The *Tao* of Project Contingency

*NLC System Management Group*

*October 27, 1998*

*Ray Larsen & John Cornuelle*
The *Tao* of Project Contingency

- Overall Purpose of Contingency Analysis
- Observations & Current Practice
- Risk Factors - Current Usage
- The *US ATLAS* Model
- Proposed System
- Evaluating Effectiveness - Examples
- Implementation
- Contingency Management
The *Tao* of Project Contingency:  

**Purpose**

- *DoE Project Management* requires adoption of a formalized model for calculating a Contingency Budget as part of the Project approval process.

- The purpose of the *Project Contingency Budget* is to generate a reserve of funds sufficient to assure successful completion of a major project on time and within total budget.

- **The purpose of Contingency Analysis** is:
  - A. To identify/quantify high risk areas of the project which require priority for R&D funding
  - B. To provide a consistent scoring basis of each line item to enable calculation of the Contingency Budget.
The *Tao* of Project Contingency: Definitions

- **Project Contingency** is the sum of individual estimates for each major subsystem.
- **Total Project Budget** is the sum of estimated **Baseline Project Cost** plus estimated **Contingency Budget**.
- **Baseline Project Cost** is defined as the estimated cost of completing the project on time and within budget.
- **Contingency** is calculated on the basis of applying **Risk Factors** that reflect project various unknowns and unanticipated expense.
The Tao of Project Contingency: Observations

• Major accelerator and detector projects typically are budgeted with contingencies of 25-35%.
• Projects typically overrun their budgets.
• The health of a project depends on having contingency available late in the project when all major overruns and schedule conflicts are felt at once.
• Strong budget/schedule controls are most necessary early in the project to avoid depleting contingency reserves.
• In high technology ventures which push the state of the art, ED&I is typically significantly underestimated, followed by labor costs for manufacturing and installation. The latter is expensive (Davis-Bacon) labor.
The Tao of Project Contingency: Observations

• **Manufacturing costs** can have a wide range in a high tech project. If the item is based on well established manufacturing technologies (e.g. magnet machining, non-exotic tooling and finishing), reasonably accurate predictions should be possible. In radiation-hardened chip design and manufacture, with very few vendors who are small and highly specialized, predictions with error bars of less that +/-100% are difficult.

• **Learning Curves** (i.e. predicting quantity manufactured pricing of a new design) are also difficult for high tech one-of-a-kind projects, and quantity pricing could go positive as well as negative for exotic technologies.

• **Learning curves** (and estimates in general) are applied by the estimator with justification documented in a **Cost Book**.
The Tao of Project Contingency: Risk Factors - Present Usage

• DoE has adopted the use of a formalized Risk Analysis to calculate contingency.

• **Risk factors include: Technical, Cost and Schedule**

• The ATLAS (LHC) group refined these to include a Design Maturity risk factor because they felt risk factors (interpreted linearly as percentages of line item cost) were intuitively too low.

• **Weighting factors were also applied to resultant Technical and Cost risks depending on whether single or composite risks are present.**
# The Tao of Project Contingency: ATLAS System

<table>
<thead>
<tr>
<th>RISK FACTOR</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Existing design Off shelf</td>
<td>Minor mods to existing design</td>
<td>Major mods to existing design</td>
<td>New design Routine</td>
<td>New design Non-routine</td>
<td>New design Some R&amp;D</td>
<td>New design Advances art</td>
<td>New design Exotic</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Off the shelf catalog item</td>
<td>Vendor quote fr. established dwgs</td>
<td>Vendor quote fr. design sketches</td>
<td>Inhse estimate fr. prev. experience</td>
<td>Inhse estimate fr. ltd. experence</td>
<td>Inhse estimate fr. min=&gt;0 exper.</td>
<td>Top-down est. similar program</td>
<td>Engineering judgment</td>
<td></td>
</tr>
<tr>
<td>Schedule</td>
<td>No impact on another item</td>
<td>Cld delay complt in non-crit. item</td>
<td>Delays complt in crit. path item</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>Detail design &gt;50% done</td>
<td>Prelim. design &gt;50% w/analysis is</td>
<td>Concept w/few dwgs; many SK's</td>
<td>Concept only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maturity</td>
<td>&gt;50% done</td>
<td>50% w/analysis is</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WT. FACTOR</th>
<th>1</th>
<th>2</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Design OR Mfg at risk</td>
<td>Design AND Mfg at risk</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Matl OR Labor at risk</td>
<td>Matl AND Labor at risk</td>
<td></td>
</tr>
<tr>
<td>Schedule</td>
<td>Always =1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Maturity</td>
<td>Always =1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Tao of Project Contingency: Examples Using ATLAS System

<table>
<thead>
<tr>
<th>WBS</th>
<th>DESCRIPTION</th>
<th>RISK FACTORS</th>
<th>WEIGHTING FACTORS</th>
<th>TOTAL % CONTINGENCY</th>
<th>BASIS OF ESTIMATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.5.2.1.1</td>
<td>Fiber optic timing receiver</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>1.1.5.2.1.2</td>
<td>HV vacuum cable plant</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1.1.5.2.1.3</td>
<td>Vacuum pump power sup</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1.1.5.2.1.4</td>
<td>Straw-into-gold machine</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>1.1.5.2.1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.5.2.1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.5.2.1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.5.2.1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.5.2.1.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The *Tao* of Project Contingency: Adoption of a System

- ATLAS treats risk factors linearly, as a percentage of Baseline cost, and weighting factors introduce a limited degree of (realistic) non-linearity.
- ATLAS system works but is awkward to use and weighting factors are confusing to estimators.
- A minimum modification would be to expand ranges of basic risk factors and eliminate weighting factors.
- Design Maturity should be retained.
- Manufacturing/vendor risk should be added to highlight special large volume manufacturing estimating that is typical of many NLC systems.
The Tao of Project Contingency: 
Adoption of a System - Proposal

• **Adopt five Risk Factors:**
  • Technical
  • Design Maturity
  • Manufacturing/Vendor
  • Cost
  • Schedule

• **Request Estimators (Engineering) to select and record Risk Factors for appropriate sub-units.**

• **Management develops an appropriate formula to combine Risk Factors to derive a Percentage of the Baseline line item cost.**
The Tao of Project Contingency:
Adoption of a System - Proposal
Risk Factor Definitions
The *Tao* of Project Contingency: Adoption of a System - Proposal

- **Select and record the five risk scores for each appropriate line item.**

- **Cap the maximum Risk Scores as follows:**
  - Technical: \( 10 = 100\% \)
  - Manufacturing: \( 10 = 100\% \)
  - Design Maturity \( 10 = 40\% \)
  - Cost: \( 10 = 50\% \)
  - Schedule: \( 10 = 20\% \)

- **Apply a formula combining risk scores to achieve a total estimate for each appropriate line item.**
The *Tao of Project Contingency*: 
*Rationale for Risk Factor Caps*

- **Technical or Manufacturing difficulty:** A maximally high risk for one of these could cause an estimate to be off by 100% or more.

- **Design Maturity:** Refers to the state of current design, not the design difficulty per se. Therefore a contingency is needed to guard against underestimating duration or scope of effort. For this, 40% is a high contingency.

- **Cost:** Refers primarily to lack of information on which to base cost, occurring mainly in the early stages of a project. Scaling estimates for quantity manufacturing of a unique design is an example where large errors are possible. A maximum of 50% is a high contingency.
The Tao of Project Contingency: Rationale for Risk Factor Caps

- **Schedule:** A certain contingency will be spent because of delays during which costs accumulate across a wide front because of the “standing army” problem. These delays rarely are felt early in a project (although they are present and modern tools attempt to identify them) but accumulate and become critical in the late stages. An overrun of 20% for this reason alone is a very large contingency.

- **If the combined net risk for a Subsystem is higher than 50%,** the Subsystem in question clearly should be flagged for more R&D before it can be confidently budgeted.

- **A Major Subsystem** (major cost driver) with >50% cost risk (e.g. Klystron, Modulator, DLDS component or Beamline Structure) could jeopardize the entire project unless risks are contained via R&D prior to CDR.
The Tao of Project Contingency: Evaluation

• Contingency Analysis is not an exact science and is at best subjective. The best tests are based on real examples generated by experienced people. It helps to have experienced reviewers to help bring reality to the estimates.

• The second part of this talk will illustrate possible implementation including some examples.
The *Tao* of Project Contingency: 
**Implementation**

- Subsystem managers are primarily responsible for bottoms-up cost analyses.
- Subsystem managers should seek help from outside their own groups as needed to make sure they are getting the best available cost estimating expertise.
- System managers should get groups together to resolve apparent discrepancies in estimating of similar object between groups. This will help standardize definitions and models and lead to more consistent estimating.
- Contingency should be estimated after baseline costs.
- Under this proposal, actual calculation of contingency will be performed from risk factors as a post process & then reviewed with each manager.
The Tao of Project Contingency:
Contingency Budget Management

- The Contingency Budget is managed by the Project Management Group.
- Contingency is allocated as a formal procedure and results in movement of funds in the current budget out of contingency and into the appropriate subsystem.
- Contingency management also consists of moving unneeded funds away from a subsystem budget and into the contingency budget.
- The group that makes decisions on Contingency is called a Change Control Board (CCB).
The Tao of Project Contingency: Contingency Budget Management

- Budget changes after a CCB action are immediately documented in the Project Budget presentations.
- Earned value milestones are recalculated to reflect the new approved budgets.
- A history of CCB actions is maintained so the budget change history of each subsystem can be monitored.
- As a general procedure, all subsystem budgets are periodically reviewed with a bottoms-up Cost to Complete analysis.
- If the overall project baseline (Estimate at Complete) changes significantly, e.g. due to cost overruns or schedule slip, the entire project is Re-Baselined as required by top management and the DoE.
The *Tao* of Project Contingency: Summary

- Contingency Analysis rules to be used by NLC will be agreed upon, documented and promulgated as part of the NLC Management Plan, as required by DoE.
- The Contingency Budget is an entity managed separately from the Baseline Budget.
- The NLC proposes an expanded set of Risk Factors, no Weighting Factors, and a formula for converting scores to a Contingency Budget.
- Subsystem Managers will oversee Risk Factor scoring, with Project Management responsible for the integrated Contingency Budget calculation and management.
- Experts/specialists will review budget as well as contingency estimates for consistency of approach.