US CMS Contingency Plan

Detector Contingency Working Meeting

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Fermilab

Contingency and Risk

Risk management is an integral part of US CMS Project Management, and will remain so throughout the life cycle of the Project.

Risk identification is an art. Common risks include unclear project scope, poorly defined requirements, lack of required resources, and poor cost or schedule estimation.

US CMS risk is minimized by accepting management responsibility for complete subsystems for which we define the project scope.

Risk management procedures include an attempt to quantify the residual risk and provide appropriate contingency allocation.

US CMS Contingency Principles

Apply uniform risk analysis across all U.S. subsystems to determine appropriate contingency percentage [see “US CMS Contingency Analysis Procedures, September 26, 1996”].

Contingency is held entirely by Project Management, not by subsystem managers or coordinators, which gives Project Management the ability to apply midcourse corrections where most needed.

Allocation of contingency is by decision of the Project Manager, upon request of the subsystem manager or coordinator, with the advice and consent of the Management Board and concurrence of the relevant funding agency.

Contingency Allocation Need

The need for contingency allocation cannot be assessed without simultaneously addressing the project scope and quality of the cost estimate.

If the cost estimate is unrealistic and/or incomplete, or the technical, cost, or schedule risk is large, the needed contingency allocation is relatively large.

If the cost estimate is comprehensive and complete, and the technical, cost, and schedule risks are small, the needed contingency allocation is relatively small.

US CMS Cost and Contingency

The US CMS Detector Project is designed to cost (base cost + contingency).

Base cost is the cost of doing things right the first time, unless from previous experience it is know more than one iteration will be needed.

Contingency allocation is intended to cover the cost of omitted items and unexpected technical difficulties, unanticipated cost increases, and unforeseen schedule issues.

Contingency allocation is not intended to cover the cost of scope change or delays in the funding.

US CMS Contingency Analysis

We have adopted a quantitative procedure to assign contingency percent based on an analysis of technical, cost and schedule risks.

- **Developed by Martin Marietta for the EMPACT Collaboration at the SSC Lab**
  - » **developed by professional cost estimators**
  - » **based on experience with capital projects**
- **Refined by the SDC Collaboration**
- **Consistent with DOE Orders 4700.1 (Project Management Systems) and 5700.2D (Cost Estimating, Analysis, and Standardization).**
- **Accepted by DOE in the October 1992 review of SDC.**
- **Resultant aggregate contingency percentage is our best estimate of necessary contingency allocation.**

US CMS Contingency Analysis (cont.)

Contingency analysis procedure:

- Assign separate technical, cost and schedule risk factors of from 1% to 15% at an appropriate WBS level
- Multiply each factor by a weight between 1 and 4
- Sum to obtain composite contingency percentage
  - » Technical (design) risk: 2% - 60%
  - » Cost risk: 1% - 30%
  - » Schedule risk: 2% - 8%

The application of this procedure must be tempered by common sense.

Lessons learned from today's descriptions of contingency experience will be used to further refine our contingency analysis procedure.

Contingency Analysis

US CMS Contingency Analysis Procedures, September 26, 1996

Contingency analysis example

- **US CMS HCAL contingency analysis**

US CMS contingency estimate (October 1996)

The Compact Muon Solenoid

US CMS
Contingency Analysis
Procedures

September 26, 1996

This document details the contingency analysis procedures for the US CMS WBS elements. The material is extracted from the US CMS Cost and Schedule Procedures draft of June 30, 1994.

Contingency Analysis

1. Risk Analysis

Risk analysis is to be performed for each WBS element. Results of this analysis will be related to a contingency which will be listed for each WBS element. The goal is to make the method of cost estimation and contingency determination uniform across all WBS elements.

2. Procedures

a. Base Cost Estimate
The base cost estimate is the estimated cost of doing things correctly the first time, **unless** from past experience you are fairly certain that it will take more than once. In other words, contingency should not be included in the base cost.

b. Cost Contingency
Cost contingency is the amount of additional money, above and beyond the base cost, that is required to ensure the project's success. This money is to be used only for omissions and the unexpected difficulties that may arise. Contingency is held entirely by US CMS project management and not by individual subsystem managers or coordinators. Contingency costs are explicitly part of the total cost estimate.

c. Contingency Estimation
The procedure for estimating cost contingency is to:

1) Compare the conceptual state of the element with Table 1 to determine risk factors;

2) Compare the potential risk within an element with Table 2 to determine the appropriate weighting factors;

3) Multiply the individual risk factors by the corresponding weighting factors, and then sum them to determine the composite contingency percentage;

4) Do this for each element at a chosen level, preferably level 5 or 6 of the WBS;

5) Calculate the dollar amount of contingency for an element by multiplying the base cost by the calculated contingency percentage.

Table 1
Technical, Cost, and Schedule Risk Factors

Technical	Cost	Schedule	Risk Factor
Existing design and off the shelf hardware	Off the shelf or catalog item	Not used	1 %
Minor modifications to an existing design	Vendor quote from established drawings	No schedule impact on any other item	2 %
Extensive modifications to an existing design	Vendor quote with some design sketches	Not used	3 %
New design, nothing exotic	In-house estimate based on previous similar experience	Delays completion of non-critical path subsystem item	4 %
New design, different from established designs or existing technology	In-house estimate for item with minimal experience but related to existing capabilities	Not used	6 %
New design, requires some R&D but does not advance the state-of-the-art	In-house estimate for item with minimal experience and minimal in-house capability	Delays completion of critical subsystem item	8 %
New design, development of new technology which advances state-of-the-art	Top-down estimate from analogous programs	Not used	10 %
New design, way beyond the current state-of-the-art	Engineering judgment	Not used	15 %

Table 2
Technical, Cost, and Schedule Risk Weights

Technical	Cost	Schedule	Risk Weight
Not used	Material cost OR Labor rate	Same for all	1
Design OR Manufacturing	Material cost AND Labor rate	Not used	2
Design AND Manufacturing	Not used	Not used	4

3. Input Format

In a spreadsheet format, create a copy of your WBS. Pick a level at which you will do detailed contingency analysis, and include the following additional columns:

WBS #	Elem. Desc.	Tech Risk	Cost Risk	Sched. Risk	Tech Wt.	Cost Wt.	Sched. Wt.	Comp. Risk %

Input all information following the procedure outlined above.

Example: (from the SDC Si Tracker)

WBS #	Elem. Desc.	Tech Risk	Cost Risk	Sched. Risk	Tech Wt.	Cost Wt.	Sched. Wt.	Comp. Risk %
1.1.1.4.1	Cooling Rings	6	4	8	4	2	1	40
1.1.1.4.2	Bridge Struc.	4	4	4	4	1	1	24
1.1.1.4.3	Coolant Distr.	4	3	4	2	2	1	18

A more detailed example is provided in the Appendix.

4. Backup Information

Keep all supporting information used in deriving risk factors. Most of the backup information will be the above spreadsheet itself.

US CMS Hadron Calorimeter Contingency Analysis

		Tech. Risk	Cost Risk	Sched. Risk	Tech. Wt.	Cost Wt.	Sched. Wt.	Cont. (%)	Base Cost	Total Cost
2	**Hadron Calorimeter**							**31**	**33,262**	**43,514**
2.1	**Barrel Hadron Calorimeter (HB)**							31	25,377	33,340
2.1.1	Barrel							31	22,889	30,063
2.1.1.1	Mechanical Structure	4	4	8	4	2	1	32	9,501	12,541
2.1.1.2	Optical System	3	4	4	4	2	1	24	3,082	3,822
2.1.1.3	Phototransducers	6	4	4	4	2	1	36	2,671	3,632
2.1.1.4	Electronics	6	4	4	4	2	1	36	1,400	1,904
2.1.1.5	Tooling	3	4	8	4	2	1	28	3,748	4,797
2.1.1.6	Shipping	1	4	4	2	1	1	10	388	427
2.1.1.7	Prototypes (2 wedges)	6	6	4	4	2	1	40	2,100	2,940
2.1.2	Outer Barrel							32	2,488	3,277
2.1.2.1	Mechanical Structure	4	4	8	4	2	1	32		
2.1.2.2	Optical System	3	4	4	4	2	1	24	891	1,104
2.1.2.3	Phototransducers	6	4	4	4	2	1	36	1,020	1,388
2.1.2.4	Electronics	6	4	4	4	2	1	36	577	785
2.2	**Endcap Hadron Calorimeter (HE)**							34	4,465	5,984
2.2.1	Barrel							35	2,887	3,890
2.2.1.1	Mechanical Structure	4	4	8	4	2	1	32	751	991
2.2.1.2	Optical System	3	4	4	4	2	1	24	57	71
2.2.1.3	Phototransducers	6	4	4	4	2	1	36	1,194	1,624
2.2.1.4	Electronics	6	4	4	4	2	1	36	885	1,204
2.2.1.5	Tooling	3	4	8	4	2	1	28		
2.2.1.6	Shipping	1	4	4	2	1	1	10		
2.2.1.7	Prototypes (2 wedges)	6	6	4	4	2	1	40		
2.2.2	Outer Barrel							33	1,577	2,094
2.2.2.1	Mechanical Structure	4	4	8	4	2	1	32	170	224
2.2.2.2	Optical System	3	4	4	4	2	1	24	372	461
2.2.2.3	Phototransducers	6	4	4	4	2	1	36	647	879
2.2.2.4	Electronics	6	4	4	4	2	1	36	388	528
2.3	**Forward Calorimeter (HF)**							23	3,420	4,191

US CMS Project Cost Estimate

15 Oct 96

WBS Number	Description	US Mfg Total (K$)	US EDIA Total (K$)	US EDIA (%)	US Base Cost (K$)	US Cont (K$)	US Cont (%)	Total US Cost (K$)
US CMS Total Estimated Cost (FY'96 $s)		**94,956**	**25,025**	**21%**	**119,981**	**25,805**	**22%**	**145,786**
						Under Review		
US CMS Total Subsystem Cost (FY'96 $s)		**71,943**	**19,343**	**21%**	**91,285**	**24,993**	**27%**	**116,278**
1	**Endcap Muon System**	**23,675**	**5,733**	**19%**	**29,408**	**6,856**	**23%**	**36,264**
1.1	Muon Measurement System	23,675	5,733	19%	29,408	6,856	23%	36,264
2	**Hadron Calorimeter**	**27,414**	**5,882**	**18%**	**33,296**	**10,226**	**31%**	**43,522**
2.1	Barrel Hadron Calorimeter	20,827	4,550	18%	25,377	7,962	31%	33,340
2.2	Endcap Hadron Calorimeter	3,815	650	15%	4,465	1,519	34%	5,984
2.3	Very Forward Calorimeter	2,772	682	20%	3,454	745	22%	4,199
3	**Trigger/Data Acquisition**	**10,421**	**3,892**	**27%**	**14,313**	**4,112**	**29%**	**18,425**
3.1	Endcap Muon Level 1 CSC Trigger	1,208	893	43%	2,102	609	29%	2,711
3.2	Calorimeter Level 1 Regional Trigger	3,089	1,499	33%	4,588	1,330	29%	5,918
3.3	Luminosity Monitor	387	48	11%	435	87	20%	522
3.4	Data Acquisition	5,737	1,452	20%	7,189	2,085	29%	9,274
4	**Electromagnetic Calorimeter**	**6,982**	**1,913**	**22%**	**8,895**	**1,650**	**19%**	**10,545**
4.1	Barrel Photodetectors	2,384	484	17%	2,868	671	23%	3,539
4.2	Front-End Electronics	3,320	920	22%	4,240	722	17%	4,962
4.3	Crystal Processing	435	358	45%	793	77	10%	870
4.4	Monitoring Light Source	808	106	12%	914	168	18%	1,082
4.5	Crystal Development	35	45	56%	80	12	15%	92
5	**Tracking**	**3,450**	**1,922**	**36%**	**5,373**	**2,149**	**40%**	**7,522**
5.1	Forward Pixel Tracker	3,450	1,922	36%	5,373	2,149	40%	7,522
6	**Common Projects**	**23,013**	**0**	**0%**	**23,013**	**0**	**0%**	**23,013**
7	**Project Management**	**0**	**5,682**	**100%**	**5,682**	**813**	**14%**	**6,495**
7.1	Project Administration	0	3,254	100%	3,254	424	13%	3,678
7.2	Technical Coordination	0	2,428	100%	2,428	389	16%	2,817

Contingency Management

Contingency management procedures are detailed in the US CMS Project Management Plan draft, September 30, 1996.

Project contingency is the difference between total estimated cost (TEC) and the estimate at completion (EAC).

Annual funding request will include a projection of the required use of contingency over the life of the project, based on an update of the EAC.

The actual use of contingency will be reflected in the difference between BCWP (Earned Value) and ACWP, i.e., by the Cost Variance.

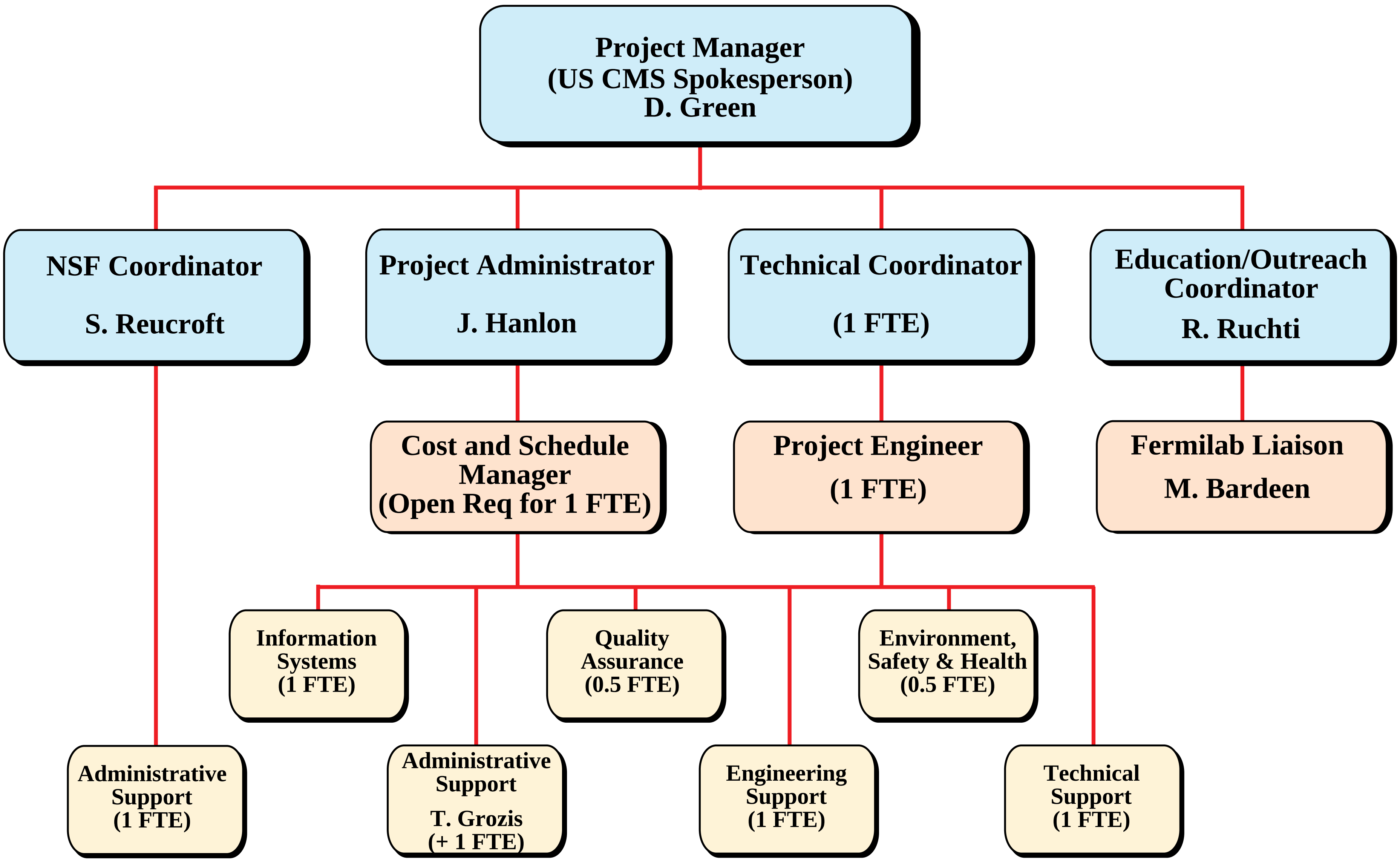
Contingency Management (cont.)

All ECRs that will require future use of contingency must be explicitly approved by Project Management.

Allocation of contingency is reflected through a request for funds in excess of the baseline budgeted cost. (Contingency is not part of the baseline cost.)

The use of contingency will be tracked by the US CMS Project Office at Fermilab over the life of the project.

US CMS Project Office



15-Jan-97

Summary

- Risk is minimized in US CMS by accepting full responsibility for complete subsystems with well-defined scope and clear requirements, and by comprehensive cost and schedule estimates.
- US CMS has a well-defined contingency analysis procedure designed to evaluate the residual technical, cost, and schedule risks.
- We have done our best to estimate our contingency allocation needs.
  - We will continue to refine our contingency analysis procedure and review our contingency allocation needs.
- Contingency management procedures are specified in our Project Management Plan; a functioning Project Office is in place.