

# Appendix L: Estimating the Cost of Construction of Facilities (CoF) and Ground Support Equipment (GSE)

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Estimating facility costs is a specialized type of cost estimating.<sup>1</sup> The acquisition and development of real property is governed by Federal statute, with additional guidance and requirements levied in Office of Management and Budget (OMB) Circulars, such as A-11 and A-94. NASA directives and requirements, largely found in the NASA Online Directives Information System (NODIS) as part of the 8800 series of directives, also provide useful information.

The estimator should work closely with the Center facilities organization to ensure that estimates are complete and in compliance with these statutes and directives. This appendix provides estimating techniques and rules of thumb that were developed for application at the Kennedy Space Center (KSC). The techniques can be used as examples to assist the estimator in collecting and analyzing local data and as estimating tools and references appropriate for use at each respective installation.

The following topics are described in this appendix:

- L.1. CoF and GSE Overview**
  - L.1.1. COF Types and Affected Ground Support Equipment**
- L.2. Facility Funding Types**
  - L.2.1. Non-CoF Funding**
  - L.2.2. Facility Planning and Design (FP&D) Funding**
  - L.2.3. Phasing of Funds**
- L.3. Estimating CoF and GSE Projects**
  - L.3.1. Conceptual Parametric Estimates**
  - L.3.2. BOE**
- L.4. Historical Information**
  - L.4.1. Historical Cost and Schedule Data**
  - L.4.2. Historical Schedule Growth**
  - L.4.3. Historical Cost Growth**
- L.5. Conclusion**

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<sup>1</sup> G. C. Butts, "Accurate Estimates in Less Than a Minute," presented at the AACE International Conference, Las Vegas, NV, 2006.

## L.1. CoF and GSE Overview

It can be difficult to estimate costs for CoF and GSE due to many factors, including numerous variations of types, sizes, unique features, site location, site conditions, economic conditions, and local infrastructure capability. Federal law and NASA Facility Project Requirements, including NASA Procedural Directive (NPD) 8820.2D, dictate a rigid budget process for CoF projects that requires that CoF funding requests be submitted years before the design has been completed or final requirements are known. Figure L-1 captures the funding process. For more specific details on NASA policy and the CoF process, refer to NPD 8820.2D at [http://nodis3.gsfc.nasa.gov/lib\\_docs.cfm?range=8](http://nodis3.gsfc.nasa.gov/lib_docs.cfm?range=8).

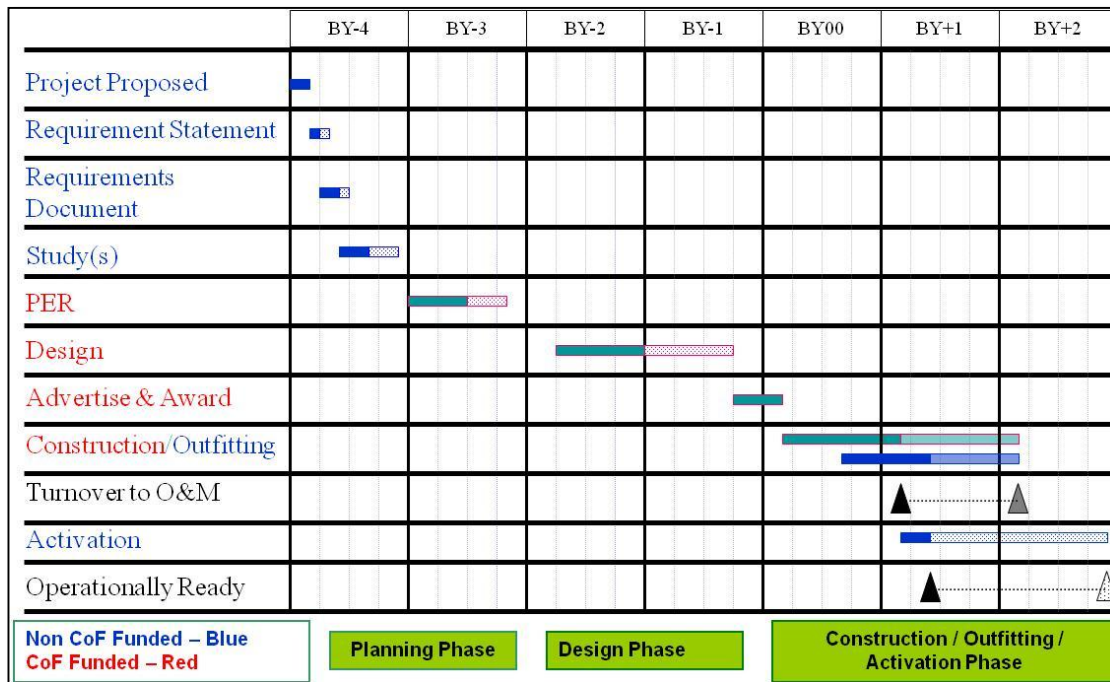


Figure L-1. The CoF Funding Process

### L.1.1. COF Types and Affected Ground Support Equipment

Congressional authorization and appropriations are required for the funding of revitalization projects, construction of new facilities, acquisition of related collateral equipment, environmental compliance design of facility projects, and advanced planning for future facility needs. Preliminary Engineering Reports (PERs) are required for each type of facility need. This includes site investigation and sufficient preliminary design to fully develop project scope, assess risks, identify construction complexities, and provide a realistic cost estimate prior to inclusion in the NASA budget submission to the OMB.

Here are details on these projects:

- Revitalization projects—Substantial renewal and upgrade work of the physical plant to meet current and future needs, thereby extending its useful life (e.g., a facility project that extends the useful service life beyond the original design life).
- Construction of new facilities—The erection or modification of real property required to support a new capability, including additions, sidewalks, parking lots, driveways, and upgrades. This includes alterations to existing facilities that change the original purpose of the facility (e.g., remodeling a warehouse, or portion thereof, into office space).

- Collateral equipment—Includes building support equipment and large, substantially affixed equipment/property that is normally acquired and installed as a part of a facility project and includes the following:
  - Building-support equipment. Common types of building-support equipment are situated within the facility (e.g., elevators, transformers, compressors, heaters, ventilators, and air conditioners). It also includes systems and subsystems, such as electrical, plumbing, pneumatic, fire-protection, fire-suppression, control and monitoring systems.
  - Large, substantially affixed equipment/property of any type. Other than building-support equipment, this type of equipment/property is built in such a way that the installation costs including building envelope modifications, special foundations, and utility service exceed \$300,000.<sup>2</sup> Noncollateral equipment, when acquired and used in a facility or a test apparatus, can be severed and removed after erection or installation without substantial loss of value or damage to the premises where installed.<sup>3</sup>
- Environmental Compliance—Environmental concerns are becoming a larger factor in the overall process, and this trend is only expected to grow. Failure to consider environmental issues will impact a project's schedule and, therefore, its budget.
  - All CoF projects require an environmental analysis.<sup>4</sup> Many of these projects require an Environmental Assessment (EA), which typically takes from 3 to 8 months to perform. Major projects generally require an Environmental Impact Statement (EIS). These typically take 1 to 3 years to complete but can run much longer if there are substantial objections from the community.
- Advanced Planning—Front-end planning to define project requirements using comprehensive planning tools such as the Project Definition Rating Index (PDRI), team building, and other techniques.

**CAUTION:**

It is critical for project success that the correct color of money is allocated!

## L.2. Facility Funding Types

There are three basic types of funding required for facility construction:

- Research & Development (R&D);
- CoF ; and
- Facility Planning and Design (FP&D)

Under NASA policy, most CoF projects will require some type of non-CoF funding for activation and non-collateral equipment. Most facility construction and renovation projects require multiple funding types for completion.

Demolition funding is unique: it can sometimes be CoF- or non-CoF-funded depending on the specific circumstances. For example, if an entire building is to be demolished, it can be done with CoF funding even though items in the building may be classified as R&D. However, if, for example, the demolition is for something initially built with non-CoF money, then non-CoF funding could be used for demolition. Table L-1 gives examples of CoF and non-CoF items.

**Rule of Thumb:**

Items that can easily be moved are usually R&D. Items that cannot be easily moved are usually CoF.

<sup>2</sup> NASA Facility Project Requirements, NPF 8820.2F Appendix A, paragraph A-23.

[http://nodis3.gsfc.nasa.gov/lib\\_docs.cfm?range=8](http://nodis3.gsfc.nasa.gov/lib_docs.cfm?range=8)

<sup>3</sup> NASA Facility Project Requirements, NPF 8820.2F Appendix A, paragraph A-86.

[http://nodis3.gsfc.nasa.gov/lib\\_docs.cfm?range=8](http://nodis3.gsfc.nasa.gov/lib_docs.cfm?range=8)

<sup>4</sup> 14 CFR Part 1216 ([http://www.access.gpo.gov/nara/cfr/waisidx\\_00/14cfr1216\\_00.html](http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1216_00.html)) and NPR 8820.2F paragraph 1.3.16.7.

### L.2.1. Non-CoF Funding

Non-CoF funds are used for noncollateral equipment such as furniture, carpeting, telephone systems, GSE, and Special Test Equipment (STE). Other non-CoF costs include relocation/move-in expenses and calibration.

**Table L-1. Example Comparison of CoF and Non-CoF Items**

Examples of CoF Items	Examples of Non-CoF Items
<ul style="list-style-type: none"> <li>• Building structure (foundation, walls, roof, etc.)</li> <li>• Vinyl tile and ceramic tile</li> <li>• Heating, ventilation, and air conditioning (HVAC) systems</li> <li>• Alternating current (AC) power</li> <li>• Electrical conduit</li> <li>• Fire-detection system hardware</li> <li>• Fire-suppression systems</li> <li>• Potable water</li> <li>• Wastewater systems</li> <li>• Facility gas systems (from source to facility 5-foot line)</li> <li>• Facility grounding and lightning protection</li> <li>• Cranes (including control systems and software programs)</li> <li>• Elevators (including control systems and software programs)</li> <li>• Exhaust systems</li> <li>• Cabling duct banks (power and communications)</li> <li>• Emergency power generation</li> <li>• Original finished flooring and ceiling</li> <li>• Signs (except personnel name signs)</li> </ul>	<ul style="list-style-type: none"> <li>• Activation</li> <li>• Furniture and window treatments</li> <li>• Carpeting</li> <li>• Systems furniture</li> <li>• Electronic equipment racks</li> <li>• Removable raised flooring</li> <li>• Raised flooring and Heating, Ventilation and Air Conditioning (HVAC) for raised flooring systems (equipment racks, computers, data equipment)</li> <li>• GSE</li> <li>• Hardline tubing and flexible hoses from facility 5-foot-line interface panel to GSE</li> <li>• Communication cable (including data circuits) and “end item” equipment</li> <li>• Telephones</li> <li>• Computers</li> <li>• Fire-detection software</li> <li>• Application software</li> <li>• Laboratory equipment and systems, including work benches, sinks, cabinets, and exhaust “hoods”</li> <li>• Uninterruptible Power Systems (UPS)</li> <li>• Direct Current (DC) power</li> <li>• Premise wiring</li> <li>• Operational Intercom System—Digital (OIS-D)</li> <li>• Cafeteria and kitchen equipment/furniture</li> <li>• Labor for connecting facility interfaces</li> </ul>

### L.2.2. Facility Planning and Design (FP&D) Funding

FP&D funding is a hybrid of non-CoF and CoF funding, but it must be clearly established early during Pre-Phase A Formulation.

Design is the cornerstone of any project. A good design is crucial for meeting the project’s schedule, scope, and budget requirements. A poor design may not adequately cover the requirements of the project. If the drawings are incomplete, ambiguous, unclear, or open to interpretation, the contractor will interpret specifications and requirements to its benefit, increasing the number of change orders that will occur later and driving up cost.

#### L.2.2.1. CoF Design Fees

In addition, 2 percent of the CCE may be required for a Preliminary Engineering Report (PER), and 2 percent may be required for a study. The Federal Acquisition Regulation (FAR) prohibits payment of more than 6 percent of the CCE for the actual design; however, the remaining 4 percent is allocated for site visits, design reviews, and other costs.

In practice, the higher the project costs, the smaller the design budget percentage should be in relation to the total cost. Consequently, the smaller the project, the larger the design budget should be in relation to the total cost. Smaller projects require a basic amount of work, including weekly meetings, site visits, and submittal review. It takes just as long to review a floor-covering submittal for a 1,000-square-foot building as for a 1-million-square-foot building, but on the larger projects, there are enough fees to cover this activity.

**CAUTION:**

The line between CoF and non-CoF can be unclear and difficult to determine. There can be severe consequences for errors. Involve Center CoF Program Managers and Headquarters early, and document your assumptions!

Engineering News Record (ENR) has proposed a new fee-determination formula in an attempt to adjust for these issues:

$$\text{Basic Services Design Fee} = 1.25/(\text{Log } C)^{1.5}$$

where *C* = current construction cost in dollars

$$\text{Basic Services Design fee} = \text{percentage value}$$

However, the proposed new fee-determination formula does not hold up against actual design fees negotiated at KSC. The following formula is a better fit for the average of 44 projects at KSC:

$$Y = 16.73 \times x^{0.37}$$

The formula estimates a 66 percent probability for design costs to not exceed the calculated amount. To increase the probability of not exceeding the calculated amount by 84 percent, the formula needs to be modified as follows:

$$Y = 16.73 \times x^{-0.34}$$

The calculated amounts by project costs are shown in Figure L-2.

**Rule of Thumb:**

If the project is 10 percent non-CoF and 90 percent CoF, 10 percent of the FP&D funding will be R&D and 90 percent will be CoF funded.

**Exception:** Facility planning funding is always non-CoF funding.

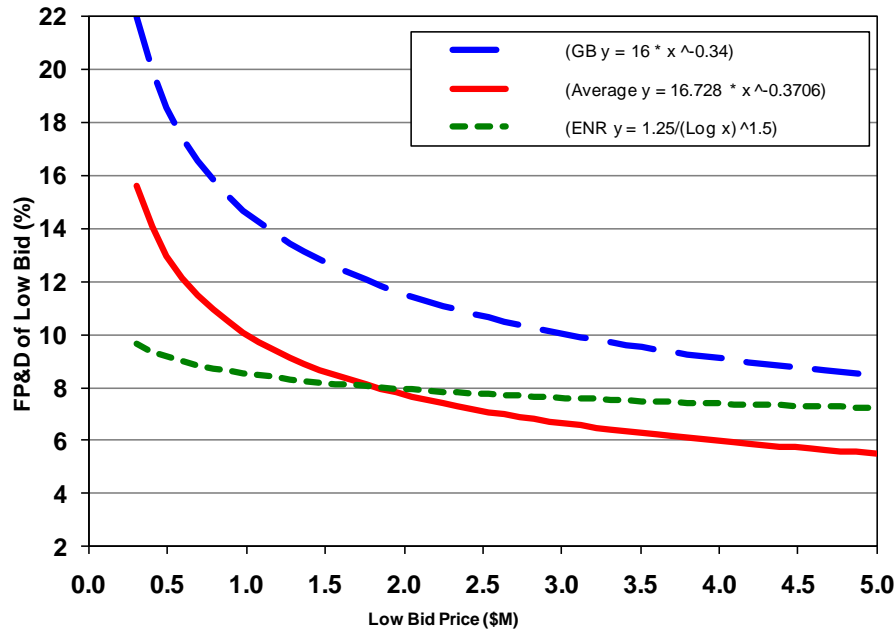


Figure L-2. FP&D Fee Calculations

The estimator needs to remember that the relationship used to estimate FP&D fees should be applicable to the specific Center and site being evaluated.

Note that the FP&D fees for new projects are, on average, 1 percent higher than modifications to existing projects. This is attributed to the required EIS. Also, technically complex projects generally require a higher design fee than indicated in Figure L-2.

According to the *Means Estimating Handbook*, design and architectural fees range from 15 percent for small or complex projects down to 4 percent for large projects or projects involving uncomplicated or repetitive work.<sup>5</sup>

### L.2.2.2. GSE Design

The design of GSE typically costs more than normal building design costs. Historically, the range of final costs for the design of GSE has been 1 to 212 percent of the total bid, mainly due to the variety of items and quantities ordered. Only one design and 50 copies of the same item may be built; or, it is conceivable that only one unique item is ordered.

**Rule of Thumb:**

Normal GSE design cost is 10 to 50 percent of the total GSE cost.

**Rule of Thumb:**

The smaller or more unique the equipment, the higher the GSE design cost.

<sup>5</sup> *Means Estimating Handbook*, Second Edition, Reed Construction Data, 2003, p. 20.

### L.2.2.3. Design Duration

The industry average for the duration of the design phase for projects between \$500,000 and \$5 million is 8 months, but at KSC, the design phase averages 10 months due to design changes, unforeseen conditions, new requirements, etc.

A recent American Institute of Architects (AIA) survey of architecture firms determined that the average time between the award of a design contract and the award of a construction contract for a facility was about a year. However, there is considerable variation from project to project. According to the AIA survey, for commercial/industrial projects, the design phase up through contract award was less than 6 months for 40 percent of the projects, while for more than a quarter of projects, this period extended beyond a year. The size and complexity of a project are key reasons for variation in design time, but three other factors also influence design time:

- Client decision making—and whether these decisions need single or multiple approvals
- Financing and funding for the project
- Regulatory approvals—land entitlement, special-use permits, zoning, environmental issues, and historical considerations

### L.2.3. Phasing of Funds

Once the total project budget has been determined, the next step is phasing funding correctly. This is critical for project success! Unless special permission is obtained for a Limit of Government Obligation (LOGO) contract, **all funds estimated for the contract award are required to be transferred to the Center before the contract can be awarded**, even though money may not be spent for years. Rely on your Center experts to determine optimum fund phasing, but if time does not allow, Table L-2 and Table L-3 are offered as guidelines.

**Table L-2. Typical Fund-Phasing for Small, Simple Projects with Values Less Than \$10 Million**

Item	Typical Range	Rule of Thumb	Color of \$	Year Required
Environmental Impact	1–3%	1%	FP&D	Minimum of 3 years before construction
Study	2–5%	2%	R&D	Minimum of 2 years before construction award
Design <sup>6</sup>	8–15%	10%	FP&D	Minimum of 1 year before construction award
Construction	37–83%	57%	CoF & R&D	Budget Year (BY) of award
Construction Services <sup>7</sup>	8–15%	12%	CoF & R&D	BY of award
Outfitting and Activation <sup>8</sup>	0–30%	20%	R&D	Outfitting is BY, and activation is typically 1 year after award

<sup>6</sup> See the design section for more information.

<sup>7</sup> Funding for Supervision, Inspection, Engineering, and Services (SIES) and support requests from support contractors.

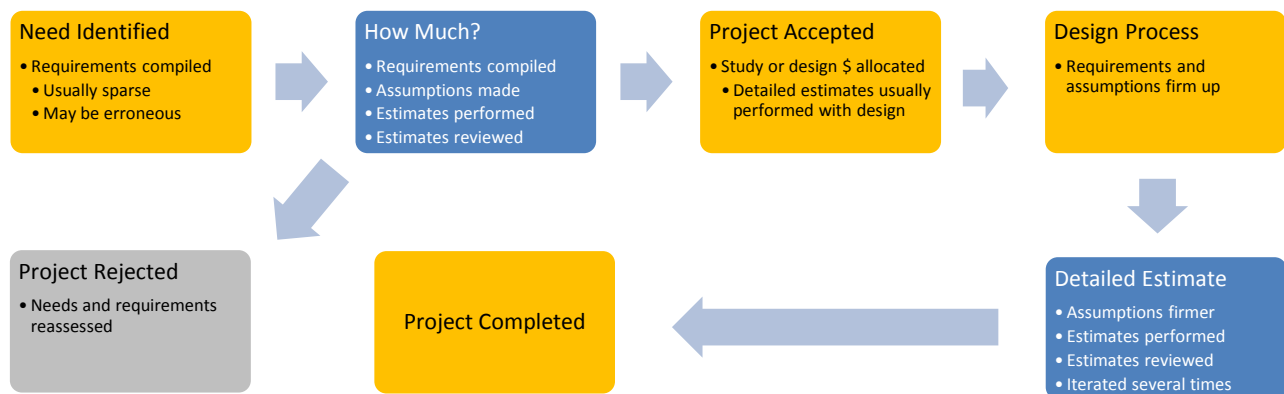
<sup>8</sup> Whatever is required to make the facility fully functional.

**Table L-3. Typical Fund-Phasing for Larger, More Complex Projects**

Item	Typical Range	Rule of Thumb	Color of \$	Year Required
Study <sup>9</sup>	1–3%	2%	R&D	Minimum of 3 years before award
Environmental Impact	1–3%	2%	FP&D	Minimum of 3 years before award
PER <sup>10</sup>	2–5%	2%	FP&D	Minimum of 2 years before award
Design	5–15%	8%	FP&D	Minimum of 1 year before award
Construction	29–71%	46%	CoF & R&D	Year of award
Construction Services	8–15%	12%	CoF & R&D	Year of award
Outfitting and Activation	0–30%	20%	R&D	Outfitting is BY, and activation is typically 1 year after award

### L.3. Estimating CoF and GSE Projects

When the need for a CoF or GSE project is identified, the first question is, usually, how much will it cost? The usual progression is similar to Figure L-3.



**Figure L-3. CoF and GSE Estimating Process**

This appendix focuses on the “How Much?” portion of Table L-3 since there are many books available that discuss the “Detailed Estimate” portion of the process.

#### L.3.1. Conceptual Parametric Estimates

Conceptual parametric estimates are typically done at the beginning of a project. Parametric estimates use comparable historical project cost data, which are adjusted to fit the known new project parameters. The costs are then escalated using a cost index to determine how much it would cost to construct the same project today. Although it sounds simple, numerous variables must be taken into account, such as changes to building codes, Americans with Disabilities Act (ADA) requirements, site-specific conditions, design changes, new security requirements, location, size, and implementation approach (competitive

<sup>9</sup> The study typically gathers requirements, examines alternatives, and prepares estimates for each option.

<sup>10</sup> The PER starts the initial phase of design.



firm-fixed price, small business set-aside, cost plus, etc.). Meticulous record keeping and a strong Basis of Estimate (BOE) are required to effectively execute this type of estimate.

### L.3.1.1. Potential Problems with Conceptual Parametric Estimates

The biggest problems encountered with conceptual estimates are the lack of defined project requirements, optimistic assumptions, or the failure of project management to acknowledge probable requirements due to the expense associated with them. Figure L-4 **Error! Reference source not found.** compares a 1974 Shuttle operations concept, left, with the reality of what was actually built, right.

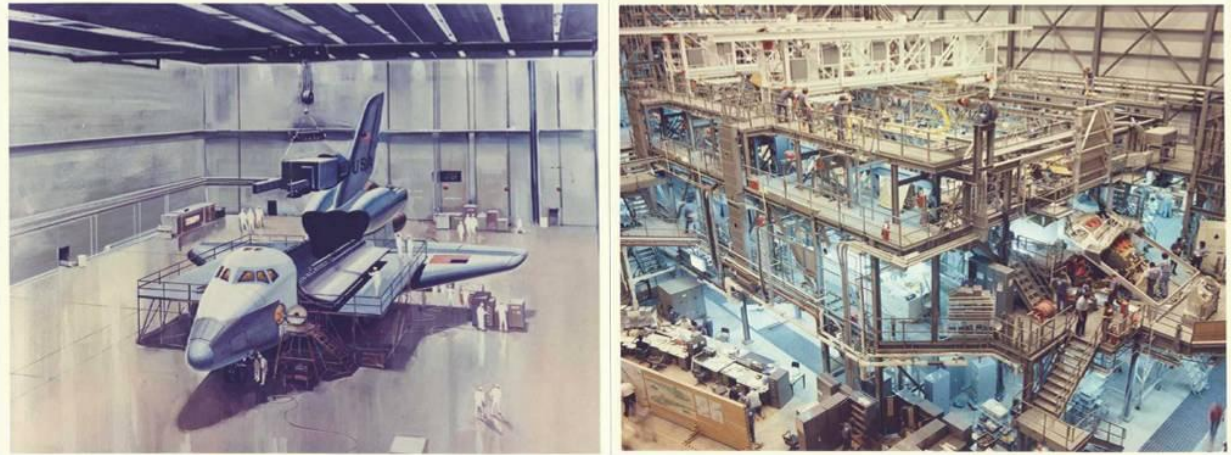


Figure L-4. Shuttle Operations 1974 Concept Versus Reality

A common, overly optimistic facilities assumption is that funds will arrive at Centers on the first day of the new fiscal year (FY). In fact, over a recent 5-year period, FP&D money showed up on average 4.6 months into the FY, and CoF funds arrived on average 7.3 months into the new FY. This issue will immediately impact costs if the project “assumes” an October 1 start. If the project deadline is fixed, the project will need to be accelerated to meet the same completion date.

The estimator should identify the level of accuracy that can be expected based on the project information given. The Standard Classification for Cost Estimate Classification System, from the American Society for Testing and Materials (ASTM), offers some guidance for this purpose.<sup>11</sup> Figure L-5 shows the expected accuracy of complex project estimates over time. Note that on the x-axis, C-30 means 30 percent complete, C-60 means 60 percent complete, etc. Routine simple projects are expected to achieve better results.

<sup>11</sup> ASTM E2516-11, ASTM Standard Classification of Cost Estimate Classification System, April 2011.

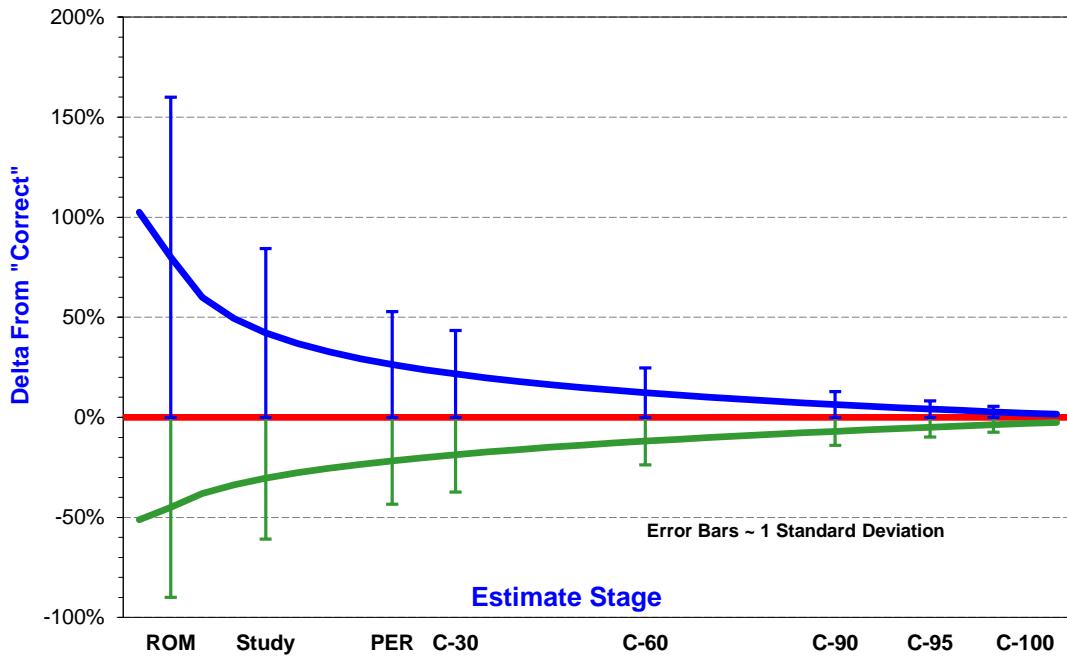


Figure L-5. Expected Average Estimate Accuracy by Phase

Exclusions from the estimate should be avoided. If they cannot be avoided, they must be clearly stated. Communication is critical to project success. The estimator should be aware that the project team often has a preconceived cost value for a project (usually low) at the earliest stages of scope definition. The estimator must prepare an unbiased and realistic estimate based on the scope of work to be accomplished, and the analyst should not become prejudiced by any preconceived optimism.

Another problem in using conceptual estimating methods is relying on the models or Cost Estimating Relationships (CERs) to produce an estimated value, but neglecting to adjust the calculated costs for the unique aspects of the project being estimated.

Often, the estimator fails to fully understand the basis of the historical cost information available. For example, if a historical average unit's cost value of \$100,000 per hospital bed were normalized to cover only hospital costs and not the associated costs for parking structures and related infrastructure, then the estimator would need to be aware of this and adjust the estimates accordingly.

### L.3.2. Basis of Estimate (BOE)

The BOE document is important for conceptual estimates because the Rough Order of Magnitude (ROM) estimate is usually used to obtain project approval and, subsequently, funding. The project's customer may have a vested interest in concealing information that may substantially affect the project cost, fearing that if the initial estimate is too high, the project may not obtain approval. However, once the project is initiated, scope creep can increase the size of the project. When new requirements are added and the project construction is delayed by the Planning, Programming, Budgeting, and Execution (PPBE) process for long periods, management will wonder why the ROM estimate was not accurate. In fact, the conceptual estimate may have been very accurate; but the project that was estimated was different from the project that was built years later. Documenting the BOE by identifying the scope of the project estimated, when it will be built, and any other assumptions and cost data used in developing the estimate can be used to defend the methods used.

## L.4. Historical Information

Many estimating methodologies discussed here require relevant historical project cost data. These methods may encompass capacity factors, parametric estimating models, unit costs, or historical project costs that can be used as a base case in the derivation of an analogy estimate. A large effort is required to gather, sort, and analyze historical project data. Both cost and design scope information must be identified and collected. It is best to collect the information at the lowest level of detail possible, since it can always be summarized later if required. After the data have been collected, it should be normalized for time, location, site conditions, project specifications, and project scope. Estimates can be prepared quickly if relevant historical project information is available. If you do not have any relevant historical information, consult the following KSC site for data: [http://www.ksc.nasa.gov/nasa-only/finance/COST\\_EST/Index.htm](http://www.ksc.nasa.gov/nasa-only/finance/COST_EST/Index.htm).<sup>12</sup>

Construction companies such as R.S. Means and Marshall & Swift, as well as the Department of Defense (DOD) and many other organizations, produce square-footage (area) costs for various common building types. However, they do not contain area costs for a specialized item, such as a new launch pad or test stand. Caution must be used since these sources typically estimate costs only to the 5-foot line of the facility, and the estimate may not include costs for activation or site-specific, NASA-specific, and infrastructure requirements that drive up costs.

### Rule of Thumb:

Assume that published area costs must be increased by 30 to 75 percent, depending on the size and type of facility for unique requirements and excluded costs.

### L.4.1. Historical Cost and Schedule Data

From initial optimism to changing requirements, NASA has historically had a difficult time meeting scheduled project completion dates within a given budget. One reason for this is that some projects develop incomplete or optimistic schedule plans. For a humorous perspective on the importance of planning, John Harvey-Jones,<sup>13</sup> chairman of Imperial Chemical Industries from 1982 to 1987, shared his insight on consequences of not going through the rigors of planning:

*Planning is an unnatural process; it is much more fun to do something. The nice thing about not planning is that failure comes as a complete surprise and is not preceded by long periods of worry and depression.*

—John Harvey-Jones MBE

### L.4.2. Historical Schedule Growth

A review of all available historical projects indicates that, on average, GSE schedules slip substantially from the awarded contract duration.

Careful data analysis indicates that for GSE projects, there is delineation between projects that are shorter than 120 days in duration and those that are longer.

<sup>12</sup> The user must be behind NASA's firewall and within the NASA Data Center (NDC) domain to access this site.

<sup>13</sup> Harvey-Jones was a Member of the Most Excellent Order of the British Empire and host of *Troubleshooter* on the BBC.

These values were calculated with the following formula:

$$\text{Project Closeout Date} - \text{Notice to Proceed (NTP) Date}^{14} = \text{Actual Days}$$

$$\text{Actual Days} \div \text{Original Contract Duration} = \text{Change in Schedule from Original}$$

Figure L-6 shows the cumulative percent probability that the schedule will slip. For CoF projects, there is a 50 percent probability that a project scheduled to be completed in 120 days or fewer will increase by 2.33 times the initial schedule. There is less than a 10 percent probability that the project will be completed on or before the originally awarded contract duration.

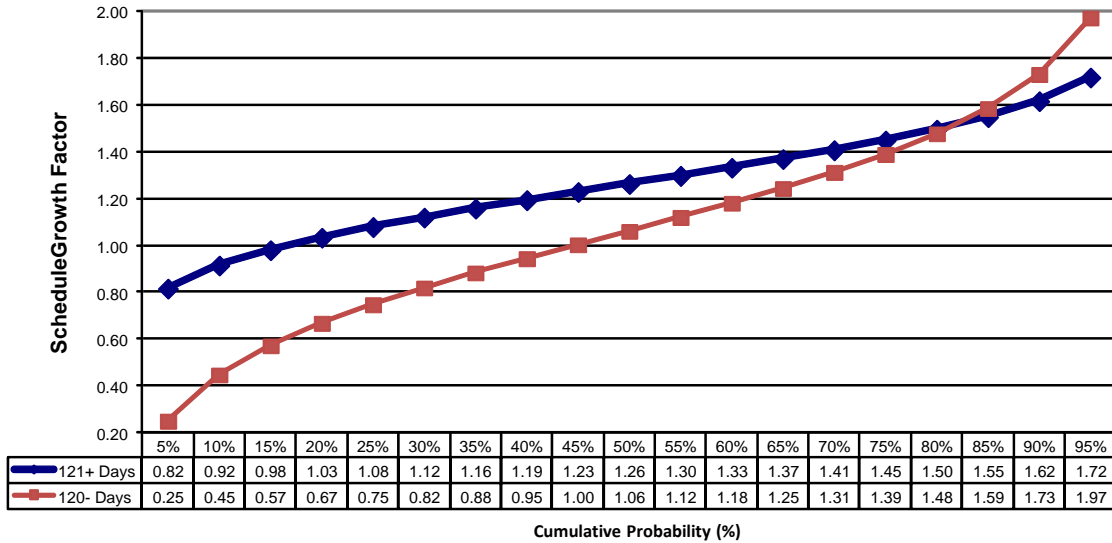


Figure L-6. Historical GSE Schedule Slips

It is important to note that these data are only for the duration of NASA-managed projects and do not include any delays for design, funding, or procurement activities. Limited anecdotal evidence suggests that these delays may be comparable.

### L.4.3. Historical Cost Growth

Most CoF and GSE projects increase in cost from the time of the award to the time of completion. Changes to the contract after the award are typically more expensive due to two factors: (1) lack of competition and (2) disruption to existing work processes. Contract cost growth and delta from award cost are discussed in the next section.

#### L.4.3.1. Historical CoF Contract Cost Growth

The majority of NASA's CoF projects incur cost growth over time. The reasons for this are varied and complex. The available data are presented here in an effort to enable better planning. The data in Figure L-7 show that for projects that are estimated at \$1 million or more, there is less than a 40 percent probability that the project will be completed for the estimated value. However, since most of NASA's CoF projects have a 10 percent contingency, the same project will have a 55 percent probability of completing the work with the allocated funding.

<sup>14</sup> NTP is similar to Authority to Proceed (ATP).

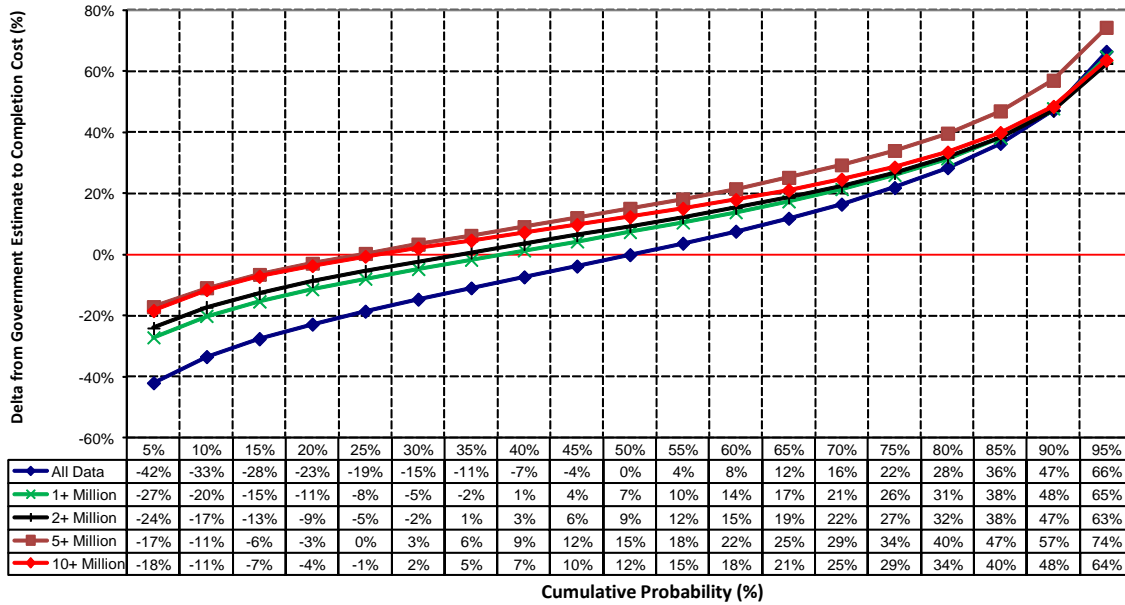


Figure L-7. CoF Estimate Growth Percentage from 100% Design Estimate at Completion

### L.4.3.2. Historical GSE Contract Cost Growth

A review of 1,286 GSE items procured for the Space Shuttle program shows that most of these items had experienced cost increases from contract award to contract closeout. How much of an increase appears to depend on the contract size. Typically, it was found that the larger the project, the higher the cost growth (see Figure L-8).

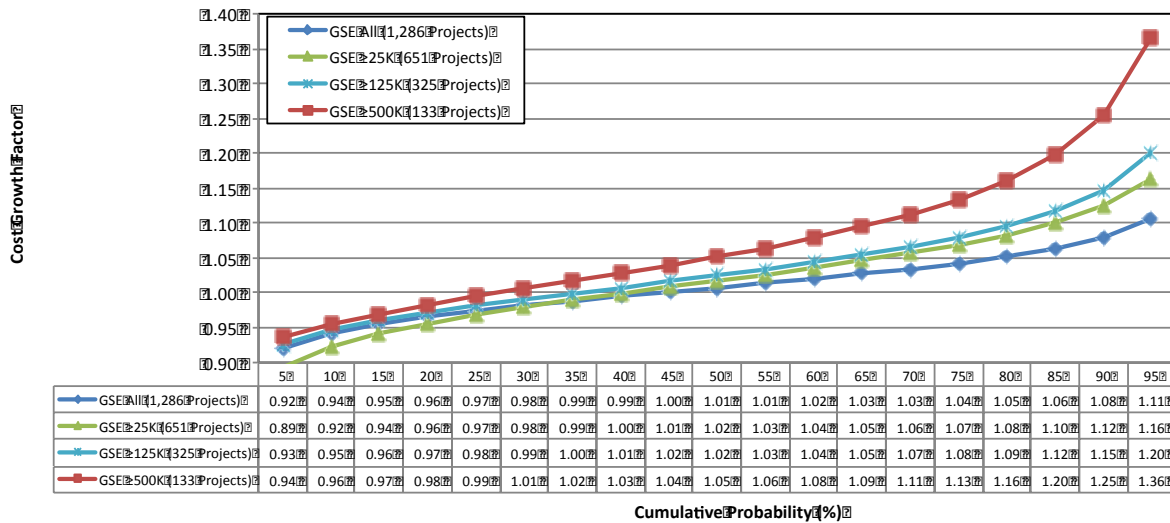


Figure L-8. GSE Historical Cost Growth Probability

Figure L-9 shows the delta from the final Government estimate and the awarded cost.

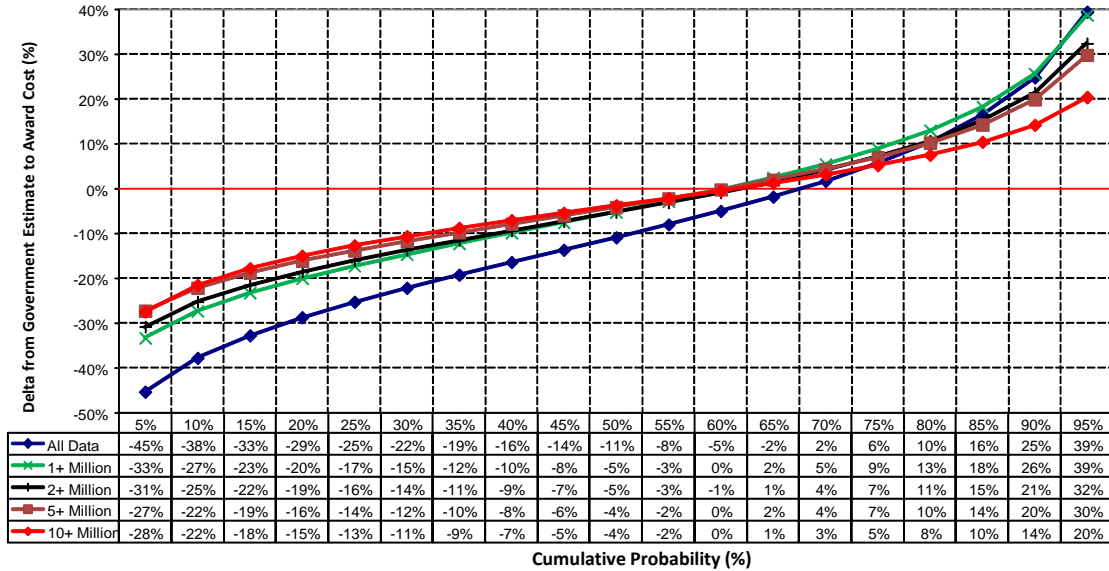


Figure L-9. CoF 100 Percent Design Estimate Delta from Award Cost

Figure L-10 shows that approximately 60 percent of all projects are awarded for the estimate cost or less.

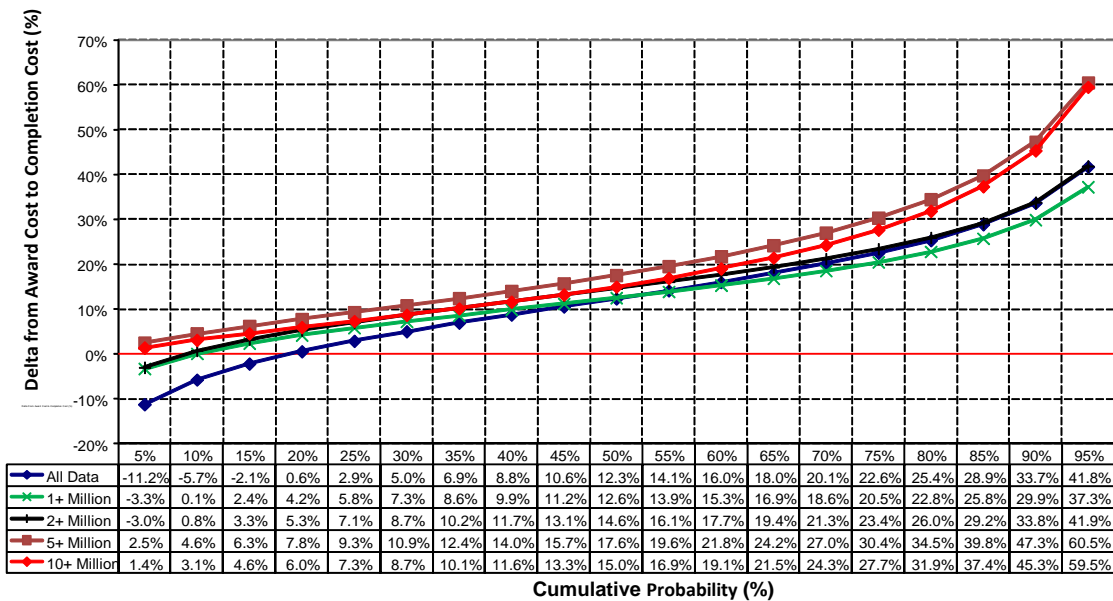


Figure L-10. CoF-Awarded Cost Compared to Completion Cost

Figure L-10 shows that approximately 90 percent of all projects increase in value from the initial awarded contract cost. Furthermore, there is a 50 percent probability that costs will increase by 12 percent or more. This increase is funded from the project contingency as well as from the delta between the estimated value and the awarded contract value.

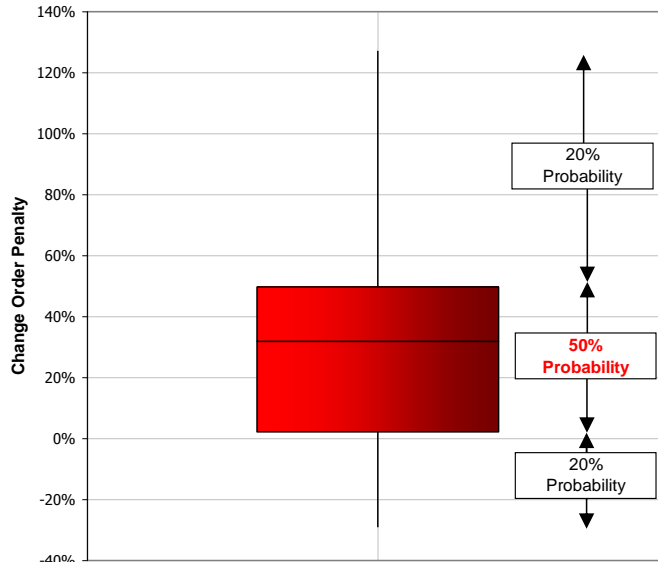
### L.4.3.3. Other Historical Data

It is generally accepted that change orders cost more than a competitive procurement. How much more is often a subject of great debate. In an attempt to quantify probable cost impacts, historical change orders were analyzed. Approximately 6,000 change orders for 404 projects between 1987 and 2007 were

reviewed. Some records were incomplete, while other records were for very small changes. These were omitted from analysis, leaving 261 unique projects and 2,752 change orders. Here is a summary of the results:

- The average change order submitted by a contractor is 76.1 percent higher than the Government estimate for the change.
- The average negotiated price above the Government estimate is 29.7 percent higher.
- The average competitive bid for projects over \$1 million is 2.2 percent lower than the Government estimate.

Of course, averages only tell a part of the story. The box plot in Figure L-11 shows the probable change order penalty for changes over \$1 million. The chart includes the 2.2 percent delta that the low bid generally is below the Government estimate on projects costing more than \$1 million.



**Figure L-11. Historical Change Order Penalty**

Thus far, we have discussed the delta from the Government estimate for change orders. However, the total cost of the change is really larger, if you consider that 1,383 bids were 7.9 percent (on average) under the Government estimate.

## L.5. Conclusion

Analysis clearly shows that change orders cost more and that some contractors are more prone to inflated change orders than others. If change orders are planned, the Agency must budget adequately for them. The application of these concepts and the introduction of a KSC-developed model for adjusting historical estimates can be found by contacting Glenn Butts at [glenn.c.butts@nasa.gov](mailto:glenn.c.butts@nasa.gov) or the Cost Analysis Division (CAD) at [hq-cad@mail.nasa.gov](mailto:hq-cad@mail.nasa.gov).