Cost Model Comparison:
A Study of Internally and Commercially Developed Cost Models in Use by NASA

Garima Gupta
Mentors: Eleanor Basilio, Sherry Stukes, Greg Welz
Jet Propulsion Laboratory
California Institute of Technology

1. Abstract

NASA makes use of numerous cost models to accurately estimate the cost of various components of a mission – hardware, software, mission/ground operations – during the different stages of a mission's lifecycle. The purpose of this project was to survey these models and determine in which respects they are similar and in which they are different. The initial survey included a study of the cost drivers for each model, the form of each model (linear/exponential/other CER, range/point output, capable of risk/sensitivity analysis), and for what types of missions and for what phases of a mission lifecycle each model is capable of estimating cost. The models taken into consideration consisted of both those that were developed by NASA and those that were commercially developed: GSECT, NAFCOM, SCAT, QuickCost, PRICE, and SEER. Once the initial survey was completed, the next step in the project was to compare the cost models' capabilities in terms of Work Breakdown Structure (WBS) elements. This final comparison was then portrayed in a visual manner with Venn diagrams. All of the materials produced in the process of this study were then posted on the Ground Segment Team (GST) Wiki.

2. Background

The Ground Segment Team (GST) at the Jet Propulsion Laboratory (JPL) recently finished with the development of the *Ground Segment Earth Cost Tool (GSECT)*. The objective of this tool is to cost the Mission Operations and Ground Data Systems (MOS/GDS) components of a simple (single-instrument) Earth-orbiting mission. The tool is meant to be used during Pre-Phase A, when a mission is just beginning to be conceptualized. GSECT builds on cost estimation models used by NASA for planetary spacecraft and is based on the cost data of the Earth-orbiting Wide-Field Infrared Survey Explorer (WISE) Mission because the WISE mission most closely parallels the Earth-orbiting missions that JPL will be conducting in the future.

GSECT is just one of the models that JPL, and NASA as a whole, uses to estimate cost during the project formulation stages of a mission. Each model is created for a different purpose and many are used together to produce a well-founded estimate. The purpose of this study was to analyze some of the cost models in use by NASA today and in turn provide a context for the recently-developed GSECT Suite. Through this process, the GST wanted to accomplish two things: first, find ways to make GSECT a more accurate and encompassing model, and second, be able to justify the costs that GSECT generated in comparison to other cost models.

There were seven models included in the study:
- Ground Segment Earth Cost Tool (GSECT)
- NASA/Air Force Cost Model (NAFCOM)
- Software Cost Analysis Tool (SCAT)
- QuickCost Model
- Space Operations Cost Model (SOCM)

- Parametric Review of Information for Costing and Estimation (PRICE) – Software (True S)
- Software Evaluation and Estimation of Resources (SEER) – Software Estimation Model (SEM)

3. Method

First, we needed to generate a selection of models to survey and compare. We chose those that were widely used by NASA and those that had been developed by JPL. We started with only five models, but the list grew to seven models after a discussion with John Jack, who is currently a Senior Systems Engineer at Tecolote Research, Inc. Once we had the selection of models that we would compare, we then had to gain access to each one. GSECT and SCAT are available to all JPL employees and QuickCost and SOCM are available to the public. We gained access to NAFCOM from SAIC employee, Julie McAffee. The remaining two models (PRICE – True S and SEER-SEM) were obtained through a NASA-wide license.

After acquiring each of the models, we compiled a database of details characterizing each model. These details included:

1. General Overview
   a. By whom the model was developed
   b. To whom the model is available
   c. System Requirements
   d. Types of Missions the model is capable of costing (and for which phases)
   e. Ease of Use
2. Cost Drivers that the model took into account
3. Form of Model
   a. Types of Cost Estimating Relationships (CERs) – linear, exponential, etc.
   b. Whether the model returns a range or point estimate
   c. Whether the model is capable of risk/sensitivity analysis

Once this initial survey was complete, we could begin the comparison process. But to do so, we first had to normalize the output of each model to the output of the GSECT suite. In other words, we had to map the output of each model to JPL's Standard Work Breakdown Structure (WBS) elements (only the 7.XX and 9.XX components – MOS/GDS), on which the GSECT suite is based.

JPL Standard WBS Elements on which GSECT is based:

- Management & Systems Engineering (07.01, 07.02, 09.01, 09.02)
- Navigation (07.06, 09.06)
- Tracking (07.03)
- Infrastructure (09.14, 09.15, 09.16)
- Flight Operations Team (07.04, 07.05, 07.07, 07.09, 07.10)
- Flight Operations Tools (07.15, 09.03, 09.04, 09.05, 09.07, 09.09, 09.11, 09.19)

After mapping and normalizing, we were able to compare the models' overall capabilities.

Once this study was complete, all of the results and accompanying handbook of details were posted on the GST Wiki available for the entire team to access and update with new information over time.

4. Results

Model Overview

Model	Development Organization	Availability	Cost Object
GSECT	JPL	JPL Only	Simple, Single-Instrument Earth-Orbiting Missions (Phases A – E)
NAFCOM	SAIC	All of NASA	Earth-Orbiting, Planetary, Manned & Unmanned Missions (Phases C & D)
SCAT	JPL	JPL Only	Software Element
QuickCost	NASA	Public	Earth-Orbiting, Planetary Satellites (Bus & Instruments)
SOCM	SAIC	Public	Earth-Orbiting, Planetary Missions (Phase E)
PRICE – True S	PRICE Systems, L.L.C.	NASA-Wide License	Software Element
SEER – SEM	Galorath, Inc.	NASA-Wide License	Software Element (Phases A-D, E: maintenance only)

Form of Model

Model	Form of CERs	Range or Point Estimate	Risk/Sensitivity Analysis
GSECT	Linear, Constant	Range	Yes
NAFCOM	Exponential	Point	Yes
SCAT	COCOMO Algorithms, Monte Carlo Method	Range	Yes
QuickCost	Logarithmic, Exponential	Point	No
SOCM	Linear	Point	No
PRICE – True S*	-	-	-
SEER – SEM	Exponential	Point	Yes

*PRICE could not be configured such that it was comparable to GSECT, so it was excluded from the study after this point.

Cost Drivers

		Cost Drivers					
		Instruments	Data	Spacecraft	Mission Phase Durations	Subsystems (General)	Subsystems (Specific)
Model	GSECT	✓	✓	✓	✓	✓	✓
	NAFCOM	✓			✓	✓	✓
	SCAT*						
	QuickCost	✓			✓		✓
	SOCM	✓	✓	✓	✓	✓	
	PRICE - True S*						
	SEER - SEM*						

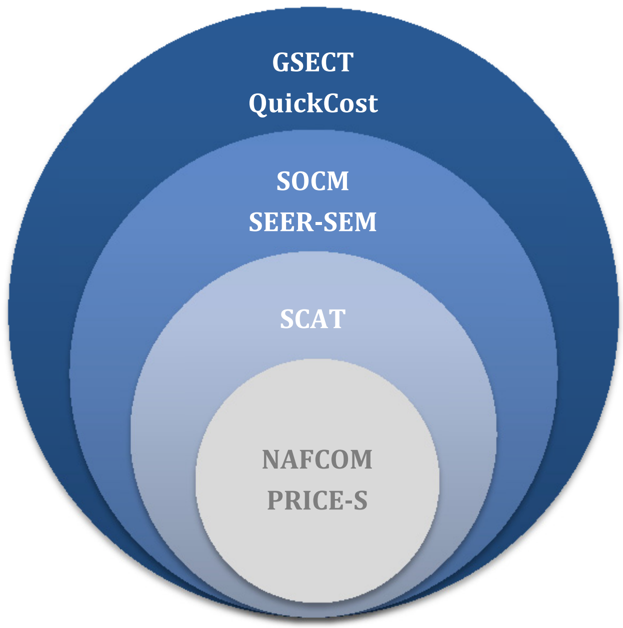
Table: This table compares the cost drivers of each of the models to the cost drivers of GSECT, which make up the column headings and are explained in more detail below.

*SCAT, PRICE-True S, and SEER-SEM only cost the software component of a mission, and thus had very specific cost drivers, whereas the other models had a broader category of cost objects and thus had cost drivers mores similar to those of GSECT.

- Instruments
  - Number of Targeted Instruments
  - Presence of Mapping Instruments
  - Need for New Instrument Capability
- Data
  - Engineering Data Rate (EDR)
  - Science Data Rate
  - EDR Latency Rate
- Spacecraft
  - Whether the spacecraft was built by JPL
  - Number of Partners
  - Frequency of Maneuvers
  - Whether the Spacecraft vendor is using his own Ground Data System during the Assembly, Test, Launch & Operations Phase
  - Whether the Flight System has flown with the Ground System before
- Subsystems (General – accounts for the Power, Command and Data, Thermal, Propulsion, and Attitude Determination and Control Systems)
  - Whether subsystem is needed for mission
  - Whether the subsystem is developed by JPL
- Subsystems (Specific)
  - Power
    - Risk Posture
    - Type of Power Management
  - Thermal
    - Type of Thermal Management
  - Propulsion
    - Number of Propellants
    - Number of Systems

Final Comparison

	Model						
WBS Element	GSECT	NAFCOM	SCAT	QuickCost	SOCM	PRICE- True S	SEER-SEM
Management & Systems Engineering	✓		✓	✓	✓		✓
Navigation	✓		✓	✓	✓		✓
Tracking	✓		✓	✓			✓
Infrastructure	✓			✓	✓		
Flight Operations Team	✓			✓	✓		✓
Flight Operations Tools	✓		✓	✓	✓		✓



As we can see from this table and accompanying diagram, the GSECT and QuickCost models seem to be the most encompassing of the models taken into consideration, though QuickCost is not limited to just MOS/GDS costing. When generating an estimate, these two models account for all of the MOS/GDS WBS elements, while the SCAT, SOCM, and SEER-SEM models do not account for some of the WBS elements. NAFCOM might cost the MOS/GDS components of a mission, but its output is at such a high level of detail that we could not map it to the JPL Standard WBS Elements. Similarly, the PRICE – True S model was too complex to configure such that it was comparable to GSECT.

5. Further Research & Conclusions

The purpose of this study was to provide a context for the recently-developed GSECT and in the process, find ways to make GSECT a more accurate and encompassing model and to also provide the GST with reasons to justify the costs that GSECT generated. All of this was accomplished, for we discovered that GSECT is the only model in use by NASA, specifically JPL, today that estimates cost for *only* the MOS/GDS components of a mission. A more important conclusion that arose from this study was that each model has a different purpose and takes into account different cost drivers, so it is imperative to use more than one model to generate a well-founded estimate. Further research that can be done with this project is the surveying of the various model databases to find WISE-like missions to add to the GSECT database.

6. References

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