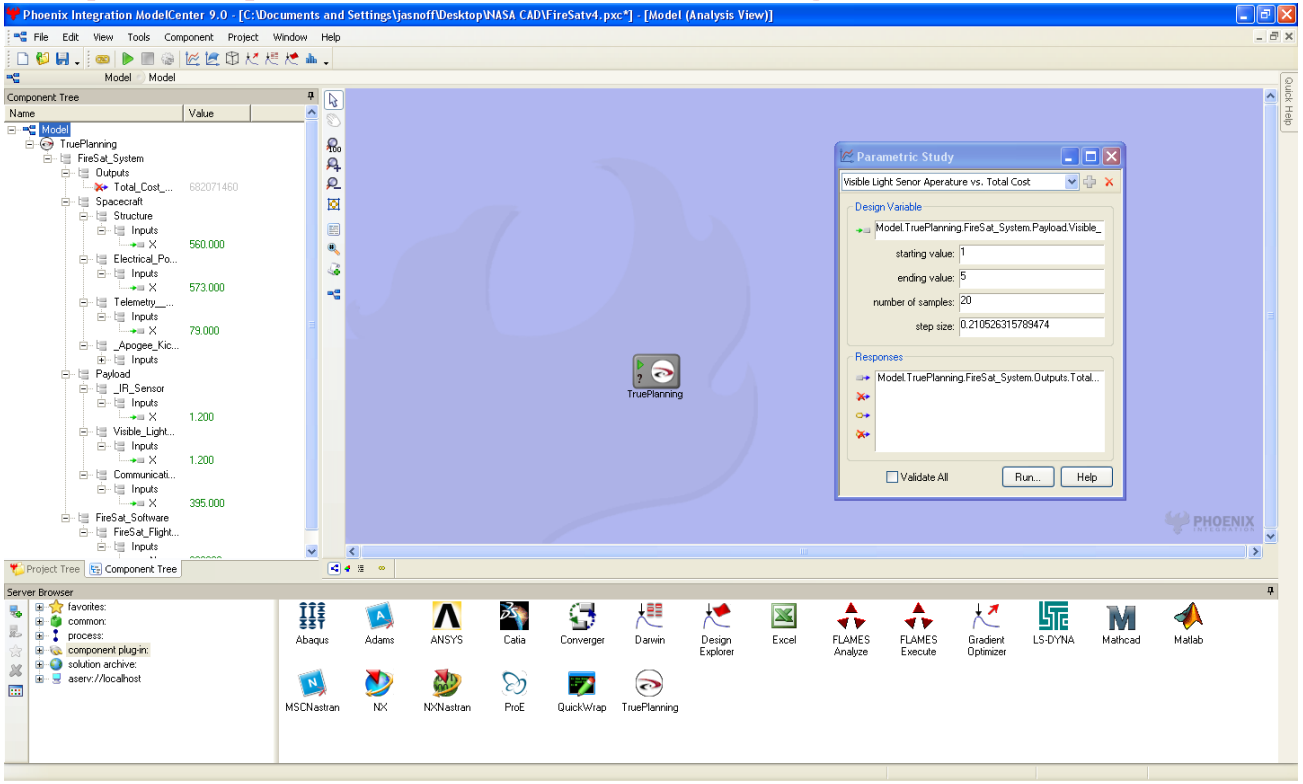
ModelCenter 9.0



ModelCenter 9.0 contains a "plug in" for TruePlanning allowing exposure of all TruePlanning inputs and outputs.

This allows the ability to take full advantage of ModelCenter System Engineering tools

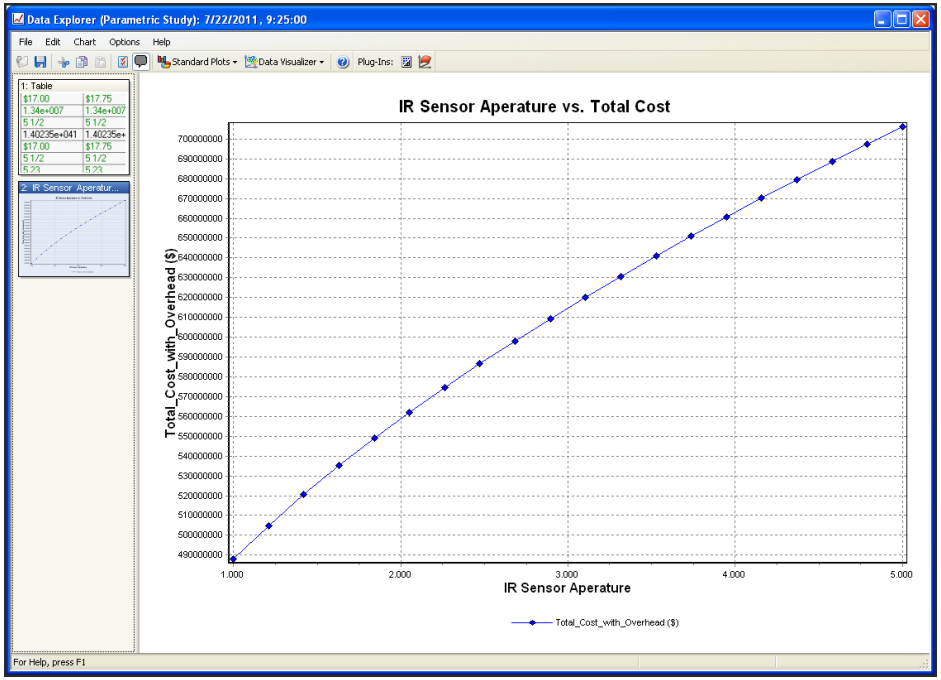
FireSat Sensitivity Modeling – Parametric Study - Sensors Cost Estimating Relationship (CER) in TruePlanning

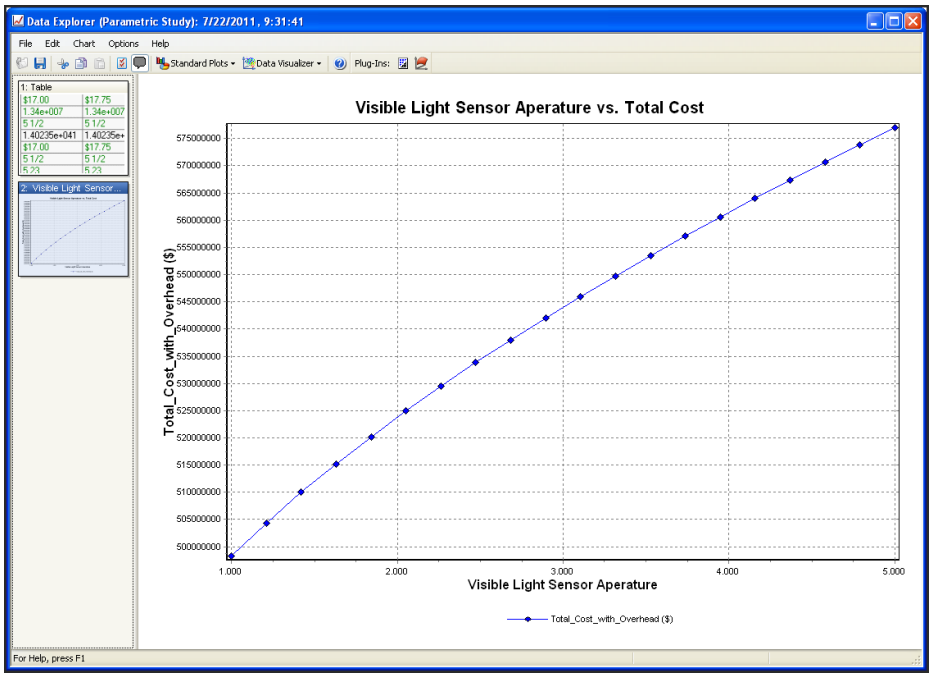


Using ModelCenter 9.0, we want to do a "Parametric Study" of the Aperture Diameter to understand how variations of Aperture size influence cost.

TruePlanning model opened in ModelCenter 9.0 showing selected inputs.

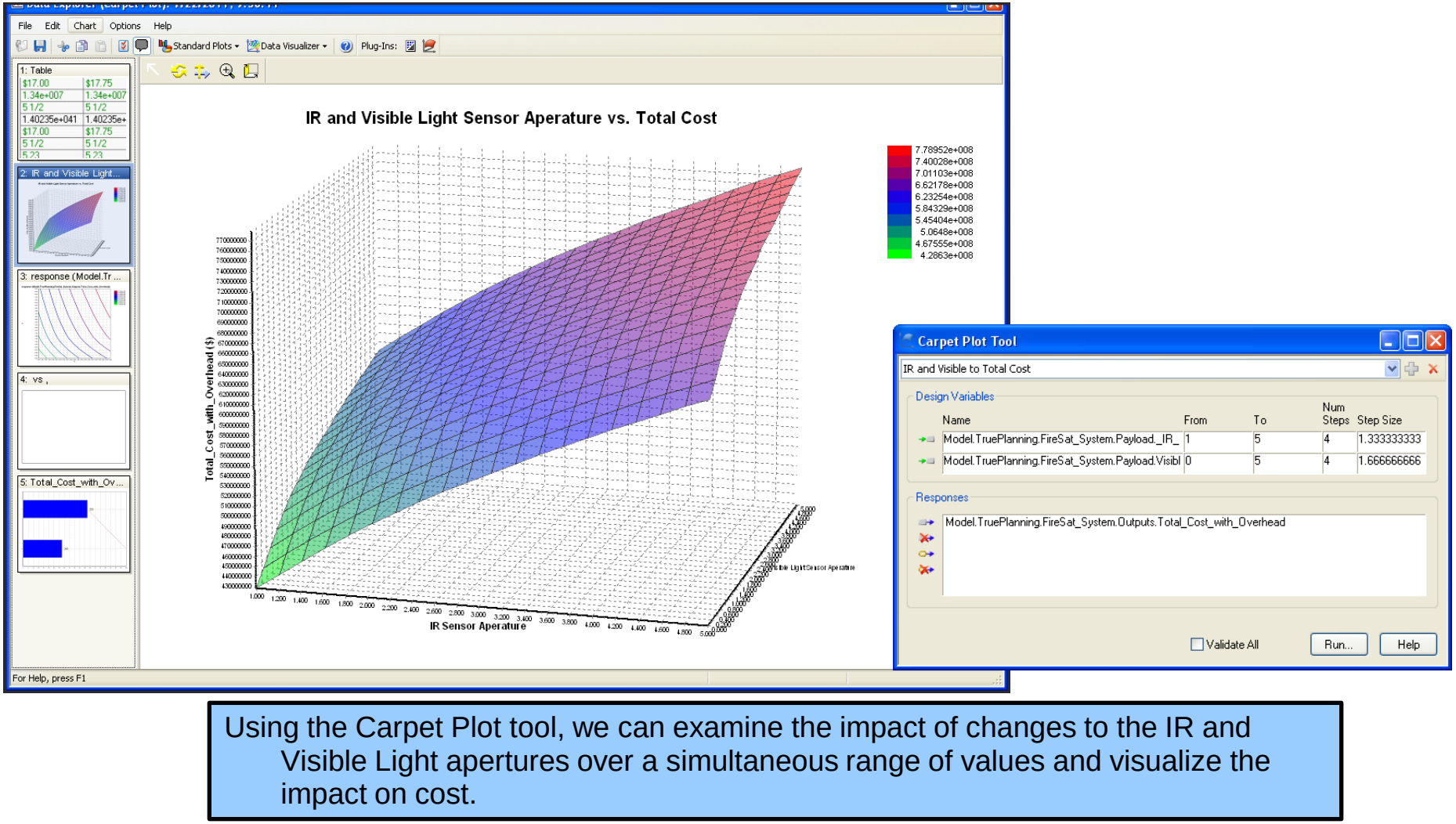
FireSat Sensitivity Modeling – Parametric Study - Sensors





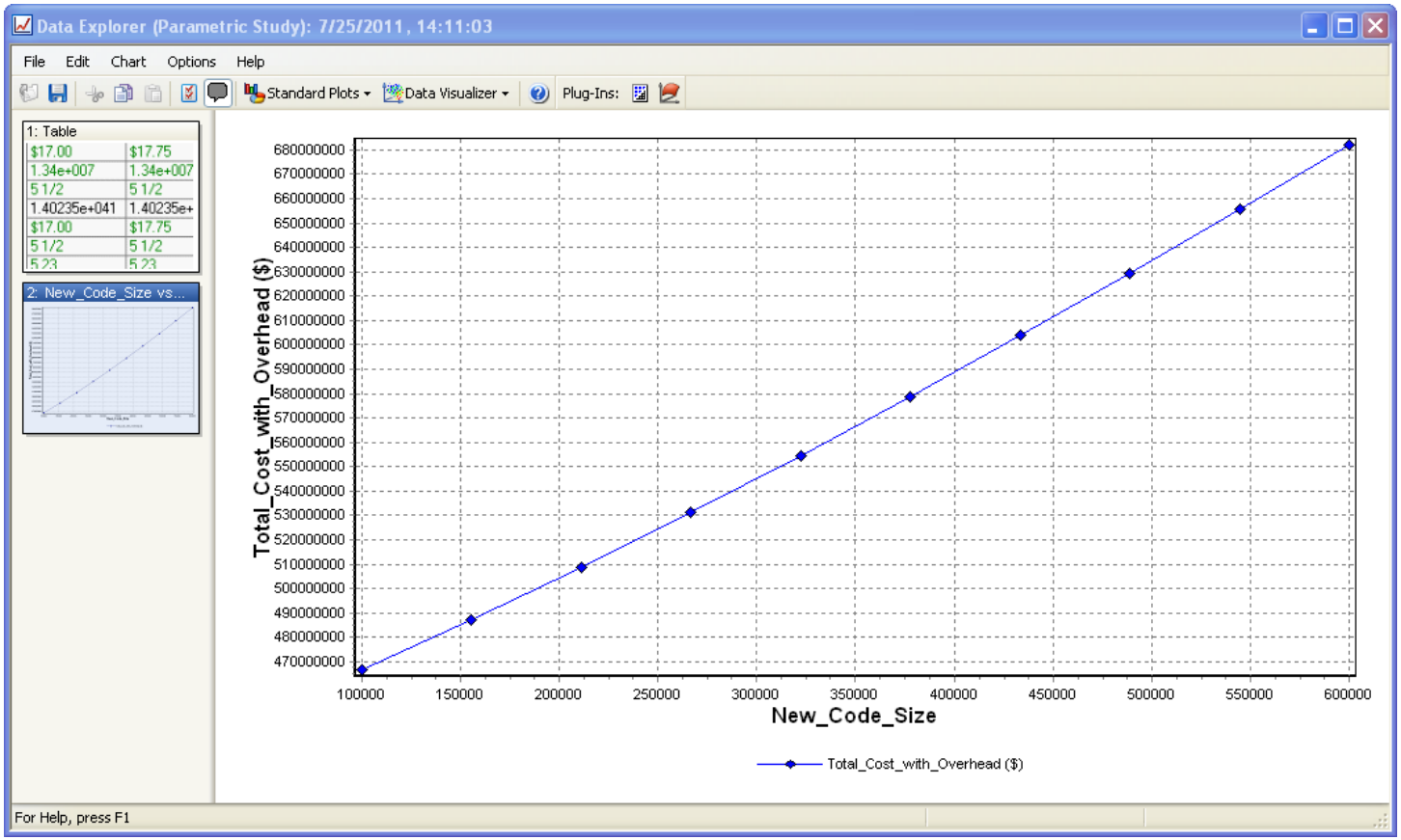
For this study we use ModelCenter 9.0 to iterate a range of aperture parameters for IR Sensor and Visible Light Sensor to examine the impact on Total Cost

FireSat Sensitivity Modeling – Carpet Plot, ModelCenter 9.0



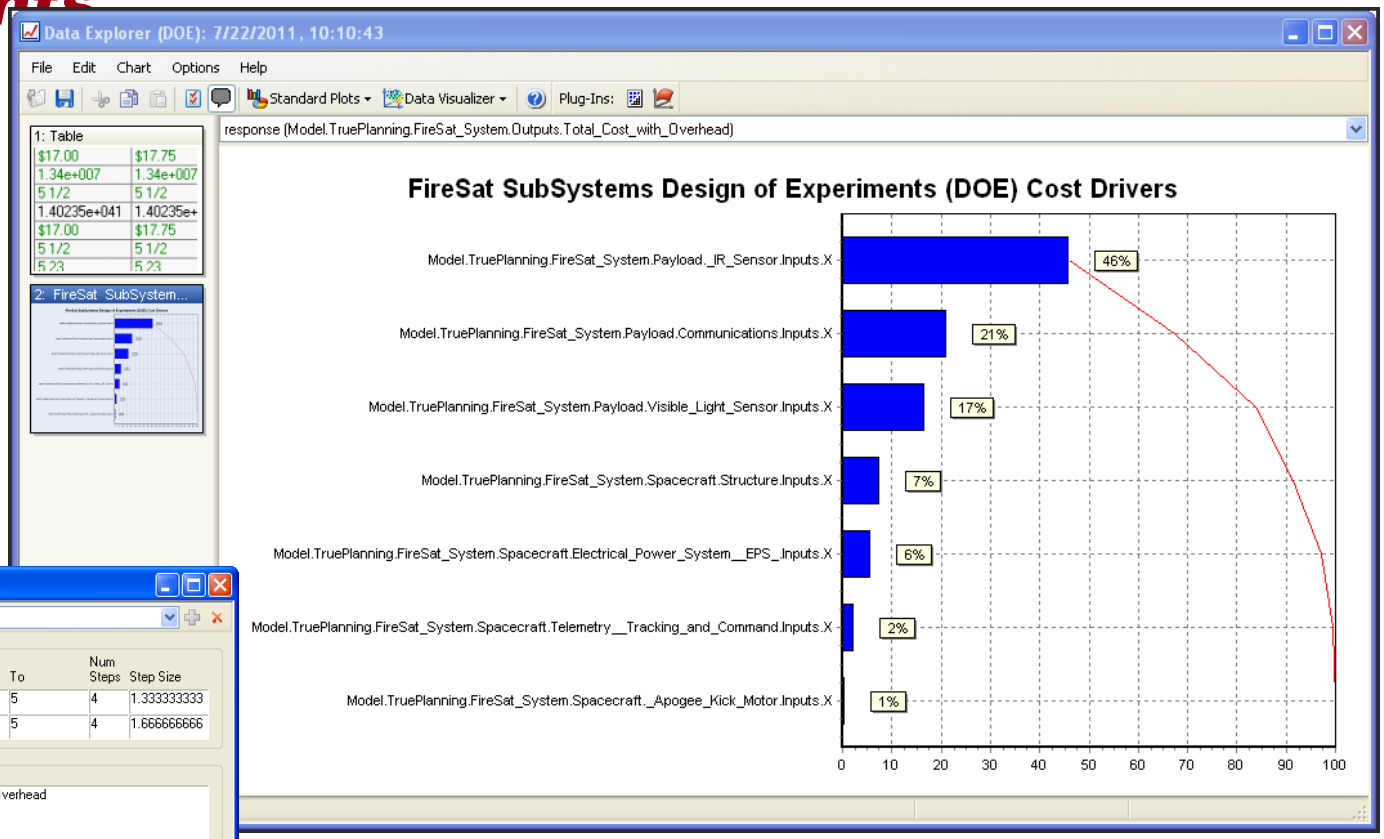
Using the Carpet Plot tool, we can examine the impact of changes to the IR and Visible Light apertures over a simultaneous range of values and visualize the impact on cost.

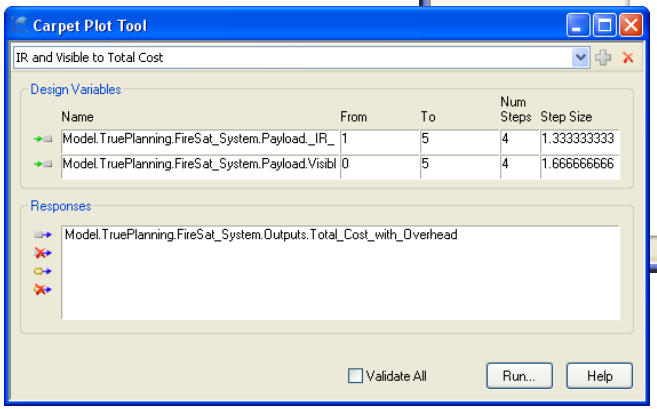
FireSat Sensitivity Modeling – Parametric Study - Software



In addition to examining subsystems, we can also use ModelCenter to look at sensitivity of code growth to total cost.

FireSat Sensitivity Modeling – Design of Experiments

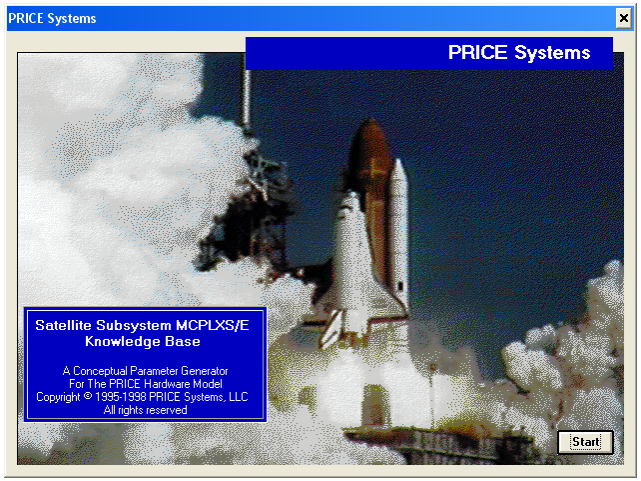


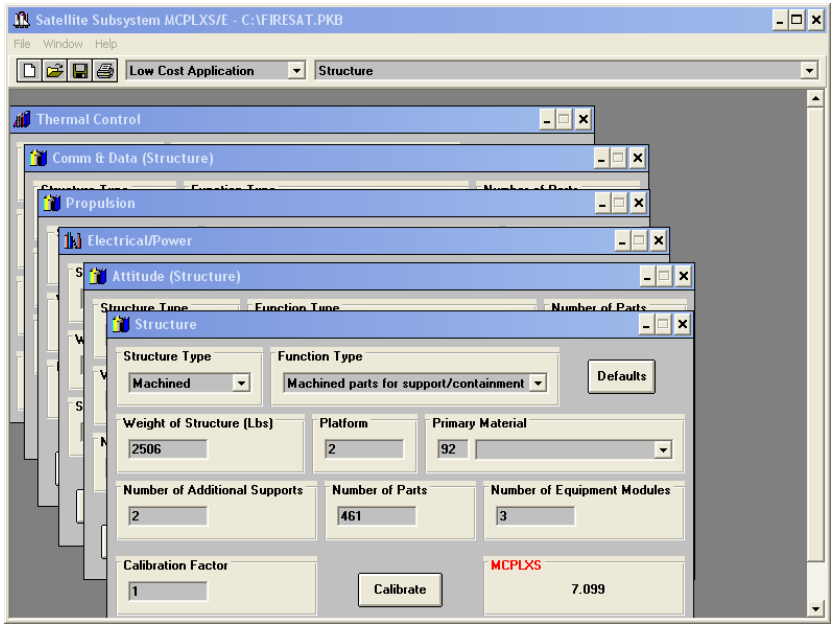


In Using the DOE tool, we can examine which of the subsystems are the largest cost drivers over a range of variation.

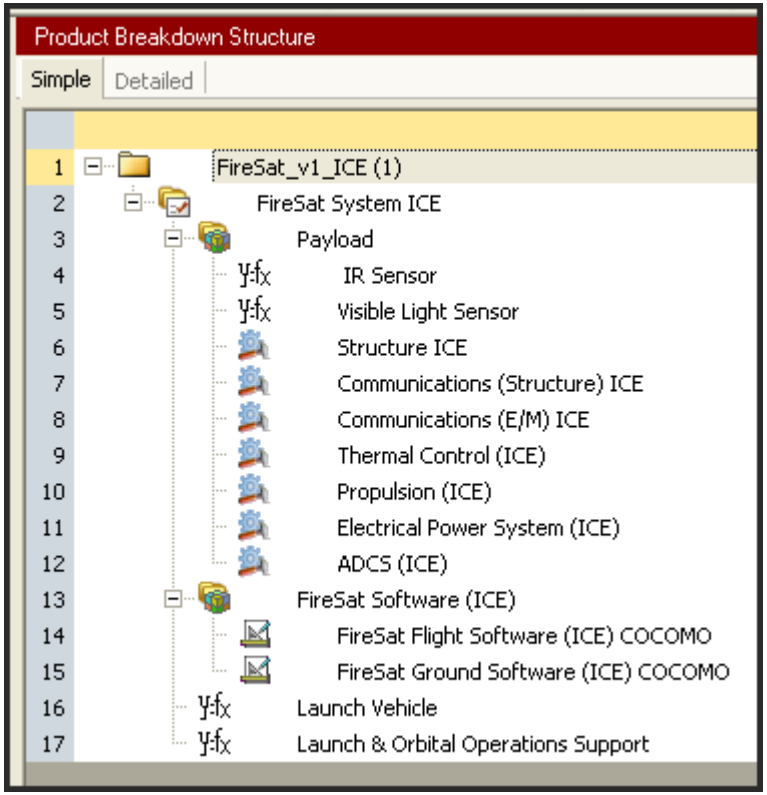
FireSat Sensitivity Modeling – Independent Cost Estimate

- In addition to understanding the sensitivities of the data-driven FireSat model, we also want to develop an Independent Cost Estimate (ICE) using PRICE Systems cost research.
- For the Hardware ICE, we construct a model using calibrated NASA historical data contained in the Satellite Subsystem Knowledge Base (SSKB)
- For the Software ICE, we use the COCOMO model contained in TruePlanning





FireSat Independent Cost Estimate (ICE)



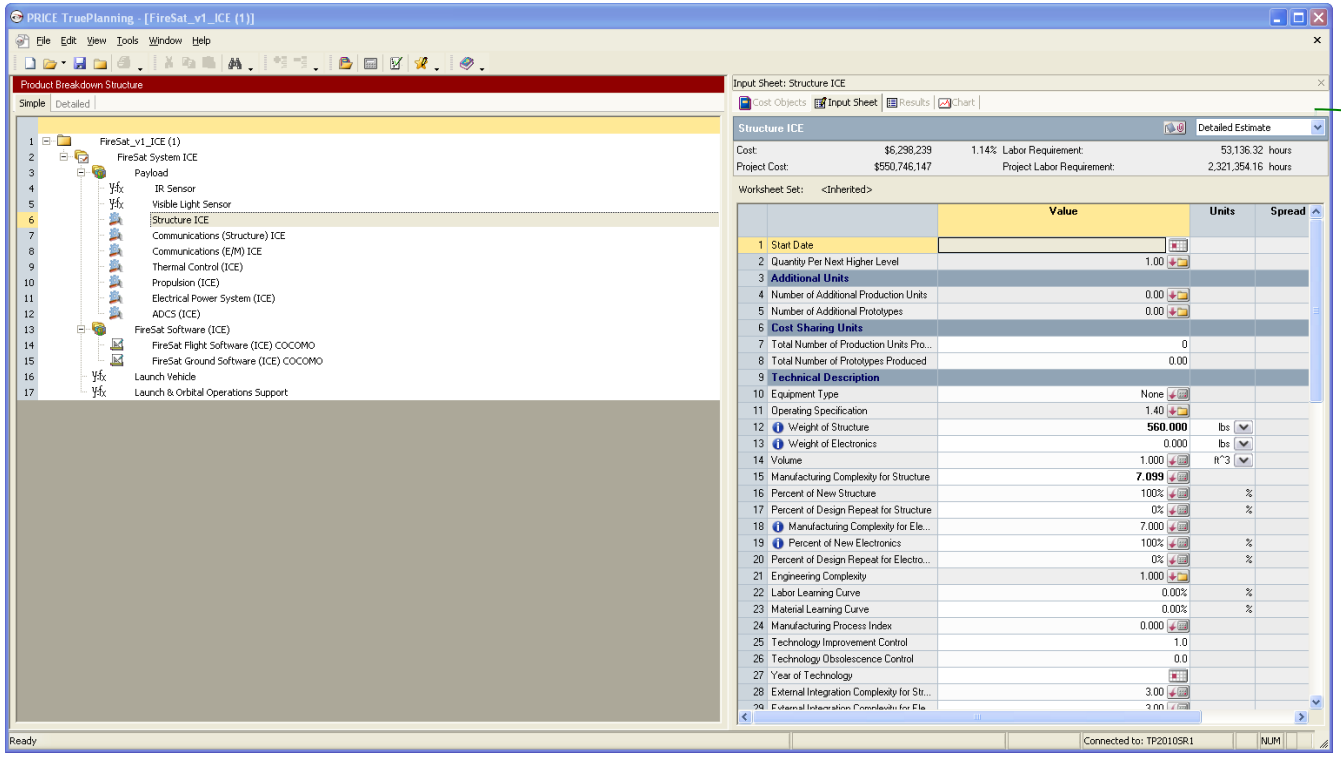
FireSat IR and Visible Sensor CER from SMAD

Independent Cost Estimate (Hardware) for Subsystems from calibrated TruePlanning Hardware model

Launch Vehicle from CER library (SMAD)

The Independent Cost Estimate substitutes the SMAD CERs with calibrated TruePlanning Hardware models

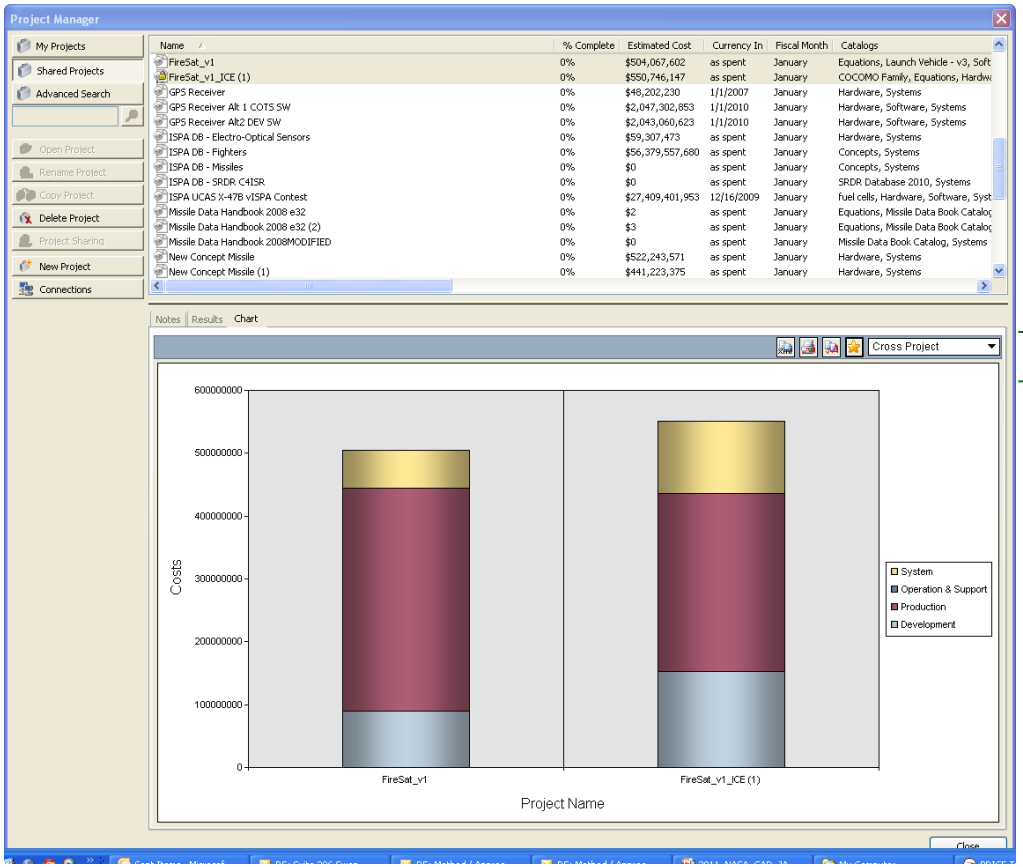
FireSat - TruePlanning Hardware Estimating Model – Independent Cost Estimate (ICE)



For the ICE, we have replaced the SMAD subsystem CERs with TruePlanning for Hardware model.

This allows independent modeling of the subsystems estimate taking into account historical NASA calibrations in the Satellite Subsystem Knowledge Base (SSKB)

FireSat ICE vs. FireSat SMAD CERs



TruePlanning Project Manager display all projects within the SQL database

Cross Project chart selection control

FireSat estimate $504M vs. FireSat ICE @ $550M displayed in column chart format

TruePlanning® by PRICE® Systems

Benefits of Data Driven Results in TruePlanning Framework

- Ability to include CERs as part of the TruePlanning Framework.
  - Leverages additional capability such as risk analysis, escalation, activity based costing and consolidated reporting.
- Ability to have both databases of historical data points including estimating CERs within the same framework.
  - PRICE Cost Research/Calibrated can be intermingled with your own CERs thus increasing estimate fidelity.
- Integration with System Engineering tools such as ModelCenter to conduct sensitivity, Design of Experiments, optimization studies, etc.

Benefits of Data Driven Results in TruePlanning Framework

- Repository for all data used to generate the databases and CERs
  - Ability to embed the entire database including EXCEL files and trend line analysis within the TruePlanning estimate for complete auditability.
- In conjunction with the TruePlanning framework, you can integrate data-driven CERs, TruePlanning cost objects (models) and your own custom models to achieve higher fidelity estimates tied to both actual data points, calibrated data and PRICE cost research.

Zachary Jasnoff
- Solutions Architect, PRICE Systems, Rosslyn VA

- **Over 25 years parametric and detailed estimating experience**
- **Past estimating experience includes:**
  - **Lockheed-Martin**
  - **Boeing**
  - **US GAO**
  - **JPMorgan (Risk and Resiliency)**
- **Graduate of Wharton/Penn Engineering**
- **Conducted extensive consulting assignments with DARPA, DHS and DoD**
- **Presented courses in**
  - hardware estimating,
  - software estimating,
  - life cycle cost,
  - Cost Estimating Relationships,
  - Information Technology,
  - risk analysis and
  - supplier assessment
- **Developed TCO/Risk model for the banking industry**
- **Presented papers at DoDCAS, ISPA/SCEA, ISACA, DJR and PRICE Systems Symposiums**