Automated Processes & Procedures for Ground Segment Cost estimation

ABSTRACT: The NASA contracting environment has become increasingly competitive, resulting in the submission of more mission proposals than ever before. JPL has historically used a labor-intensive process for preparing cost estimates for the Mission Operations/Ground Data Systems (MOS/GDS) portions of mission proposals. This manual process has proven expensive and unwieldy, and, on occasion, inaccurate. This paper will present an alternative to this process by describing a new two-tiered cost estimating approach to be used at JPL for MOS/GDS.

Introduction

This paper will describe the concepts, design, successes and failures of JPL's ground segment cost estimating process known as Team G. The 'Team' has created a process that results in efficient Ground Segment cost estimating with an extremely rapid turnaround, typically less than 5 hours. Furthermore, the cost estimates that are produced are backed-up by the various in-house and outside organizations that do the work (due to pre-arranged relationships).

Background

NASA's mission proposal process is generally a two-step process. NASA publishes an Announcement of Opportunity to the various NASA centers and the world at large. Proposals are prepared and submitted to NASA (Step 1). NASA selects a subset (typically 2 – 5) of these for further consideration. For this subset a second, more detailed proposal (Step 2) is prepared and submitted to NASA for final selection. The Step 1 proposals are generated using internal funds and clearly the support for Step 1 must be provided as efficiently as possible, especially in light of the fact that a single organization may submit multiple proposals. Step 2, on the other hand, requires a much greater level of detail and usually receives some study money from NASA and so naturally has significantly more funding for proposal preparation.

Historically, JPL's response to this process was using a labor intensive approach for estimating MOS/GDS costs and designs in both Step 1 and Step 2 proposals. The new approach presented in this paper, known as Team G, reduces the level of effort needed for Step 1, where funding is scarce, and provides a separate related but process using experts for Step 2 proposals where more details are required and more funding is available.

Team G Methodology

Key to Team G's success was recognizing what was necessary and adequate versus what was being provided by our grass roots estimating. In Step 1 proposals the MOS/GDS section is usually a few short paragraphs with a couple tables of costs. What was being generated by the grass roots estimating process was a large amount of documentation with detailed discussions, more in-line with what is needed for a Step 2 proposal. Team G's method for reducing Step 1 proposals cost was to move from a team of experts generating a grass roots estimate to a single generalist using parametric models. The models were developed by the different domain experts and tied together to cover all of the MOS/GDS costs. A trained MOS/GDS generalist, through interviews with the proposal team, is able to fill-in the models, and where the models are inadequate, contact a domain expert to provide additional information. The result of this change

is that Team G can generally create a reasonable Step 1 estimate for MOS/GDS in a single two hour interactive session using only one generalist and occasionally a domain expert. This is a vast improvement of coordinating eight or more domain experts for several hours, over many days to generate a single estimate.

The Step 2 proposal support is still similar to JPL's historic method of grass roots estimating, but with a slight twist. The level of detail required for a Step 2 proposal, and the funding available makes it reasonable to perform a detailed grass-roots estimate using experts. What has changed over the historical approach is that the results of the Step 2 proposal work is fed directly back into the models used to generate the Step 1 proposals, so that the parametric models gain more fidelity. Where the costs differ between Step 1 and Step 2, the Step 1 models are altered to capture the new knowledge garnered through generating the Step 2 proposal. The experts who generated the Step 2 costs are usually the same experts who built the Step 1 parametric models, so the updates are usually easy to accomplish.

Comparison to the Previous Process

The historical JPL process for generating Ground Segment cost was a labor intensive effort that was fraught with many pitfalls. Ground segment costs for both Step 1 and Step 2 proposals were developed in similar fashions, by sending someone from the proposal team to the various organizations that provided Ground Segment products and services. This required that each proposal team retain the expertise of a Ground Segment expert for a period of weeks or months. Some organizations in JPL, for example Interplanetary Network Directorate (IND) provided cost estimating for several areas, but even this support had required many hours from several cost experts to produce a cost. If there was more than one proposal going through the system, as there usually were, the availability of the experts became more difficult. Where different experts were used for the same cost area, different results usually occur. Finally, because the costs came from different areas and tied together by a third party there were frequent duplications in the costs and there were missing parts that each area thought the other areas were covering.

The Team G process resolves these issues for Step 1 proposals. By using the models which have been reviewed and modified to remove duplications and fill-in holes in a consistent, repeatable manner at a fraction of the cost. This has reduced the need to use the experts, except for special cases that don't fit the models. It is estimated that the previous process involved approximately 50 work-hours for a Step 1 proposal, the new process involves about 5 work-hours AND provides greater fidelity and consistency.

Step 2 proposals should also see improvements because of Team G. As part of the creation of the Step 1 models Team G has laid the foundation for the coordinated effort of the different Ground Segment experts to avoid overlaps and holes. Also, because of being tied to the Step 1 parametric models, any cost deviations due to differences between experts are identified and clarified early. Finally, because the experts are used primarily for Step 2 proposals, which are a small fraction of the Step 1 proposal submitted, the availability of the experts is significantly greater.

The Team G preparation and process for Step 1 proposals

The greatest surprise about team G is the question that nobody has asked, "why didn't we do this earlier?" Proposals by their nature usually require a grass roots approach for designing the spacecraft, mission, and ground systems. The experts in each of these areas generally followed

rules of thumbs and used their own models to help them with their estimates. So it seemed reasonable that we continued to do this. Meanwhile, for pre-proposal work JPL had recognized the utility of using models to address the cost of common features in spacecraft, mission, and ground segment cost in Team X.

As team G was being design and organized, a fundamental question was asked: what was "good enough" for proposals. When discussing the level of detail required for Step 1 Proposals, the question becomes: how much is too much. After many discussions of this topic, we came to the conclusion that a proposal will never be won based on the Ground Segment Design/Cost. If we develop inaccurate, unsubstantiated, or inconsistent costs, a proposal could be lost, but in practice, a proposal will be won based on its scientific or research merits. Our goal then is to develop a credible design and credible and consistent costs. This can be, and has been largely automated in our process. The concept of process automation will not work for all areas of a proposal but works well for Ground Segment design and cost and would likely work well for other areas as well

It quickly became apparent that parametric models could be used effectively for Step 1 proposals but only if the implementing organizations agreed with the model results. The only way to achieve acceptance of the models was to have the implementing organization build the models, be responsible for keeping the models current, and to have them review our usage of the models.

Toward this end team G developed a structure for how all the models would come together and operate. We then went from organization to organization to capture their expertise into models.

The Step 1 Process –

Capturing the Experts in Cost Models

Capturing the experience of experts was performed by providing very loose guidelines for the development of the cost models. In our survey of possible methods, we received everything from simple email guidelines, to very detailed cost models already incorporated in Excel spreadsheets. We had to adapt each of these into our cost model structure, but this was easy and quite straightforward. The most important aspects to a cost model are the comments that describe its use. We spent more time incorporating comments for each cost model field than we did implementing the tables and algorithms. This contributed significantly to our success. As an example, let's say that our cost model asks for 'instrument complexity' and provides us with 'very simple', 'simple', 'moderate', or 'complex' as options. The algorithm for determining cost can be highly accurate, but if the user of the cost model does not have well defined guidelines for the definition of each option, then the cost has very little chance of being correct. We provide these guidelines in the comments.

The layout of a cost model

Each cost model is laid out with the following:

1. An algorithm sheet which contains either tables or algorithms which determine the ultimate costs.
2. A Graphical User Input (GUI) sheet which contains GUI components for making choices.
3. A Cost Breakdown Structure (CBS) sheet which breaks the costs down by their detailed cost components.

4. A Work Breakdown Structure (WBS) sheet which breaks the costs down by WBS elements. (Coincidentally with the formation of Team G, JPL had standardized on a WBS to be used for all future proposals, which all our customers would use.)

The algorithm sheet provides a specific location for creating and maintaining the cost algorithms. Since the cost algorithms are maintained by different organizations, this provides a single location for their updates and it simplifies their job because the details of the User Interface are not mixed with the algorithms. The algorithm sheet is typically viewed and edited by the cost model developer/maintainer.

The GUI sheet provides the primary inputs for the cost model. The user selects among different input values in order to control the cost model. Input parameters vary from about 4 to about 40 and again, these are defined by the service organizations for each cost model.

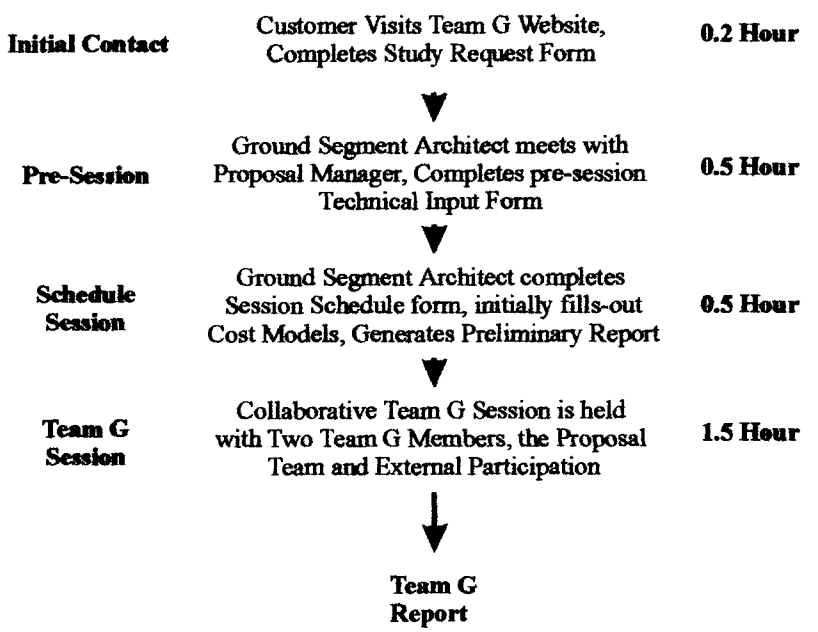
The CBS sheet provides a detailed breakout of costs according to hardware, software, operations, testing, as well as by mission phase (A, B, C, D, and E). The WBS sheet provides the costs according the JPL's Standard Work Breakdown Structure which has received significant attention in the past year. It is this breakdown which ensures that there are no overlapping costs.

The Team G process

The models are just one part of Team G. The models exist within the context of a process that ensures that the customer has done their homework to effectively use Team G and to enable strong interaction between the proposal team and Team G.

Step 1 Process Overview

Significantly more time was spent developing the Team G Step 1 Process than was spent on the implementation of tools. This approach resulted in a process that is highly efficient and the tools are built according to the requirements for the processes. The Team G process is composed primarily of session scheduling, a technical pre-session, the session itself, then post-session follow-up. Of these elements, more time is spent on session scheduling than on any other. Prior to the first Team G session, it was obvious that a significant portion of time would be spent on scheduling the sessions. Even with that knowledge, we were surprised at the amount of time and effort that was required for scheduling multiple sessions (our first proposal phase involved more than 10 concurrent proposals). We were able to significantly reduce the scheduling overhead by web-enabling our scheduling process as you can see in the diagram below. The following diagram provides an overview of the Team G process.



Collaboration

Another key element of the Team G Process is collaboration. Team G Sessions are held in the JPL facility known as the Center for Space Mission Architecture & Design (CSMAD). This

facility supports many state-of-the-art technologies. Team G makes use of only two of the key technologies: Web-based collaboration and multiple 60" projected screens. When developing the Mission Systems costs, there are often telecom and spacecraft issues. The spacecraft teams are usually at remote locations. Rather than tabling the issues or requiring the on-site attendance of the spacecraft contractors, we remote the Team G displays to customer and contractor sites. This provides all contributors with real-time interaction.

Feedback and Process Improvement

If Team G was to be used only once, then the effort to generate the models would make no sense. By the same token, if the models are static then changing experience and improvements wouldn't get captured. A central precept of the Team G process, outside of the customers view, is continued improvement of the models.

One element of the Team G process that is not shown in the process diagram is the feedback loop, or process improvement. Process improvement is actually a result of the defined Team G process. At the end of a proposal cycle, the cost model results are provided to the service organizations. At that time, they review the results and ask questions concerning the missions. This step results in improvements to the cost models, as the mission parameters are refined. A second feedback cycle occurs when a proposal is selected and moves on to Step 2. At that time, the service organizations provide personnel who perform detailed studies to produce more detailed costs. The natural starting point for Step 2 is to use the results of Step 1. If those outputs are significantly flawed, then the service organizations will naturally improve them. A third method for process improvement are annual cost model reviews. These reviews concentrate on new technologies that will need to be estimated as well as cost model improvement.

Team G Tools

Just as the process is important to the success of team G the selection and implementation of the tools for Team G was critical to its success. There was a requirement that the cost models be easily understood and maintainable by the various service organizations. There is also a requirement that the answers produced by the cost models be placed into a database for later analysis. This requirement was levied because of the desire to maintain easily accessible historic data. The requirement for easy maintainability ruled out any programming languages. Therefore, Excel or an equivalent spreadsheet was selected for the cost models. In order to satisfy the database requirement, we established connectivity to an sql-compatible database. Reports are generated directly from the database tables into adobe acrobat formatted documents.

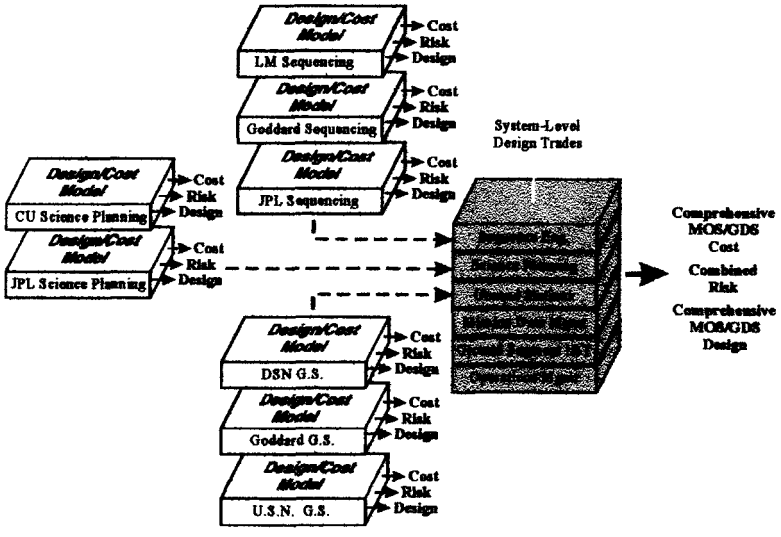
Cost Model Tool/Database Overview

The tools for Step 1 consist of automated design/cost estimating tools intended for use by Team G and by the Team X Ground Systems Chair. The primary output product of the Step 1 Tools is a Team G Proposal Preparation Package. This package consists of details of an MOS/GDS design and cost according to a Standard WBS.

The primary cost estimation algorithms are captured in the form of design/cost models. In this way, we will have a knowledge-base of the experts and do not have to fund their participation for each proposal effort.

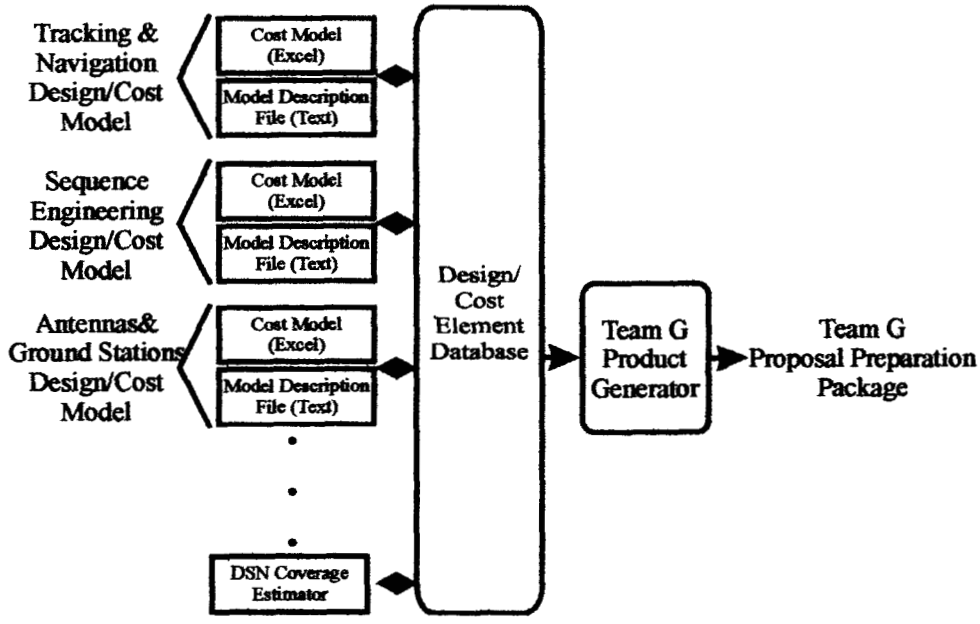
As you can see in the following figure, the ability to insert/remove different MOS/GDS design solutions provides the user with the ability to test different design combinations until the best design/cost/risk combination is selected. There are several advantages to this architecture:

- A single user can perform many design trades without communicating the changes to a large team.
- A user can develop an MOS/GDS strategy quite rapidly.
- Since the cost models are developed by 'doing' organizations, we have buy-in from the line and program organizations.
- The results of Step 2 Team G studies are fed-back into the Step 1 cost models which provides process/design/cost/risk improvement.
- The majority of the documentation will be automatically generated (thus improving on the Team X tools/procedures).
- Team G can support Step 1 efforts with a fraction of the current effort, while providing a far superior product.



The Team G Step 1 Product Generation Tool (PGT-1)

The Team G Step 1 Product Generation Tool will accept design/cost model input parameters and product a Proposal Preparation Package. It will consist of a Design/Cost Model Manager, Design/Cost Models, a database, and the Team G Product Generator. When integrated, this will serve as a powerful Team G tool that will more than satisfy the requirements needed to support Step 1 (and similar) proposals.



Design/Cost Models

The Cost Models will be contained in Excel spreadsheets. The user will enter parameters on these spreadsheets which will result in a design and associated cost. Cells from these spreadsheets will be made available to the database using the Cost Model Data Exchange Interface (described in the following paragraph.

Cost Model Data Exchange Interface

The Cost Models will exchange data with the database using a standardized interface. This interface will consist of a keyword (identified by a trailing colon ':') and a value (which will be located in the cell immediately to the right of the keyword. These will be entered into the database using an Excel macro. Keyword/Values will be maintained in the database using:

Filename

Sheet Name

Keyword

Value

Design/Cost Element Database

This Design/Cost Element Database is a collection of the keyword/values contained in the individual cost models. Although called a database, this may very well be a text file, as it may simplify the implementation.

Team G Product Generator

Allows the user to determine which, among the entire array of design/cost models, to include in the baseline study. Once the selections have been made, the user can then produce the final output product. The Generator will ensure that no element of MOS/GDS is un-costed. The Generator will accept historical cost information and generate a risk assessment based on a comparison between the new study and the historical data. It incorporates Assumptions and Notes from a word file. These Assumptions and Notes will be compiled during the Step 1 Session and need to be placed into the output products.

Cost Model Development

Cost models will be developed both inside JPL and outside. Entities that do not wish to provide cost models will not be represented by Team G as an option for Step 1 unless Team G decides to develop a cost model independently. Once the first round of cost models is received and integrated, a set of cost model development guidelines will be developed and will be used for subsequent cost model development.

Cost Model Outputs

The outputs of the Cost Models are contained within each Excel spreadsheet in a form we refer to as the 'Cost Breakdown Structure'. This differs from the Work Breakdown Structure in that it is more detailed and broken into many more levels of detail. This enables us to matrix the costs into virtually any Work Breakdown Structure.

Initial Results

The initial results of Team G are positive, in that our customers (typically proposal managers) have been pleased with the Step 1 process. I attribute some of this success to the initially low expectations. After all, many people have developed cost models in the past. The difference here is that we concentrated heavily on the process and we distributed the business of developing cost models to the people who do the actual MOS/GDS work. In our first run, the process worked very well, but the costs produced were significantly higher than the proposal teams thought was appropriate. For our second run, the cost models had been updated, we had built some trust and the cost modelers seemed willing to reduce their costs somewhat by reducing the unwarranted conservatism that was inherent in the new process. Another advance was to adopt JPL's new Standard WBS which was thankfully finalized about halfway through our first run. This allowed us rapidly to identify duplicate costs, which naturally reduced costs relative to the first run. After the first run, we (Team G) pretty much sided with the proposal teams in believing that some of the costs were too conservative. After the updates and the second run, the cost estimates produced are thoroughly grounded.

Lessons Learned

The first steps are the hardest

Gathering the initial models was an uphill struggle. Many of the models used by expert were simple aids to help with the simple repetitious tasks. As such there were unsuitable to be used a generalist. We worked through this problem by sitting down with the experts and assembling a new model that captured the essence of what they were responsible for, with sufficient notes in the model so that we know what setting to use.

Another challenge was that resolution required for the models was usually less than what the experts were comfortable with, since they were used to providing estimates down to the work hour. The cost for many of the proposals that we see are in the order of 100's of millions of dollars. The Ground Segment is usually less than 10% of this cost cap. Different Ground Segment areas make up varying amounts of the total Ground Segment costs. For example, tracking costs make up a significant part of the ground segment cost, as does engineering and management, while ground communications make up a very small part. All of these factors contribute to the degree of fidelity of the models required. The more expensive portions received more more reviews to improve them, while the smaller contributors were worked until they were "good enough."

Never Underestimate Scheduling

We gave the issue of scheduling Team G sessions quite a bit of attention before we became active, but it was still not enough. Scheduling the collaborative lab, the proposal teams, the Team G members, and then rescheduling based on changes in the proposal schedule eats up more time than the actual Team G sessions. This speaks well of our sessions, but also shows that applying more resources to improving our scheduling process would likely result in further cost savings.

Don't fight against Corporate Culture

We developed a web-based technical input form as a way of automating and controlling the initial entry of required technical inputs. We worked to ensure that there were no duplicate or omitted questions and that each question was a necessary input to the process. After several weeks, we found that the proposal teams were, for various reasons, unwilling to fill-out the technical input form. Rather than making it a rigid requirement that proposal teams would be required to fill-out the form, we modified our process. Currently, we send a 'Ground Segment Architect' to the customers office for a 45 minute interview where we complete the technical input form.

Summary

The Team G process provides timely and efficient cost estimating that is backed-up by the organizations responsible for each Ground Segment activity. The Team is actively soliciting new cost models from organizations external to JPL, wherein these models will become options for JPL proposals.