Project Science

Selected Details

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Project Science Workshop

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The "Linear" Project

Executing the project consists solely of carrying out a well defined plan

- **Project goals and requirements are stable**
- **Sponsor support and funding are stable**
- **Managing institutions do not confuse the goal of project success with their other goals**
- **Resources are matched to project**
- **Resources are really controlled in one project office**
- **Project team owns the plan**

The result is that the major risks are technical

- **Remaining risks are inexperience and human behavior**

Distinct stages in a project…

- **Definition to Reference Design**
- **Reference Design to Baseline Definition**
- **…to Final Design and Commitment**
- **… to Industrialization** Manage obligations
- **Execution and Performance Measurement**
- **Integration and Plan to Completion** Manage costs
- **Endgame** “broke and done on the same day”

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Definition to Reference Design

- Define scientific question(s)
- Define science requirements
- Develop informal conceptual design
- Define and initiate needed R&D
- Define technology options*
- Produce traditional small science experiment proposal
- Define “reference design” *

Reference Design Technology Options

- **Even at the early conceptual level, work, via formal review, each of the major technology options into one of the following categories as early as possible, no later than the reference design definition**
  - **Baseline choice with fallback option and decision date**
  - **Equal options with decision date**
  - **Firm baseline choice with no option**
    - **Make this choice succeed, no fallbacks**

The Reference Design Package

- **This is the deliverable of this stage of the project**
- **Write a “Project Book”**
  - **Put it on the web as you build it**
  - **When it is mature, put it under revision control**
  - **It foreshadows the baseline definition without sacrificing anything that we do as scientists in writing experimental proposals**
  - **Start off with a methodology that looks forward**

A Project Book Outline …

- Overview
- Science Goals
- Reference Design Baseline Definition
  - Parameters
  - Sensitivity Goal
  - Options and Selection
- Program Plan
  - Roles and Responsibilities
  - Method of Accomplishment
- Work Breakdown Structure
- Subsystem WBS 1 Description
  - Overview
  - Functional Requirements
  - Concept/Options
  - Development Issues/R&D
  - Work Plan
- …
- …

Project Science

… A Project Book Outline

- …
- **Subsystem WBS N Description**
  - Overview
  - Functional Requirements
  - Concept/Options
  - Development Issues/R&D
  - Work Plan

(Includes installation and project management WBS's)

- **Schedule**
  - Summary schedule
  - Relationship to other programs
  - Schedule options
- **Cost Estimate**
  - Methodology
  - Summary by WBS
  - Cost Drivers
  - Risk areas and contingency
  - Funding profile
- **Responsibilities/Resources/Staffing**

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Reference Design to Baseline Definition

Selected Details - 20101108

The baseline...

- Scientific requirements are defined and fixed
- Technical requirements meet the scientific requirements and are fixed
- Project deliverable is defined in a conceptual design
- Subsystems are defined
  - interfaces are defined
- Work Breakdown Structure (WBS) defines all work to be performed in the project including delivery of each subsystem and their integration

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…The baseline

- Costs are estimated at the lowest level in the WBS
- Schedule is developed following the WBS
- Costs and other resources are integrated with the schedule to define the value of each scheduled activity, and a profile of obligations and costs
- Risks are assessed at the cost estimate level in the WBS and a contingency pool of funds are defined for project-wide management of risks
- Basis for performance measurement is established

The Baseline Package

- **Project Book** *
  - **Updated and more rigorous**
- **Work Breakdown Structure Dictionary** *
  - **Can be part of schedule database**
- **Integrated Project Schedule** *
  - **mature and captured in a scheduling system/tool**
- **Cost Estimating Plan** *
- **Cost Book** †
  - **down to low level in a database/cost book tool**
- **Performance Measurement Plan** *
- **Project Management Plan** *

*on the web

†not on the web

procurement sensitive

Project Science

Project Management Plan

- Objectives and Scope
- Project Description
- Institutional Roles and Responsibilities
- Organization of the Project
- Collaborative Relations
- Work Breakdown Structure
- Work Plan
- QA/ESH
- Procurement
- Cost Estimate
- Schedule
- Staffing
- Cost and Schedule Control and Performance Measurement
- Configuration Management and Change Control
- Documentation
- Reporting to sponsor
- Meetings and Reviews
- Publication

…thin…easy to read…easy to use...

…not too baroque…

Project Science

Cost Estimating Plan

- Scope
- Objectives
- Basis of Estimate
- WBS
- Costing Methodology
  - Relational Cost Database
  - Collection of Cost Information
  - Confidence
  - Cost Book
  - Integration with schedule
- Labor Pricing
  - Direct Labor Rates
  - Contract Labor Rates
- Risk Analysis, Contingency
  - Risk Analysis
  - Risk Assessment Methodology
- Escalation
- Estimators

Cost Estimate Tools

- **Standard relational databases**
  - **LIGO uses a web based interface to Access**
  - **TMT uses an Excel interface to Access**
  - **Many projects have developed tools**
    - **But they built them for internal use and may be unable to support your use**
- **Commercial estimating packages**
  - **“Success”**
  - **Construction industry tools**
- **Commercial “pricing” tools**
  - **ProPricer,…**

Advanced LIGO Cost Estimate Detail

WBS Number	LIGO.4.02.3.2.1.3.1
WBS Description	Instruments
Activity	SID32131
Description	EST: SEI PD ETF Instruments
Location	Caltech Off Campus
Cost Code	12-40232-14

Duration	105 days
Estimated By	T. Fuoy
Last Modified On	09/07/2001

Line	NSF Item Code	Cost Category	LIGO Resource Code	Description	Estimator Comments or Vendor	Cost Basis	Quantity (Hrs/Ea)	Direct Labor (AA, B1-B6) Unit Cost	Direct Labor (AA, B1-B6) Total ($)	Contract Labor (G5) Unit Cost	Contract Labor (G5) Total ($)	Equipment (D1,D2) Unit Cost ($)	Equipment (D1,D2) Total ($)	Travel (E1,E2) Unit Cost ($)	Travel (E1,E2) Total ($)	Material (G1-G4) Unit Cost ($)	Material (G1-G4) Total ($)	Subcontracts (G5) Unit Cost ($)	Subcontracts (G5) Total ($)	Total Cost ($)	Reference
1	B2	Labor	EN	Procurement Mgmt.		EE	218	45	9,810											9,810	
2	D1	Equip.	D1	L-4C vertical shallow surface seismometer	Sercel - Quote Ref. 7071	EE	3					1,056	3,167							3,167	
3	D1	Equip.	D1	LA50-62-TBD	BEI KIMCO - Quote Ref. 8413	EE	7					3,204	22,425							22,425	
4	D1	Equip.	D1	L-4C horizontal shallow surface seismometer	Sercel - Quote Ref. 7071	EE	3					1,056	3,167							3,167	
5	D1	Equip.	D1	LA18-32-TBD	BEI KIMCO - Quote Ref. 8413	EE	7					1,395	9,765							9,765	
6	D1	Equip.	D1	Capacitive Position Sensor		EE	12					3,515	42,180							42,180	
7	D1	Equip.	D1	Current Drivers		EE	12					833	10,000							10,000	
8	D2	Equip.	D2	GS-13 short period seismometers	Geotech Instruments - Quote Ref. MI020101a	VQ	6					8,301	49,803							49,803	
9	D2	Equip.	D2	STS-2	Streickeisen	VQ	3					14,000	42,000							42,000	
				Subtotal SID32131	EST: SEI PD ETF Instruments				9,810				182,506							192,316	

Labor Summary (Direct Labor plus Contract Labor)

	AA	B1	B2								B3	B4	B5
	Key/Fac	PostDoc	Mgmt	SrSci	Sci	SrEngr	Engr	Tech	Other	Total	Grad	UGrad	Admin
Hours							218			218			
Person Years							0.1			0.1			

Risk Factors		Risk Multipliers	
Technical	4	4.00%	
Cost	1	2.00%	Calculated Contingency 20.00%
Schedule	2	1.00%	Estimator Override

Staff Benefits at	25.00%	2,453
(G6) GRA Benefits at	50.00%	0
Indirect Cost at	26.00%	26,771
Total Cost		221,539
Contingency at	20.00%	44,308
Cost Plus Contingency		265,847

WBS Definition

The principal deliverables of this WBS element include:

1) electromagnetic actuators
2) Streckeisen STS-2 broadband seismometers
3) Sercel L-4C geophone
4) Capacitive displacement sensors
5) Ground and witness seismometers
6) Current Drivers for actuators

Basis of Estimate

Task List

Cost Estimating Worksheet

WBS*:
Subphase*:
Responsible Estimator*:
Estimators*:

Estimate Date:
Start Date*:
End Date*:

* - Required Fields

Links:
Cost Estimating Plan
Input Cheat Sheet
Cost Estimating Publications

Element Scope / WBS Dictionary Entry*:

Description*:

Labor

BOE*:

	Resource	Organization	Estimate Type	Start Date	End Date	FTE	Hours
1							
2							
+							

Non-Labor

BOE*:

	Expense Item	Description	Category	Estimate Type	Start Date	End Date	Unit Cost	Cyclical	Units / Cycle	Months / Cycle	Number of units
1											
2											
+											

Travel

BOE*:

	Trip	Duration	Start Date	End Date	Cyclical	Units / Cycle	Months / Cycle	Number of Trips
1								
2								
+								

Risk Factors

	Factor	%	Basis*:
Technical*:			
Cost*:			
Schedule*:			
TOTAL:	0%		
Override:			

Misc Comments:

Scoping Options:

TMT.TEL.OPT.M1.SSA.WARP - Segment Warping Harness

FAB - Fabrication

Start: Mar 2009 *End:* Dec 2009

Responsible Estimator: Ben Platt

Estimate Date: 8/28/2006

Estimators: Larry Stepp, RJ Ponchione

WBS/Subphase Dictionary

The warping harness includes all mechanisms, active components and cabling needed to apply forces to an individual primary mirror segment (TMT.TEL.OPT.M1.SEG.M1) t change its figure. The warping harness is an integral part of a Segment Support Assembly (TMT.TEL.OPT.M1.SSA). It does not include any external measurement device used to determine commands to the warping harness. Note: The cost of the control electronics is covered in TMT.TEL.CONT.M1CS.

WBS/Subphase Description

The warping harness will induce moments into the whiffletree to correct mirror surface errors. This will be done using 18 beam springs that will be attached to the center of th whiffletree plates at one end and the other will be bent by a screw and nut driven by a stepper motor.

Labor

TMT contract monitoring labor is included in TMT.TEL.OPT.MGT.

Nonlabor

The costs are the costs to manufacture all the components in the warping harnesses have been acquired from catalog prices and direct vendor quotes whenever possible. Quantities include approximately 1% construction spares.
Labor cost for assembling the connector on the motor and strain gage wires is estimated at 4 minutes each, at $85 per hour including contract fee.
The wiring from the connector to the control electronics is included in TMT.TEL.CONT.M1CS.
Cost of shipping the warping harnesses to the assembly location are included in TMT.TEL.OPT.M1.SSA.INT.

Item/Activity	Type	Start Date	End Date	Units	UM	Unit Cost	Nonlabor Cost
Assembly labor for electrical connectors	EE	Mar 2009	Dec 2009	15,700.0	ea	$5.67	$89,019
Beam Spring	VQ	Mar 2009	Dec 2009	15,700.0	ea	$8.27	$129,839
Drive Screw	VQ	Mar 2009	Dec 2009	15,700.0	ea	$1.28	$20,096
Electrical Connector	CP	Mar 2009	Dec 2009	15,700.0	ea	$2.10	$32,970
Motor Mount	EE	Mar 2009	Dec 2009	15,700.0	ea	$3.00	$47,100
Nut	EE	Mar 2009	Dec 2009	15,700.0	ea	$2.00	$31,400
Stepper Motor	VQ	Mar 2009	Dec 2009	15,700.0	ea	$7.55	$118,535
Strain Gauge	VQ	Mar 2009	Dec 2009	15,700.0	ea	$5.30	$83,210
Thrust Bearing	VQ	Mar 2009	Dec 2009	15,700.0	ea	$1.56	$24,492
Wiring	CP	Mar 2009	Dec 2009	15,700.0	ea	$0.92	$14,444
						Direct Nonlabor:	$591,105
						Burdens:	$3,694
						Nonlabor Subtotal:	$594,799

Travel

It is expected that during the course of production two vendor visits will need to be made. Currently all vendors under consideration are located in North America, however lower cost overseas vendors may be found in the future.

Destination	Duration	Start Date	End Date	# of Trips	$ per Trip	Travel Cost
Continental U.S., Canada, and Mexico.	Short - (3 days)	Mar 2009	Dec 2009	2	$834	$1,668
			Total Trips:	2	Direct Travel:	$1,668
					Burdens:	$10
					Travel Subtotal:	$1,678

Contingency

	Factor	%	Basis of Estimate
Technical	6	2%	Fairly straightforward design using common components. Primarily concern is whether components of the quality estimated will provide acceptable performance.
Cost	3	2%	Most components quoted by vendor or catalog priced.
Schedule	6	1%	Must be installed before segments can be mounted on the cell
Override			
TOTAL		30%	

Comments

Scoping Options

This estimate is for an 18-actuator-per-segment system. It is possible to descope to 15 actuators per segment with some loss in performance. It may also be possible to eliminate the strain gauges and close the control loop with the surface figure measurement alone. This would provide less information during adjustments and may reduce performance.

WBS/Phase Estimate Summary

Direct Cost: $592,773 + Benefits: $0 + Burdens: $3,705 = Budgeted Cost $596,478

Contingency: $178,943 @ 30.0%

TOTAL: $775,421

Contingency

- **Cost contingency**
  - **Not always adequate by itself**
- **Scope contingency**
  - **Deferred scope**
    - **Delay some scope until later in the project and execute it if early progress is good**
    - **Store scope in contingency pool as a planning package**
  - **Phased scope**
    - **Real reduction in scope and returned to contingency**
    - **Execute as a later project or if favorable performance permits**
  - **Permanent reduced scope**
    - **Returned to contingency and project baseline precludes return of this scope**
- **Baseline must always be definite**

Auditing a subsystem cost estimate

- **During estimating, hold major reviews for each subsystem**
  - **Appoint internal reviewers**
  - **Invite other subsystem estimators**
  - **Invite outside experts as reviewers**
- **Estimators deliver to review a presentation that is designed uniformly across all subsystems**

Cost review presentation …

- Subsystem requirements
- Subsystem parameters
- WBS
- WBS Dictionary
- Estimate summary rollup (base year)
  - Analysis by labor, materials, contingency, etc.
- Basis of Estimate examples
  - Large cost items – cost drivers
  - High cost uncertainty items
  - Fraction of estimate in various basis categories

… Cost review presentation

- **Contingency**
  - **Summary analysis of contingency**
  - **Details of high contingency $ items**
  - **Details of high contingency % items**
  - **Other risks**
- **Options for 10% cost reduction**
  - **Scope deferral**
  - **Scope reduction**
  - **Other options**
- **Summary schedule**
- **Escalation and “as-spent” profile**

Schedule

- **Plan top level milestones as input to subsystem estimators**
  - **Set “architecture” of project**
- **Subsystem estimators develop subsystem schedules**
  - **Critical path and schedule slack strategies**
  - **Workarounds sketched out**
- **Review and integration by project management with visibility across subsystems**

Schedule - Tools

- **Who does the schedule development and manages the performance measurement baseline?**
  - **The Project Manager?**
    - **Top level strategy and integration**
  - **Scientists or engineers in the project?**
    - **Substantive development and performance management**
  - **Schedule/cost contractor?**
    - **Operates the tools**
- **But scientists/engineers will want to be able to operate the tools**
  - **Tight control by the task leaders**
  - **Planning and replanning scenarios**

Schedule - Tools

- **Scientists and engineers can operate Microsoft Project**
  - **This tool is relatively simple to use**
  - **Full of errors**
  - **Does not perform a true critical path calculation**
  - **Does not accommodate integration with cost estimate database nor performance measurement**
- **Can be used as a working development and scenario tool**
  - **Files transferred to central system**
- **Not suitable for a full performance measurement system in a big science project**

Schedule - Tools

- **The sole project schedule should be held by the project management**
- **It should be captured in an industrial strength tool or combination**
  - **Primavera P3 or P3E**
  - **Open Plan**
  - **…**
- **An experienced cost/schedule professional should be hired or contracted to operate this system and provide development, audit, reporting and performance measurement support to the project management and subsystem leaders**

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Schedule - Tools

- **Choose tools very carefully**
  - **Try them and throw them away early**
- **There are big projects running on Microsoft Project**
  - **But …**
- **Use experts in support**

…to Final Design and Commitment

- **Deliverables of this phase are the complete set of**
  - **Final Design packages for each subsystem**
    - **Ready-to-build designs**
  - **System Design Requirements**
  - **Interface control documents**
  - **Acquisition strategy for each major procurement**
    - **Make or buy**
    - **Competitive procurements**
      - **Contract type**
      - **Selection strategy**

defines scope of final design

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… to Industrialization

- Complete developmental procurements and first-article tests
  - Main project technical risks confronted here
- Develop quality assurance plan
  - Overwhelmingly important
- Produce bid packages
  - Keep competition as long as possible
- Carry out selection of contracts and commit funds
- Develop adequate robust contractor oversight
- Performance signaled by obligations
- Bid jeopardy is the first big threat to contingency pool

Managing contracted effort

- **All contracts or purchases of $100K or more go through a formal planning process**
  - **market survey and source identification**
  - **careful consideration of contract type**
    - **fixed price**
    - **cost reimbursable + fee**
    - **incentives/penalties**
  - **structure of bid package or tender**
    - **competition**
    - **multiple awards followed by final selection**
- **Contract change management is a crucial element of project management**

Reviewing a procurement: Source Selection

- **RFP (Tender) includes Statement of Work, legal requirements and criteria for selection of contractor**
- **Proposals are reviewed by Proposal Evaluation Team which develops a rigorous selection recommendation**
- **Recommendation reviewed by Review Committee which comments to Project Management**
- **Selection is finalized by a Source Selection Authority from fiduciary institution**

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Managing contractors

- Crucial to manage multiple contractors on “non-interfering” basis
- Crucial to manage who is taking the risk
- Crucial to have a rigorous system to track and control all contacts between Project and contractors with a single approving authority for each contract
- Crucial to rigorously, but quickly, manage contractor change orders
- Managing “fixed price” contracts is very different from managing “cost reimbursable” contracts

Execution - Performance Measurement

- Main activities of the project are in motion
- Weekly telecons/meetings to focus on “issues”
- Monthly performance reporting by in-house teams and contractors
- Monthly meeting to review progress, cost and schedule variances
- No longer measuring by obligations, but by earned value and costs

Performance measurement

- **Early visibility leads to early project response and repair**
- **Learn to separate out performance measurement artifacts from real performance measurements**
  - **Invoicing delays retards ACWP**
  - **Original progress profiles built into earned value plan may be in error**
    - **Flat, progressive, final delivery methods may have been inappropriately applied**
    - **Learning curve effects not planned**
    - **Wrong planned values of milestones**
  - **Despite these, learn to look closely and to respect the system and make it work**

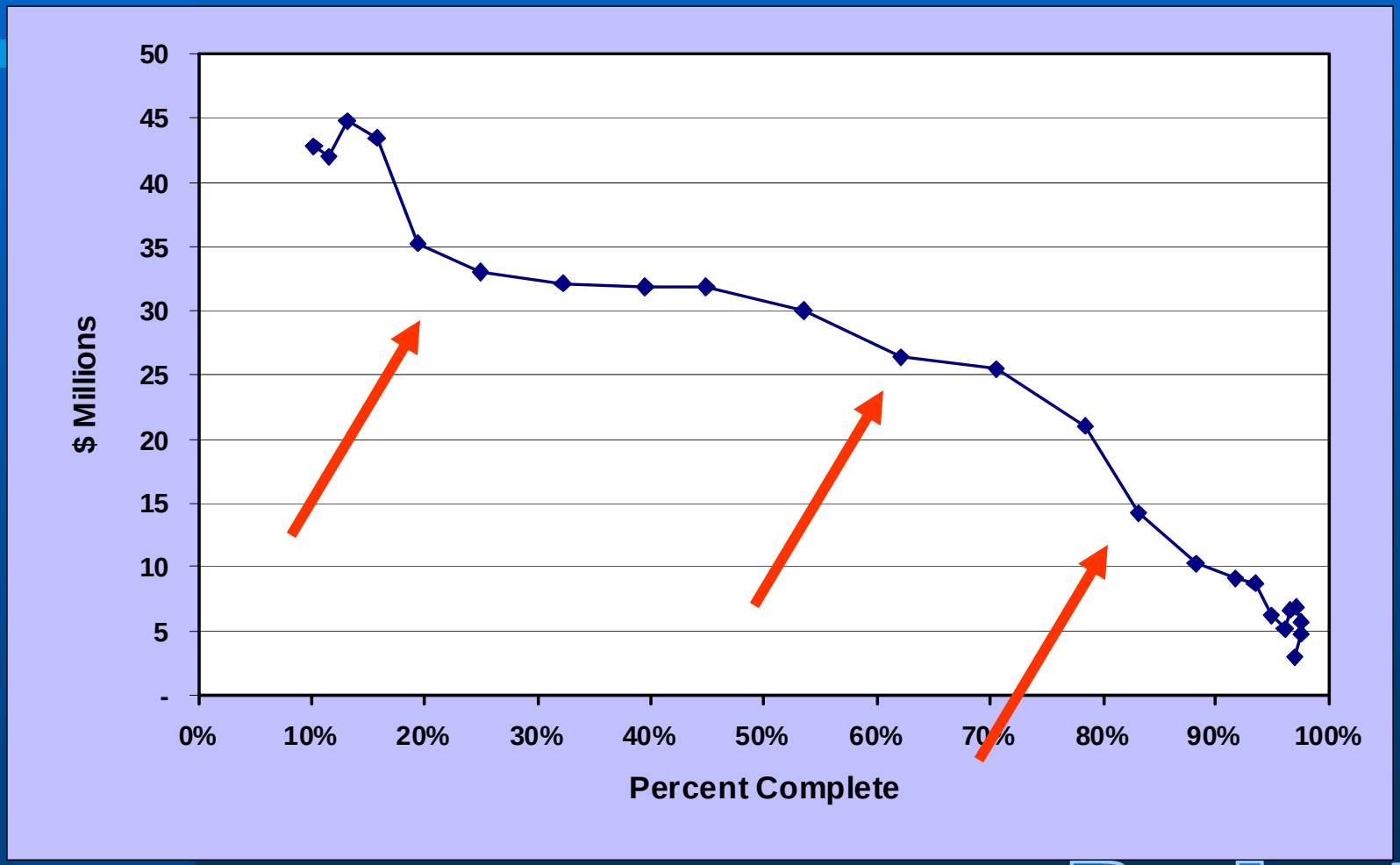
Performance measurement level

- **Cost estimate and schedule may have been detailed down to levels 5 to 9 in WBS**
- **Learn to look at appropriate level in WBS for performance measurement**
  - **In building baseline system, choose level 3 or 4 for performance measurement level**
  - **Create work packages and earned value plans at this level**
  - **Subsystem in-house and contractor reporting should be at this measurement level even if lower level detail is available**

Contingency management

- **Be very stingy with contingency till late in the project**
  - **Use it when really needed but husband it till endgame arrives**
  - **Bid jeopardy is a big consumer of contingency**
  - **Final integration, installation, commissioning is a big consumer of contingency**
    - **And it is too late for some project responses**
- **How do you manage this approach to the endgame?**

(%Contingency used)/(% Project complete)



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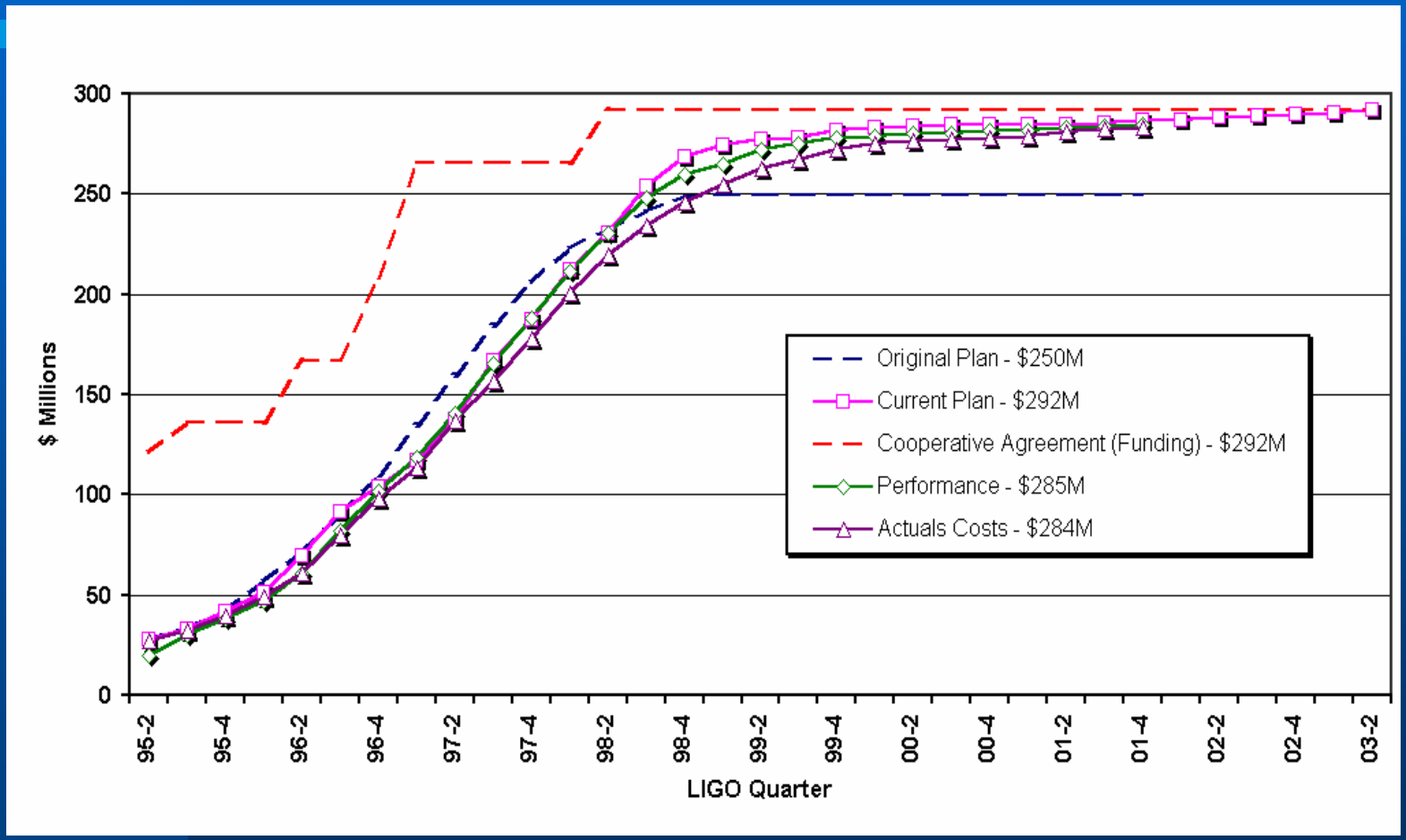
LIGO Cost Schedule Status



Project Science

Integration and Plan to Completion

- **Executing to plan**
- **Plan must be adjusted to incorporate actual progress and experience**
- **Actual costs must be put into cost estimate for completed scope**
  - **This leaves the remaining Estimate to Complete**
- **Actively manage “hidden contingency” needs**
  - **“slips of paper” in task manager back pockets**
  - **Pull them out onto the table**

Reestimate and rebaseline

- **Include revised information from actual experience and signed contractor cost/schedule commitments**
- **Revise BCWS to reflect most realistic plan so that performance measurement is meaningful**
  - **If not, Task Leaders will not use system**
- **Cost, Schedule and PMB changes made annually on average and only after careful review by Technical/Change Control Board**

Contingency in final phase …

- **If you have managed contingency centrally and well**
  - **Subsystem task leaders will trust that surpluses can be put back into contingency pool and**
  - **Later contingency requests will be judged fairly**
  - **All contingency is in the central pool**
  - **Is there “hidden contingency”?**
  - **Are there invisible risks waiting for last minute surprises?**

… Contingency in final phase

- **Actively maintain a list of possible calls on contingency with all task leaders contributing items and estimates**
  - **All the private “slips of paper”**
  - **Examine weekly in later project phases**
  - **These are not “claims” on contingency funds**
  - **They are an actively managed list of concerns**
  - **If the risks mature, change control requests are made**
  - **If the risks disappear, they are dropped from the list**
  - **Total list value is managed and compared to estimate to complete**

Analysis of Potential Contingency Needs for Detector

Contingency Liens (Construction)

Description	CR	WBS	Direct	Benefits	Overhead	Total	Resp.
OSEM Replacement		1.2.1	230,000			230,000	whitcomb
Reduced ISC Labor Costs		1.2.1	(171,000)			(171,000)	whitcomb
Beam Splitter Livingston (Replacement plus Spare Blank)	CR-010007	1.2.1	105,000			105,000	whitcomb
Seismic Remediation		1.2.1	758,000			758,000	whitcomb
R&D (Overrun)		1.3	62,000			62,000	whitcomb
Total			**984,000**	**-**	**-**	**984,000**	

Watch List (Construction)

Description	CR	WBS	Direct	Benefits	Overhead	Total	Resp.
Possible Baffling and Backscatter		1.2.1	180,000	-	-	180,000	whitcomb
Re-Coat Four Core Optics		1.2.1	45,000			45,000	whitcomb
Re-Polish Core Optics		1.2.1	40,000			40,000	whitcomb
Change Switching Power Supplies to Linear PSs		1.2.1	???			-	whitcomb
Spares		1.2.2	300,000			300,000	whitcomb
Total			**565,000**	**-**	**-**	**565,000**	

Liens on Director's Reserve (Operations)

Description	CR	WBS	Direct	Benefits	Overhead	Total	Resp.
Security Systems for Computers		1.2.2	150,000			150,000	whitcomb
Total			**150,000**	**-**	**-**	**150,000**	

Endgame

- Manage last flexibility
- Testing
- Acceptance reviews
- As-built documentation
- Transition to operations is incremental but must be managed formally

Other crucial factors

- People
- Clear, shared agendas
- Communicating openly and listening
- Trust
- Teambuilding
- Share project goals and subordinate individual goals
- Delegate authority to lowest appropriate level but make accountability very clear
- Draw organization around people, instead of trying to fit people into a predetermined organization
- Clear process