Project Science

Planning for Performance Measurement

Gary Sanders, TMT Project

Project Science Workshop

Fort Lauderdale, November 2010

From a reference design to a defined and baselined project

- **Work Breakdown Structure**
- **Project Organization**
- **Management Plan**
- **Cost Estimate and Risk Analysis**
- **Schedule Development**
- **Performance Measurement**

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Work Breakdown Structure (WBS)

Work Breakdown Structure (WBS)

- **Break down all of the work required to complete the project**
  - **Include all physical deliverables, subsystems**
  - **Include R&D, design, prototyping, fabrication, assembly, installation, acceptance testing leading to a deliverable product**
  - **Include administration, system engineering, purchasing, reporting not directly related to deliverable products**
  - **Break work down to 5-8 levels from top when mature**
- **Organize work in a way to support delivery of "products"**
- **If work will be accomplished through major contracts, represent them in the WBS**

Work Breakdown Structure (WBS)

- **WBS will structure cost estimating, schedule planning, tracking of actual costs and progress**
- **It should reflect how you will manage the project toward its goals**
- **Do not make the common mistake of organizing it to keep accountants happy, or to reflect geography or existing organizations**
- **Structure your organization to parallel the WBS**
- **Write a Work Breakdown Structure Dictionary and maintain it**
  - **For each entry in the WBS Dictionary state:**
    - **What the element is**
    - **And what it is not**

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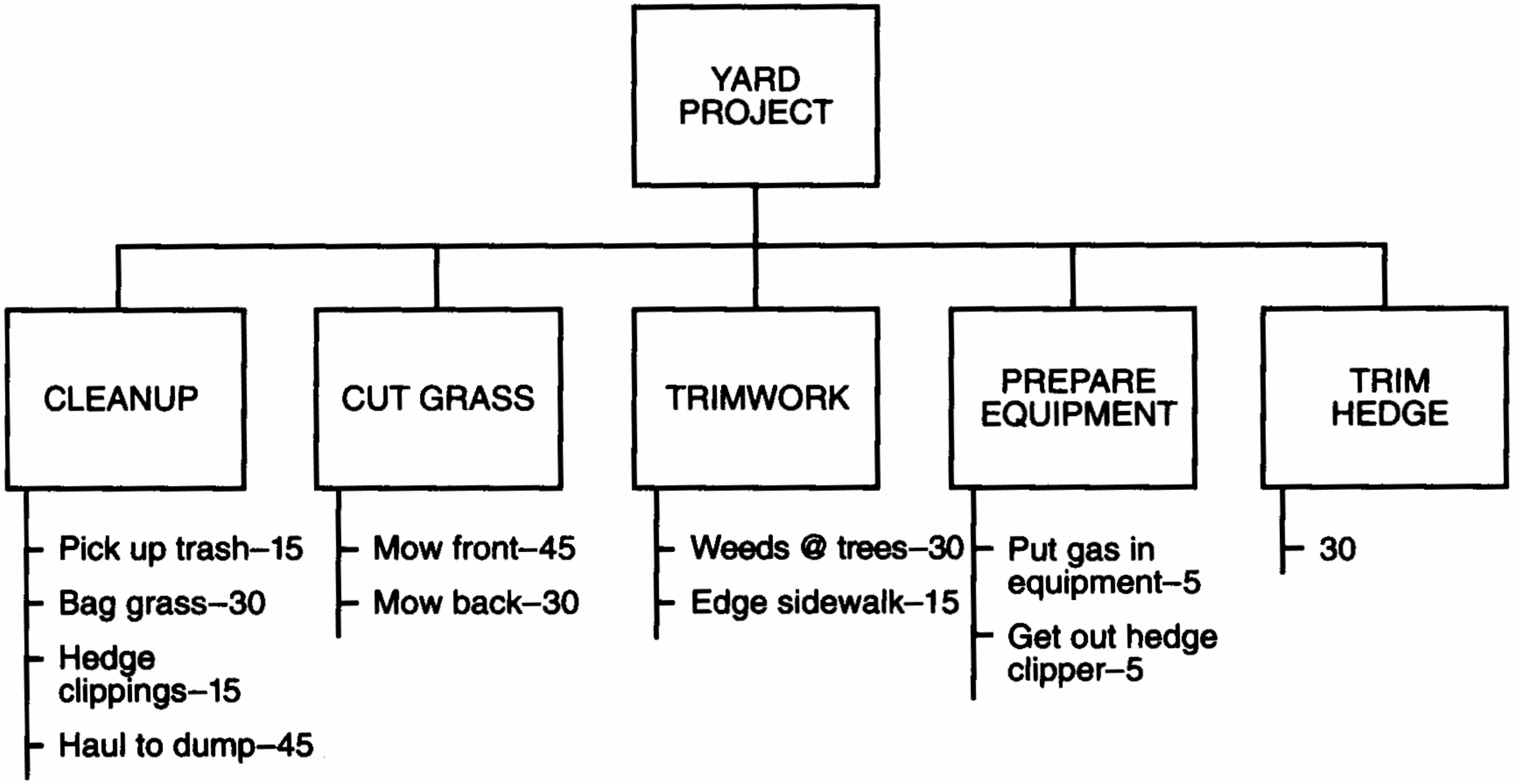
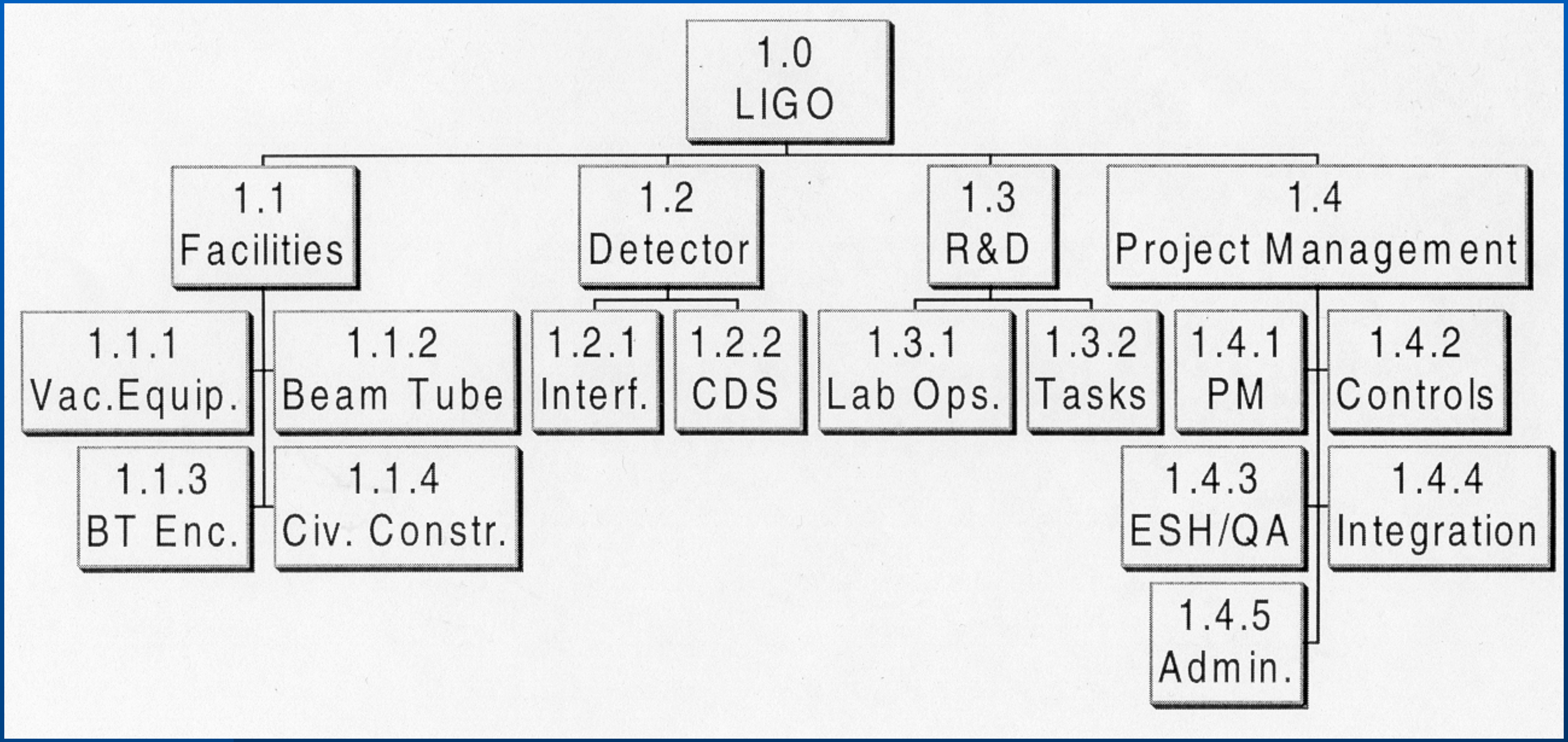
Figure 5-3. Work breakdown structure for yard project.



*** Fundamentals of Project Management** ,
James P. P. Lewis, 2nd ed., 148pp, **ISBN:**
0814471323, AMACOM, February 2002

LIGO Work Breakdown Structure



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522. GEM

- **522.5010 Tracker**
  - 10.01 R & D
  - 10.02 Silicon Tracker
  - 10.03 IPC Tracker
  - 10.04 Reserved
  - 10.05 Reserved
  - 10.06 STS/IPC Assembly
  - 10.07 Installation andFinal Test
  - 10.08 Project Management
  - 10.09 Conceptual/ Preliminary Design
- **522.5020 Calorimeter**
  - 20.01 R & D
  - 20.02 Inner Barrel Calorimetry
  - 20.03 Scintillating Barrel Hadronic Sections
  - 20.04 Endcap Calorimetry
  - 20.05 Forward Hadronic Calorimetry
  - 20.06 Passive Absorber
  - 20.07 Vacuum
  - 20.08 Cryogenics
  - 20.09 Instr., Power & Operational Control
  - 20.10 Final Assembly
  - 20.11 Hall Installation
  - 20.12 Calibration and Test Beam Program
  - 20.13 Subsystem Management
  - 20.14 Conceptual/ Preliminary Design
- **522.5030 Muon**
  - 30.01 R & D
  - 30.02 Barrel Region - CSC
  - 30.03 Endcap Region - CSC
  - 30.04 Installation - CSC
  - 30.05 Project Management - CSC
  - 30.06 Conceptual/ Preliminary Design
- **522.5040 Magnet**
  - 40.01 R & D
  - 40.02 Design Completion
  - 40.03 Fabrication & Assembly
  - 40.04 Installation and System Testing
  - 40.05 Project Management
  - 40.06 Conceptual/ Preliminary Design
- **522.5050 Electronics**
  - 50.01 R & D
  - 50.02 Front End
  - 50.03 Data Acquisition
  - 50.04 Trigger
  - 50.05 Integration
  - 50.06 Project Management
  - 50.07 Conceptual/ Preliminary Design
- **522.5060 Computing**
  - 60.01 R & D
  - 60.02 Global Control System
  - 60.03 On-line Computing
  - 60.04 Network and Communications
- **522.5070 Interface**
  - 70.01 CDS Support
  - 70.02 Beam Pipe
  - 70.03 Detector Access Equipment
  - 70.04 Detector Safety Systems
  - 70.05 Utility Services
  - 70.06 Cranes
  - 70.07 Auxiliary Equipment
  - 70.08 Gas Services
  - 70.09 Survey Systems
  - 70.10 Magnetic Shielding
  - 70.11 Test Beam/Calibration Hall
  - 70.12 Cable & Plumbing Routing
- **522.5090 Project Management**
  - 90.01 Planning & Controls
  - 90.02 Engineering & Integration
  - 90.03 ES&H & QA
  - 90.04 Administration

gem DETECTOR PROJECT

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Advanced LIGO WBS

- 4.0 Advanced LIGO
  - 4.1 Facility Modifications (FAC)
  - 4.2 Seismic Isolation (SEI)
  - 4.3 Suspensions (SUS)
  - 4.4 Prestabilized Laser (PSL)
  - 4.5 Input Optics (IO)
  - 4.6 Core Optics Components (COC)
  - 4.7 Support Optics (SOS)
  - 4.8 Interfer. Sensing & Control (ISC)
  - 4.9 Data Acquisition and Diagnostics (DAQ)
  - 4.10 Support Equipment (SUP)
  - 4.11 Not used
  - 4.12 Computing & Data Analysis (LDAS)
  - 4.13 Installation (INS)
  - 4.14 Project Management (PM)
    - 4.14.1 Project Management
    - 4.14.2 Project Controls
    - 4.14.3 Administration
    - 4.14.4 Document Control
    - 4.14.5 System Engineering
    - 4.14.6 ES&H
    - 4.14.7 Quality

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TMT WBS in graphic form to Level 3

Levels: 1, 2, 3

- TMT
  - TMT.FAC Facilities
    - TMT.FAC.MGT Management
    - TMT.FAC.ENC Enclosure
    - TMT.FAC.INF Infrastructure
  - TMT.TEL Telescope
    - TMT.TEL.MGT Management
    - TMT.TEL.SYS Systems Engineering
    - TMT.TEL.STR Structure
    - TMT.TEL.OPT Optics
    - TMT.TEL.CONT Controls
    - TMT.TEL.INT Integration
  - TMT.INS Instrumentation
    - TMT.INS.MGT Management
    - TMT.INS.AO Adaptive Optics
    - TMT.INS.INST Instruments
  - TMT.DEOPS Operations Design
    - TMT.DEOPS.MGT Management
    - TMT.DEOPS.FAC Facilities Management
    - TMT.DEOPS.CIS Comm. & Info. Services
    - TMT.DEOPS.SCMS Site Conditions Mon. Sys.
    - TMT.DEOPS.FOMS Fac. Operation Man. Sys.
    - TMT.DEOPS.AIV Assembly, Integ., Verif.
    - TMT.DEOPS.OSW Observatory Software
  - TMT.PM Project Management
    - TMT.PM.PMO Project Man. Office
    - TMT.PM.PS Project Scientist
    - TMT.PM.EPO Educ. & Pub. Outreach
    - TMT.PM.ESH Env. Safety & Health
    - TMT.PM.QA Quality Assurance
    - TMT.PM.IT Information Technology
    - TMT.PM.SE System Engineering
    - TMT.PM.BUS Business Operations
    - TMT.PM.OS Observatory Scientist

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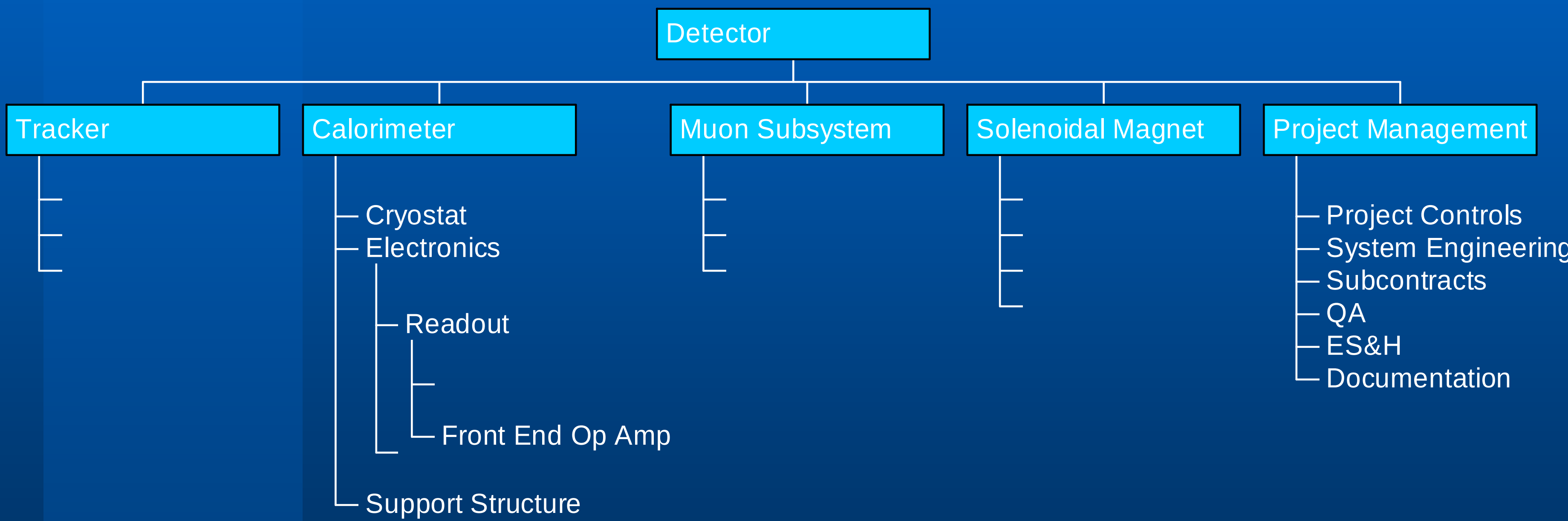
Project Organization

Work Breakdown Structure (WBS)



Previous
Next

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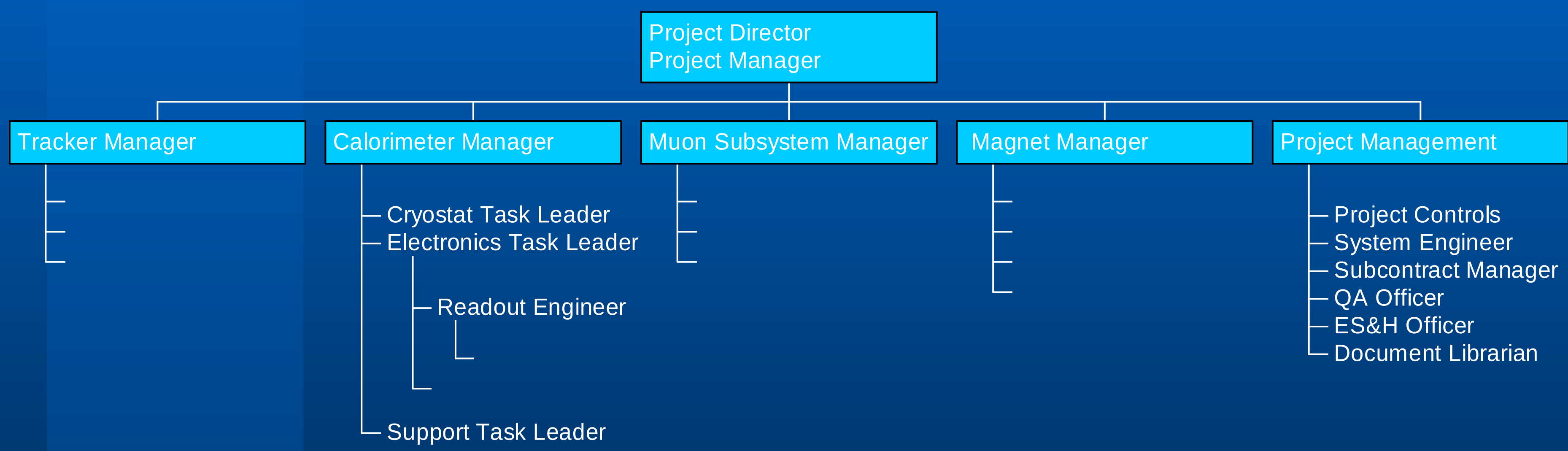
Project Organization



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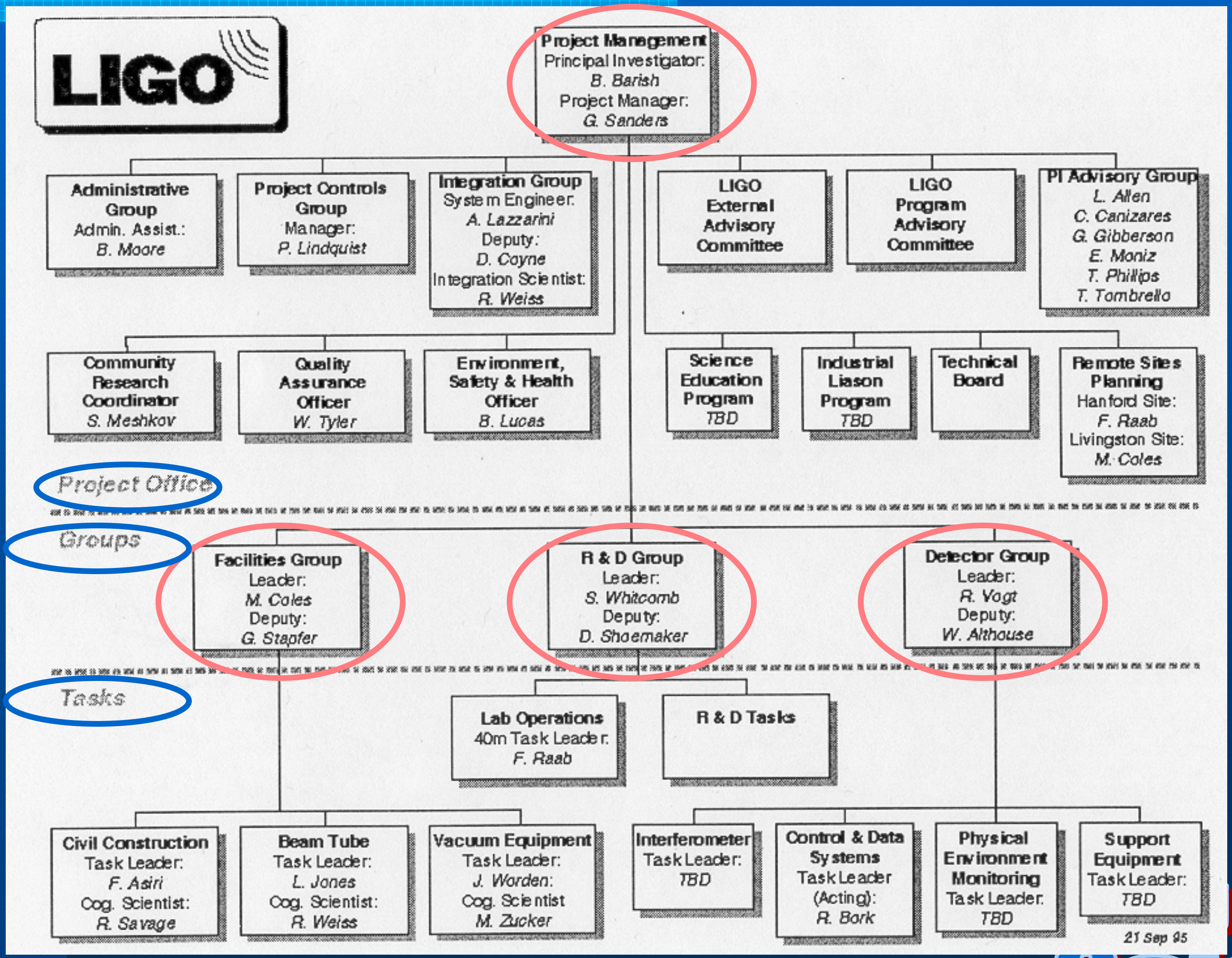
LIGO Organization



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LIGO organization philosophy

- Organization has only three levels
  - Tasks - execute specific tasks
  - Groups - coordinate related work (subsystem)
  - Project Office - integrate and insure progress and control
- "Product Oriented"
  - Middle managers under pressure to deliver a "product"
- Integration
  - Project Management at top level provides integration and system engineering

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Project Management's roles

- **Responsible to deliver the Project**
- **Manage system engineering and Project cost/schedule/technical progress**
- **Assure scientific success**
- **Chair Technical Board/Change Control Board**
- **Chair weekly Project Control Meeting**
- **Chair monthly Performance Meeting**
- **Responsible for interactions with sponsor**
- **PM should have no individual tasks**

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Change Control/Configuration Management

- **Baseline must be documented**
- **Baseline is fixed and respected**
- **Changed only by a disciplined process**
- **Changes proposed formally and reviewed**
- **Adopted changes must be documented and communicated**
- **Change history must be traceable**

Remember Boccacchio...

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Technical/Change Control Board

- Members are leaders of subsystems and PM, subcontracts, project controls, QA
- Review of all requests for:
  - cost changes >$50K
  - major milestone changes > 1 month
  - technical interface or performance changes
- Recommendation to Project Management
- Reviews all major technical choices

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Project Controls Group

- **Responsible to provide detailed visibility of Project performance in cost and schedule**
- **Manage review of technical configuration changes**
- **Manage cost estimating and revisions**
- **Manage schedule development and routine and urgent revisions**
- **Manage performance measurement**
- **Manage formal reporting to sponsor**
- **Manage procurements, industrial contracting and payment actions**
- **Manage all documentation**

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Cost Estimate

Cost Estimate - Basis

- **Establish detailed Work Breakdown Structure**
- **All estimating to be done "bottom up" by the engineers and scientists directly responsible for each item**
  - **scientist + engineer**
- **Establish a written Cost Estimating Plan that defines uniform formats and procedures for all estimators**
- **Each estimated item should have all information supporting the estimate for that item recorded in a standard Basis of Estimate worksheet for that item. The Basis sheet should be signed and dated by the estimator.**

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ALMA Work Element Sheet

ALMA Work Element # ######
ALMA Work Package # TBD

Task Name $0
WBS Number *e.g., 1.1.4.45*
Estimator *Name*
ACDS # (Obsolete) Example
Currency $ *($, Euro, Yen, or PS (Pound Sterling))*
Basis of Estimate *EN-Engineering/ Bottom Up/ Parametric; VQ-Vendor Quote; PO-Place Order; or AC-Actual Cost*

Assigned Risk factors

Technical Risk	8	*(1, 2, 3, 4, 6, 8, 10, or 15; see definition)*
Cost Risk	10	*(1, 2, 3, 4, 6, 8, 10, or 15; see definition)*
Schedule Risk	8	*(2, 4 or 8; see definition)*

Multipliers for Contingency

Technical Multiplier	2	*(2 or 4 are valid)*
Cost Multiplier	1	*(1 or 2 are valid)*
Calc. Contingency:	34%	*(Estimator may override)*

FE Band

Task Description
(Text for the WBS dictionary)

Labor

Name or Position	Grade (1, 2, 3, 4,	Estimated Effort (Actual Staff wks)	(Alternative) Estimate (Level of Effort)	Duration (Months)	Likely External Contract? (y or n)	Travel Requirements % of time	weeks	Chilean Position? SI,SC,OI,OC,n

Labor Total (CY2000 dollars, thousands, including indirect costs):

Labor & Travel Costs **(in $K)**
0
0 (in $K)

Chilean Positions

	Santiago	On-Site
Int'l Staff	SI	OI
Chilean	SC	OC

Labor Grades

- 5 Secretarial, administrative aides support technicians;
- 4 Jr engineer or programmer, mid-level tech, machinist, post-doc fellows, administrators;
- 3 Sr tech or machinist, mid-level engineer or programmer, Sr administrator, staff scientist;
- 2 Sr engineer or programmer, sr scientist
- 1 Top level managers & scientists

Labor Distribution

Grade	FTE's (years)
1	0.00
2	0.00
3	0.00
4	0.00
5	0.00

Employee Count, by Location

	Location	FTE's
Santiago	S	0.0
On-Site	O	0.0
Other	-	0.0

Materials and Contracts

Material Description	Parameterization Formula		Units required	Spares	Total Units	Unit Cost (K)	Subtotal
						200	
						1,500	

Parametric Variables
(for scaling costs)

NAnt	64	# of antennas
NAntACA	0	# of ACA antennas
NSta	250	# of antenna stations
NNut	4	# of Ant with nutators
NTr	3	# of Ant Transporters
NIF	4	# of IF Bands
IFBW	2	IF Bandwidth, GHz
NPol	2	# of Polarization Ch.
NChan	4096	# of Correlator Lags
Dur	9	Phase 2 Duration, yrs
NR	1	Non-recurring cost

Additional Parametric Variables

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4/26/93

GEM COST ESTIMATE SUMMARY

FY93 U.S. Dollars

GEM DETECTOR SYSTEM

WBS Code	Description	WBS Level	Material, k$	ManHours	Labor, k$	M + L, k$	Markup, k$	%	Contingency, k$	%	TOTAL, k$
	-GEM DETECTOR SYSTEM	00	274,531	3,657,544	167,306	441,837	6,029	1%	103,362	23%	551,228
10	-CENTRAL TRACKER	01	12,168	190,275	9,786	21,954	0	0%	5,369	25%	27,324
20	-CALORIMETER	01	68,570	1,012,430	37,976	106,546	0	0%	28,870	27%	135,415
30	-MUON	01	40,631	891,791	36,819	77,449	0	0%	20,897	27%	98,347
40	-MAGNET	01	64,787	348,234	33,232	98,019	6,029	6%	21,277	21%	125,325
50	-ELECTRONICS	01	52,619	465,971	22,552	75,171	0	0%	17,100	23%	92,272
60	-COMPUTER & CONTROLS	01	10,390	168,299	5,478	15,869	0	0%	3,591	23%	19,460
70	-INTERFACE SYSTEMS	01	21,814	122,305	3,567	25,381	0	0%	4,433	18%	29,813
90	-PROJECT MANAGEMENT	01	3,551	458,239	17,897	21,448	0	0%	1,825	9%	23,274

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GEM COST ESTIMATE DETAILS

04/27/1993

40.03.1.2.3 VESSEL SUPPORT STRUCTURES FAB/ASSY

						MATERIAL		LABOR						TOTALS
LINE ITEM	ITEM CODE	ITEM DESCRIPTION	QUANTITY	UNIT MEAS	COST BASIS	UNIT COST	TOTAL MAT'L,$	CRAFT/ TEAM	HOURLY RATE	MH/ UNIT	TOTAL HOURS	UNIT COST	TOTAL LABOR,$	MAT'L+ LABOR,$
1	I&A	Coordinator Suppt During Const	3.00	MM	BU			INSPAD	60	147	441	8,859	26,578	26,578
2	M&S	Weld Inspec Qa Time	0.50	MY	BU	97,610	48,805							48,805
3	P/F	Saddles 304l Ss W/ 8% Waste	262.00	TON	BU	4,154	1,088,243							1,088,243
4	P/F	Support Blocks 304l Ss	80.00	TONS	BU	4,154	332,288							332,288
5	P/F	Transportation	20.00	LOADS	BU	2,596	51,920							51,920
6	P/F	Plate Section Burning	120.00	SECTION	BU	623	74,765							74,765
7	P/F	Web Section Burning	8.00	WLDMNTS	BU	1,817	14,538							14,538
8	P/F	Weld Fixturing & Alignmnet	1.00	LS	BU	41,536	41,536							41,536
9	P/F	Welding	8.00	WLDMNTS	BU	10,384	83,072							83,072
10	P/F	Blasting	16.00	WLDMNTS	BU	2,596	41,536							41,536
11	P/F	Rigging	1.00	LS	BU	103,840	103,840							103,840
12	P/F	Hydraulic Jacking System	1.00	LS	BU	207,680	207,680							207,680
13	P/F	Transporter Grease Pads	24.00	EA	BU	8,650	207,597							207,597
14	I&A	On/off Site Inspections	2.00	MM	BU			INSPAD	60	147	294	8,859	17,719	17,719
SUBTOTAL -	40.03.1.2.3	VESSEL SUPPORT STRUCTURES FAB/ASSY					$2,295,819				735		$44,297	$2,340,117

PRIME CONTRACTOR MARKUP	7.71%	$180,373
		$2,520,490
CONTINGENCY	22.00%	$554,508
COST PLUS CONTINGENCY		$3,074,998

COST MATRIX

	ENG/DES	M&S	INSP/ADM	PROC/FAB	ASSBLY	INSTALL
LABOR	0		44,297		0	0
MATERIAL	0	48,805	0	2,247,015	0	0
TOTAL, $	0	48,805	44,297	2,247,015	0	0
MANHOURS	0		735		0	0

LABOR

TOUCH LABOR =	$0
EDIA LABOR =	$44,297

RISK

Technical Risk	6%
Cost Risk	8%
Schedule Risk	8%

ESTIMATOR: G. DEIS/J. BOWERS
DATE OF ESTIMATE: 06/15/92

Magnet
Basis of Estimate

WBS: 40.03.1.2.3 Item: Vessel Support Structures
Date: 6/15/92 Rev: 0C By: G. Deis/J. Bowers

Element Scope: This element includes all of the hardware required to physically support the coil, vessel, and muon sector assemblies in the underground hall. This will include the saddles to support the outer vessel as well as any jacking hardware provided to align the magnet, to compensate for ground motion, or to move the magnet assemblies. This does not include any concrete structures, such as piers or support beams, which are assumed to be parts of the hall facility.

Technical design description:
The saddle support structures are low carbon steel weldments consisting of large flat plate sections. Four saddle weldments are provided to support each vessel assembly, including the magnet and all internal detectors. Total weight supported by four saddle supports is conservatively 3000 tons.

It is assumed that all four saddles see equal dead loads and horizontal loads.

All saddles can be hydraulically jacked to transport the vessel system and for alignment. The jacking system is part of the transporter, and will be capable of lifting the weight of the vessel system plus the saddles, and have sufficient control to enable pitch, roll and elevation positioning.

Interface to the building foundation is through shim blocks mounted to the floor.

Total weight of four saddle support weldments is 121 tons

Two sets of four are required, one set for each vessel.

Inspection/Admin
Basis:

coordinator support during construction 3 mm
off-site/on-site inspections 2 mm

EDIA/QA Material&Services
Basis: Quality Assurance weld inspection time .5my

Procurement/Fabrication
Basis: each vessel
raw materials
saddles:
121 tons 304L stainless steel in finished structures
add 8% waste giving 131 tons of raw material
mill rate = $2.00/ lb yielding $524K

support blocks:
40 tons 304L stainless steel in finished structures
mill rate = $2.00/ lb yielding $160k

weld material cost is included in welding cost

transportation $2500/load x 10 loads = $25k

plate section burning 0.5 days/ section, $600/ section x 60 sections = $36k

machine base plate 2 days/ weldment x 4 weldments = 8 days = $7k

weld fixturing and alignment $20k

welding $10k per weldment x 4 weldments = $40k

blasting $2.5k per weldment x 8 weldments = $20k

rigging $50k

total cost per vessel= $882k

total cost for two vessels = $1764k

Cost of hydraulic jacking system $200k

Cost of 24 transporter grease pads $200k

Installation/Ass'y
Material ($k): 0
Basis:
This is covered in WBS 40.02.9.2.1, 40.04.1.1 - Magnet Installation

Unit type: ea **Number of units:** 2
Estimate Type: BU

Risk Factors:
Technical: 2 Basis: Fabrication techniques are standard. Simple shapes and interfaces. Loose tolerances. Common materials.
Cost: 4 Basis: Vendor quotes on hydraulics and bottom up construction factors for structural assemblies. Mill costs for steel will vary based on the state of the national economy at the time of construction.
Schedule: 8 Basis: If built in sections off site, will have minimal impact on vessel installation schedule.

Misc Comments:

Current assumptions of floor movement vary up to 15 cm up and down.

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Previous Next

THIRTY METER TELESCOPE

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	8	2%	Fairly straightforward design using common components. Primarily concern is whether components of the quality estimated will provid acceptable performance.
Cost	3	2%	Most components quoted by vendor or catalog priced.
Schedule	8	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	

TMT
THIRTY METER TELESCOPE

TMT.INS.AO.AOS.INT - Adaptive Optics Sequencer Integration and Test

INT - Integration and Test — *Start:* May 2013 — *End:* Jul 2015

Responsible Estimator: Brent Ellerbroek — *Estimate Date:* 8/5/2006

Estimators: Corinne Boyer

WBS/Subphase Dictionary

This includes the acceptance test of the sequencer with simulated AO systems and simulated instruments and the installation and test of the AOS at the observatory with the AO sub-systems and the rest of the observatory systems.

WBS/Subphase Description

The Adaptive Optics Sequencer includes the computer and software necessary to coordinate all of the AO sub-systems and to sequence the AO internal tasks. In particular, the AO Sequencer controls the actions of the Laser Guide Star Facility System (LGSF), AM2, NFIRAOS, Prime Focus Source Simulator (PFSS), GLAO, MIRAO, MOAO and ExAO. The AO Sequencer also controls the wavefront sensors of the NFIRAOS instruments and the wavefront sensing components of the seeing limited instruments. This system does not control the instruments themselves (i.e. IRIS, WFOS, etc).

Labor

Assemble SEQ/RPG/PSFR with CTRL and spare - Sr SW Eng (25 days)

Acceptance testing - Sr SW Eng (25 days), Post Doc (5 days)

Pack CTRL and spare -- Sr SW Eng -- 8 days (2 days per system, 2 systems, 2 destinations per system)

Test with NFIRAOS --- Sr SW Eng --- 60 days (1 day per command)

Test with LGSF --- Sr SW Eng --- 30 days (1 day per command)

Total: 148 days (Sr SW Eng) and 5 days (Post Doc)

Resource	Org	Type	Start Date	End Date	Hours	FTE	$/hr	Labor Cost
Postdoctoral Scholar	General	EE	May 2013	Jul 2015	40	Discrete	$28.89	$1,156
Senior Software Engineer	General	EE	May 2013	Jul 2015	1,184	Discrete	$69.44	$82,217
				Total Hours:	1,224	Direct Labor:		$83,373
						Benefits:		$21,677
						Burdens:		$26,026
						Labor Subtotal:		$131,075

Nonlabor

The AOS and its spare must be shipped to the LGSF and NFIRAOS vendors for integration. Upon completion of this task, the spare will return to the TMT Project Office, and the AOS will be shipped to the site. Estimate for the cost of shipping to the site was provided by Clark Enterline of NOAO. Estimates for the cost of shipping to the LGSF and NFIRAOS Vendors were obtained online via the FedEx website.

Item/Activity	Type	Start Date	End Date	Units	UM	Unit Cost	Nonlabor Cost
Domestic Shipping of the AOS to NFIRAOS Vendor	CP	Dec 2014	Mar 2015	1.0	ea	$200.00	$200
Domestic Shipping of the AOS to the LGSF Vendor	CP	Dec 2014	Mar 2015	2.0	ea	$68.00	$136
Site Shipping of the AOS	VQ	Dec 2014	Mar 2015	1.0	ea	$462.00	$462
						Direct Nonlabor:	$798
						Burdens:	$5
						Nonlabor Subtotal:	$803

Travel

Four extended domestic trips will be required to integrate the AOS with the NFIRAOS and LGSF systems at their respective vendors, 2 trips to each location.

Destination	Duration	Start Date	End Date	# of Trips	$ per Trip	Travel Cost
Continental U.S., Canada, and Mexico.	Extended - (40 days)	Dec 2014	Mar 2015	4	$9,455	$37,820
			Total Trips:	4	Direct Travel:	$37,820
					Burdens:	$236
					Travel Subtotal:	$38,056

Contingency

	Factor	%	Basis of Estimate
Technical	6	2%	Integration of the components does not represent any major difficulty
Cost	6	1%	Testing at the NFIRAOS and LGSF vendor facility will depend on the readiness of NFIRAOS/IRIS and LGSF
Schedule	4	1%	Delay in completion impacts the next phase and at the end could impact the LGSF integration
Override			
TOTAL		22%	

Comments

Scoping Options

WBS/Phase Estimate Summary

Direct Cost: $121,991 + Benefits: $21,677 + Burdens: $26,267 = Budgeted Cost $169,935

Contingency: $37,386 @ 22.0%

TOTAL: $207,320

Cost Estimate - Base currency year

- **All estimates to be performed in the currency for the year in which the estimate is made, as if the work is performed or contract placed in the current year**
- **Define a standard table of currency inflation for all years in which the project is to be executed**
- **Old industrial price quotations should be corrected for inflation up to the current year if a new estimate is not obtained from industry**

OMB Escalators Provided By NSF

ALTERNATIVE PRICE MEASURES

FISCAL YEAR OVER FISCAL YEAR PERCENT CHANGE

Fiscal Year	GDP Price Index (Chain-type Weights) (1)	CPI-W (2)	State and Local Expenditure Index (3)	Federal Non-Defense Non-Pay Expenditure Index (3)	Federal Non-Defense Non-Resid. Structure Construction (4)	Private Construction Non-Resid. Structures (3)
2005	2.8	3.4	4.9	2.8	7.0	**8.2**
2006	3.2	3.7	6.2	2.6	7.3	**13.9**
2007	2.6	2.7	4.1	2.1	4.7	**7.1**
2008	2.3	2.4	3.8	1.8	4.3	**6.4**
2009	2.1	2.4	3.7	1.6	4.2	**6.2**
2010	2.1	2.5	3.7	1.6	4.2	**6.2**
2011	2.1	2.5	3.7	1.7	4.2	**6.3**
2012	2.2	2.5	3.8	1.7	4.3	**6.3**
2013	2.2	2.5	3.8	1.7	4.3	**6.3**
2014	2.2	2.5	3.8	1.7	4.3	**6.3**
2015	2.2	2.5	3.8	1.7	4.3	**6.3**
2016	2.2	2.5	3.8	1.7	4.3	**6.3**

1. The Budget Enforcement Act of 1997 requires the use of the GDP chain-type price index for adjustment of the nonpay portion of discretionary accounts for baseline (current services) estimates. The estimates for this purpose are shown on p. 3 of this package.

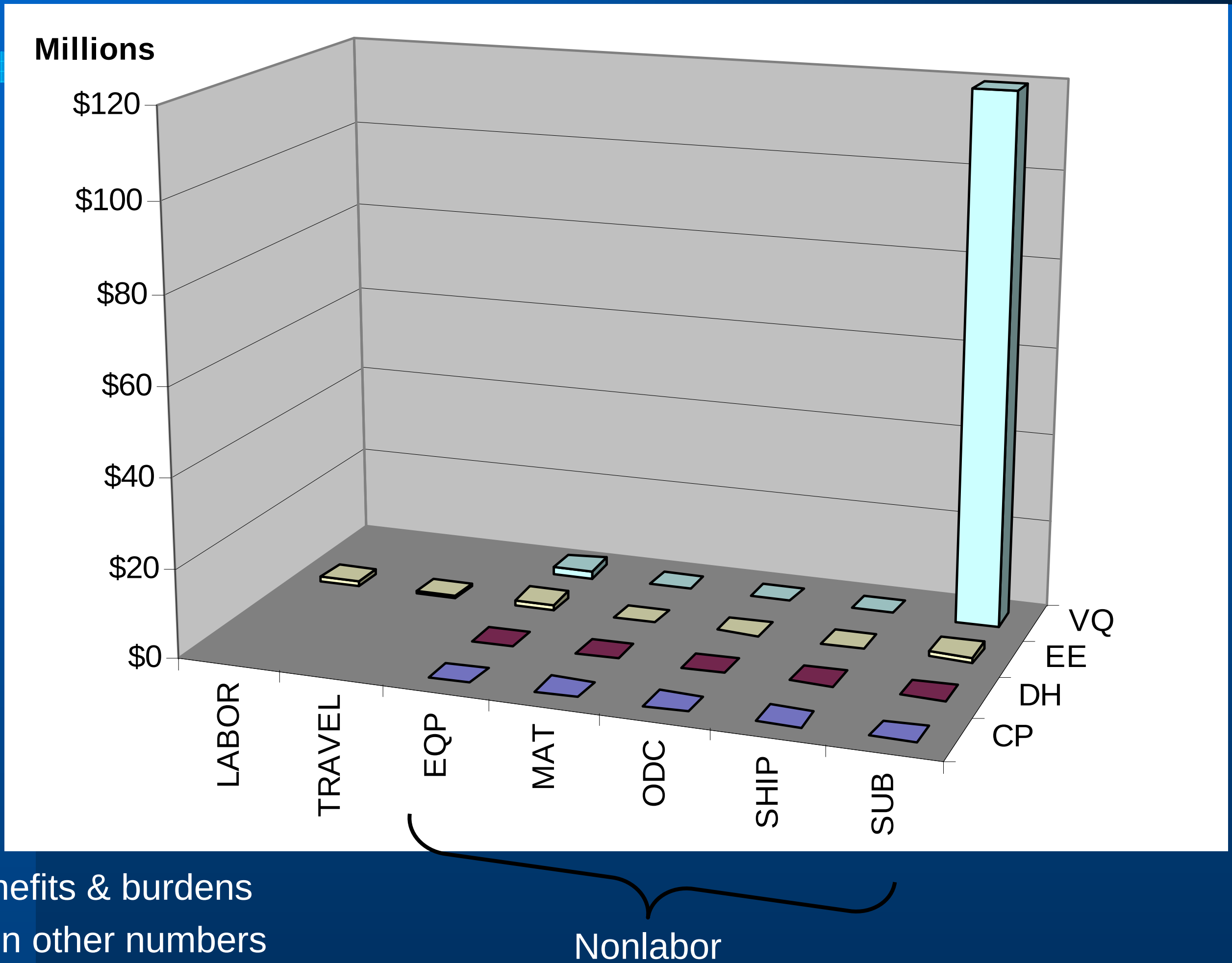
Project Science

Cost Estimate - Source of estimate

- **Clearly identify the type of the source of the estimate**
  - **Engineering Estimate (EE) - least reliable**
  - **Vendor Quotation (VQ) - better, but likely to increase**
  - **Placed Order (PO) - even better**
  - **Actual Costs (AC) - best**
  - **Other methods include Parametric, Trends, Specific Analogy**
- **For every material subsystem, work to increase the fraction of the estimate based upon industrial vendor quotations**

Project Science

Fraction of Estimate in Bases Categories



- Base-year dollars
- Labor includes benefits & burdens
- Burdens included in other numbers
- Contingency not included

Project Science

Cost Estimate - Roll up

- **Structure estimate so that all costs for a component can be "rolled up" and costs for the subsystem including the component can be "rolled up" and costs for the entire system can be...**
  - **This creates a framework for tracking actual costs during the project execution**

Project Science

Cost Estimate - Labor rates

- **Define all generic labor categories for labor charged to the Project (manager, engineer, scientist, technician, secretary, construction worker,...)**
  - **Use appropriate level of detail for maturity of Project**
- **Establish a standard labor rate for each category based upon market survey in base currency year**
- **Use labor "crew" mixes if appropriate for an operation**
- **Replace standardized rates with specific rates only when actual labor source is certain**
- **Consider vacation/sick time factors**

Project Science

TMT THIRTY METER TELESCOPE

Resource	Input Code	Salary Grade
Technical Functions:		
Post Doc	PostDoc	**N/A**
Information Tech. Specialist	IT	**42**
Design Draftsman	DsgnDft	**42**
Technician	Tech	**40**
Scientific Analyst	SciAnlyst	**43**
Assistant Scientist*	AsstSci*	**41**
Associate Scientist	AssoSci	**42**
Senior Scientist	SrSci	**43**
Lead Scientist*	LdSci*	**44**
Assistant Engineer*	AsstEng*	**42**
Associate Engineer	AssoEng	**43**
Senior Engineer	SrEng	**44**
Lead Engineer*	LdEng*	**45**
Associate Software Engineer	AssoSwEng	**43**
Senior Software Engineer	SrSwEng	**44**
Lead Software Engineer*	LdSwEng*	**45**
Business Functions:		
Administrative I	AsstAdmin	**41**
Administrative II	AssoAdmin	**42**
Associate Accountant	AssoAcct	**41**
Senior Accountant	SrAcct	**42**
Lead Accountant	LdAcct	**43**
Associate Financial Analyst	AssoFinAnlyst	**42**
Senior Financial Analyst	SrFinAnlyst	**43**
Lead Financial Analyst	LdFinAnlyst	**44**
Associate Project Controls	AssoPrjCtr	**42**
Senior Project Controls	SrPrjCtr	**43**
Associate Property Specialist	AssoProp	**41**
Senior Contracts Specialist	SrContract	**42**
Lead Contracts Specialist	LdContract	**43**
Human Resources	HR	**43**
Senior Human Resources	SrHR	**44**
Business Manager	BusMgr	**42**
Business Department Head	BusDptHd	**46**
Management Functions:		
Facilities Group Leader	FacGrpLed	**44**
Group Leader	GrpLed	**45**
Facilities Department Head	FacDptHd	**45**
Department Head	DptHead	**45**
Observatory Scientist	ObsSci	**45**
Project Scientist	ProjSci	**47**
Deputy Project Manager	DeputyPM	**46**
Project Manager	ProjMgr	**47**

* - Resources not used in TMT Construction Estimate for September 2006 Cost Review.

Previous Next

Project Science

Cost Estimate - Labor rates

- **Do estimate in man-hours and apply rates later!**
- **In mass production operations, include the "learning curve" factor**
- **In mass production operations, consider "crew" quality and trade off cost for productivity**

Project Science

LIGO II CostBook Activity Sheet Summary for a WBS - Microsoft Internet Explorer

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Address http://admdbsrv.ligo.caltech.edu/costbook/report_wbsSummary.htf?rtype=wbs&callingform=sum&wbs: Go Links

CostBook Activity Sheet Summary

for WBS Number LIGO.4.06.4.1 -- Pathfinder

(Amounts Include Staff Benefits, GRA Benefits, and Indirect Cost)

WBSNo: LIGO.4.06.4.1 - Pathfinder

COF40641A - EST: Pathfinder SPF	$490,276.25
COF40641B - EST: Pathfinder LPF	$833,015.50
	WBS Total: $1,323,291.75

Report Total:	**$1,323,291.75**
Report Contingency at 63.40%:	**$839,007.79**
Total Plus Contingency:	**$2,162,299.54**

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Project Science

LIGO II Costbook Activity Sheet Detail - Microsoft Internet Explorer

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Address http://admdbsrv.ligo.caltech.edu/costbook/report_sheetDetail.htf?sheet=COF40641A&wbsstring=LIGO.4.06.4.1%2APathfinder&rtype=wbs&callingform=sum Go Links

Costbook Activity Sheet Detail

WBSNo:LIGO.4.06.4.1 - Pathfinder
Activity:COF40641A - EST: Pathfinder SPF
Duration:365 days
Estimator:G. Billingsley on 05/02/2001

Item Code	Cost Category	Resource	Description	Comments or Vendor	Cost Basis	Cost Code	Quantity	Unit Cost	Item Amount
B2	Labor	EN	Engineer		EE	12-40641-14 CP	507	$45.00	$22,815.00
B2	Labor	OT	Other		EE	12-40641-14 CP	179	$50.00	$8,950.00
B2	Labor	SC	Scientist		EE	12-40641-14 CP	108	$40.00	$4,320.00
D2	Equip.	D2	Small Pathfinder blank cost - rollup of 6		HD	12-40641-14 CP	1	$43,010.00	$43,010.00
E1	Int Travel	E1	Deliver Mirrors to UWA, review specifications		HD	12-40641-14 CP	1	$2,075.00	$2,075.00
G5	Contract	G5	Coat 5 types of mirrors	? Virgo-Lyon	EE	12-40641-14 CP	1	$200,000.00	$200,000.00
G5	Contract	G5	Polish 3 Mode cleaner mirrors	Wave Precision	VQ	12-40641-14 CP	1	$68,445.00	$68,445.00
G5	Contract	G5	polish 3 optics	CSIRO	VQ	12-40641-14 CP	1	$129,640.00	$129,640.00
G5	Contract	G5	Shipping	Time Trax	HD	12-40641-14 CP	1	$2,000.00	$2,000.00

Subtotal:	**$481,255.00**
Staff Benefits:	**$9,021.25**
GRA Benefits:	**$0.00**
Indirect Cost:	**$0.00**
Total Cost:	**$490,276.25**
(Cost: 6x1.00% + Sched: 4x1.00% + Tech: 8x4.00%) Contingency @ 42.00%:	**$205,916.02**
Cost Plus Contingency:	**$696,192.27**

Return to WBS Summary page

Done Internet

Project Science

Cost Estimate - Audit

- Audit all detailed estimates for uniform application of Cost Estimating Plan
- Compare labor estimates for comparable operations
- Compare material costs
- Compare fraction of estimate based upon vendor quotes
- Compare risk analysis
- Use an outside and disinterested firm to independently develop or audit estimate

Project Science

Project Science

Cost Estimate - Risk Analysis

Cost Estimate - Risk analysis

- "Contingency"
  - The most misunderstood word in Washington DC re scientific projects
  - Alien concept outside the USA in funding agencies
  - "Is it a slush fund for the PM?"
- It is not possible to complete a project on plan without appropriate contingency resources

Project Science

Cost Estimate - Risk analysis

- Estimate for each item should be the expected cost of the item excluding unusual or adverse risks
- For each item, separately estimate the technical, cost and schedule risks for that item
- Use a standardized and disciplined method for all items and all estimators
- Develop an estimate of an amount of money to be held in reserve to deal with the average of all risks
- Not all risks will actually take place during the Project. This amount of money is "contingency".

Project Science

Cost Estimate - Risk analysis

- Primitive method - bulk percentage rule of thumb
  - "15% for civil works, 10% at contract signing"
  - "30% for technical systems"…
  - Rates pronounced by grizzled veterans
- Better method - Standard Risk Factor/Percentage
  - One method of this type described here
- Best method – cost of point design response to each risk estimated one by one
  - not usually practical

Project Science

Cost Estimate - Risk factors

Risk factor	Technical	Cost	Schedule
1	Existing design and off-the-shelf hardware	Off the shelf or catalog item	not used
2	Minor modifications to an existing design	Vendor quote from established drawings	No schedule impact on any other item
3	Extensive modifications to an existing design	Vendor quote with some design sketches	not used
4	New design within established product line	In-house estimate for item within current product line	Delays completion of non-critical path subsystem item
6	New design different from established product line. Existing technology	In-house estimate for item with minimal company experience but related to existing capabilities	not used
8	New design. Requires some R&D development but does not advance the state-of-the-art	In-house estimate for item with minimal company experience and minimal in-house capability	Delays completion of critical path subsystem item
10	New design. Development of new technology which advances the state-of-the-art	Top down estimate from analogous programs	not used
15	New design way beyond the current state-of-the-art	Engineering judgment	not used

Project Science

Cost Estimate - Risk percentages

	CONDITION	RISK PERCENTAGE
TECHNICAL	Design or mfg concerns only	2%
	Design and mfg concerns	4%
COST	Material cost or labor rate concern	1%
	Material and labor rate concern	2%
SCHEDULE		1%

Cost Estimate - Contingency %

**Contingency (%) = Technical risk factor x Technical risk % +
Cost risk factor x Cost risk % +
Schedule risk factor x Schedule risk %**

- **Risk Factors - from 1 to 15**
- **Risk Percentages - 1% to 4%**
- **Range of contingency generated falls between 5% and 98%**
- **Best technical judgment used to override this specific graded approach to risk analysis**

Project Science

Cost Estimate - Contingency

- This formulaic approach may seem mindless
- It makes your estimators look carefully at each and every item at the lowest level
  - Very valuable
- It provides a common point of departure for every estimator
- It helps in auditing each estimator and comparing with the practices of other estimators
- It has been applied successfully, and extended, by numerous projects

Project Science

Cost Estimate - Contingency

- Estimate of contingency made for each item at lowest practical level
- Percentage is converted to currency
- Contingency funds are held by the Project Manager and they lose their identification with each item!
- Each Task Leader controls the budget for a subsystem without the contingency funds
- Remember that the contingency pool is not designed to cover every possible risk all occurring during the Project

Project Science

Cost Estimate - Request for contingency funds

- **As the Project progresses, contingency funds can be requested by written application to the Project Manager**
- **Requests are reviewed by Technical Board/Change Control Board consisting of all other system leaders**
- **Project Manager grants requested funds, or rejects request, or requests change in schedule, technical scope or requests other corrective action**
  - **Scope contingency - require subsystem leaders to identify 10% reductions in subsystem scope**
- **Funds can be returned to contingency**

Project Science

LIGO CHANGE REQUEST

Change Request No: CR-020016 **Date:** October 1, 2002

WBS Element and Title: WBS 1.1.4 Facilities (Hanford Irrigation, Landscaping, Erosion Control)

Originator: O. Matherny **Telephone:** 509-372-8118 **CCB Sponsor:**

Technical Change Description: Hanford Laboratory Building Irrigation, Erosion Control, Landscaping

Install irrigation, erosion protection and landscaping around the new laboratory building. Approximately three acres of ground will be covered by drain rock and there will be over 400 plants to be planted.

Budget Impact: $60,000

Cost estimate based on subcontractor quote. $100,000 has been held as a Construction Planning Package for this task.

Schedule Impact:

For best results, we need to accomplish the work before spring of 2003.

Concurrence Signatures:

Technical and Engineering Support:	Date:
Detector Support:	Date:
Data and General Computing:	Date:
Hanford Observatory:	Date:
Livingston Observatory:	Date:
Project Controls Manager:	Date:

CCB Approval/Disposition:

CCB Chairman:	Date:

CIT/MIT LIGO Laboratory Form CR-01 (11/01)

- Identify WBS
- State request
- Document technical, cost, schedule impacts
- Support documenting the approval and rationale
- Attach additional material for complete package
- Traceable

Project Science

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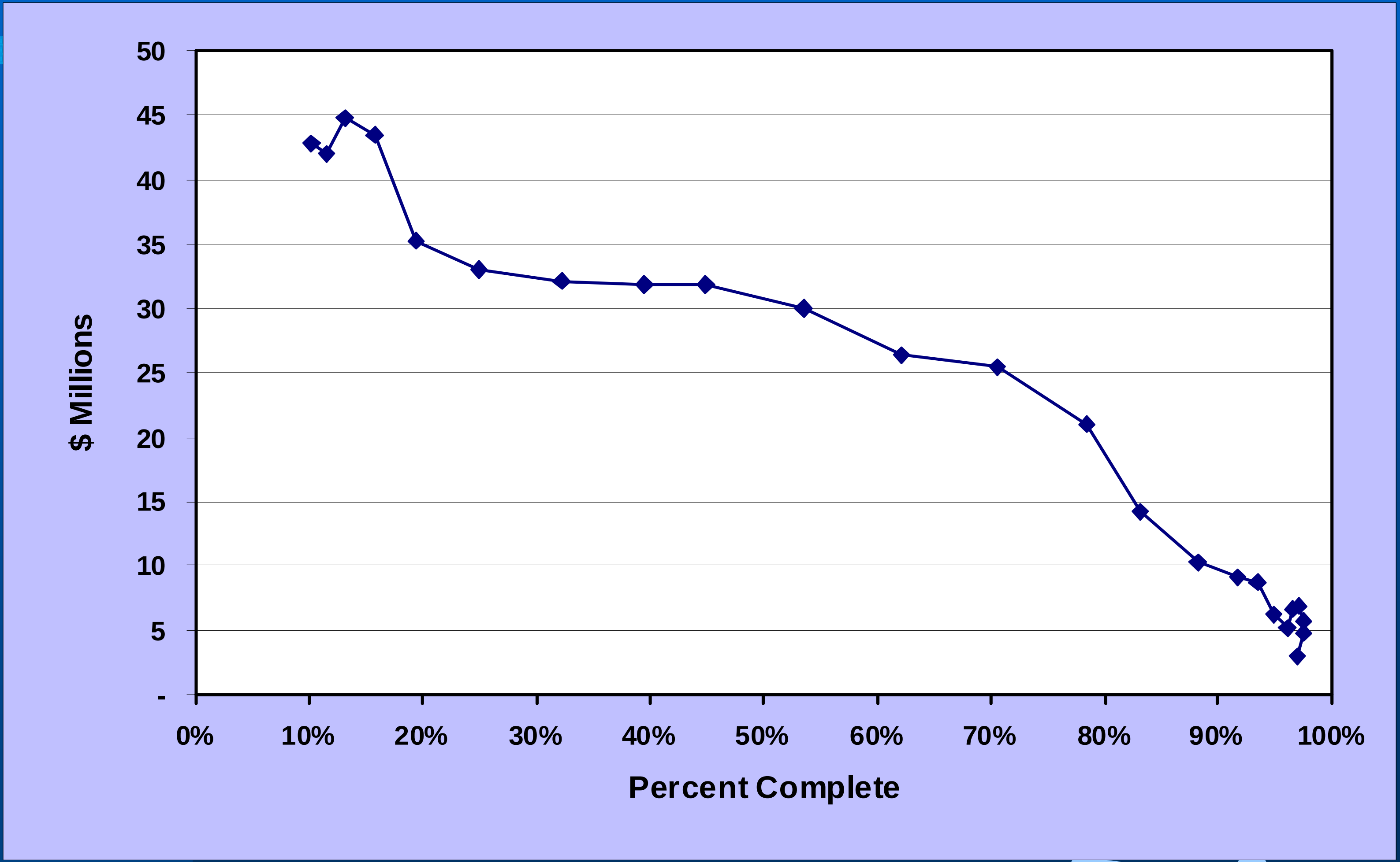
Cost Estimate - Actual Costs and Estimate to Complete

- If Project is estimated properly, 100% completion of Project will use 100% of direct estimate + 100% of contingency
  - Contingency is not to be hoarded till after project completion
- As Project progresses, direct cost estimate is exceeded and contingency funds are used
- Periodically (annually?) cost estimate is revised to reflect all new information including actual costs and use of contingency funds. New estimate is called Estimate To Complete
- Track (%contingency used)/(% Project complete)

Project Science

(%Contingency used)/(% Project complete)



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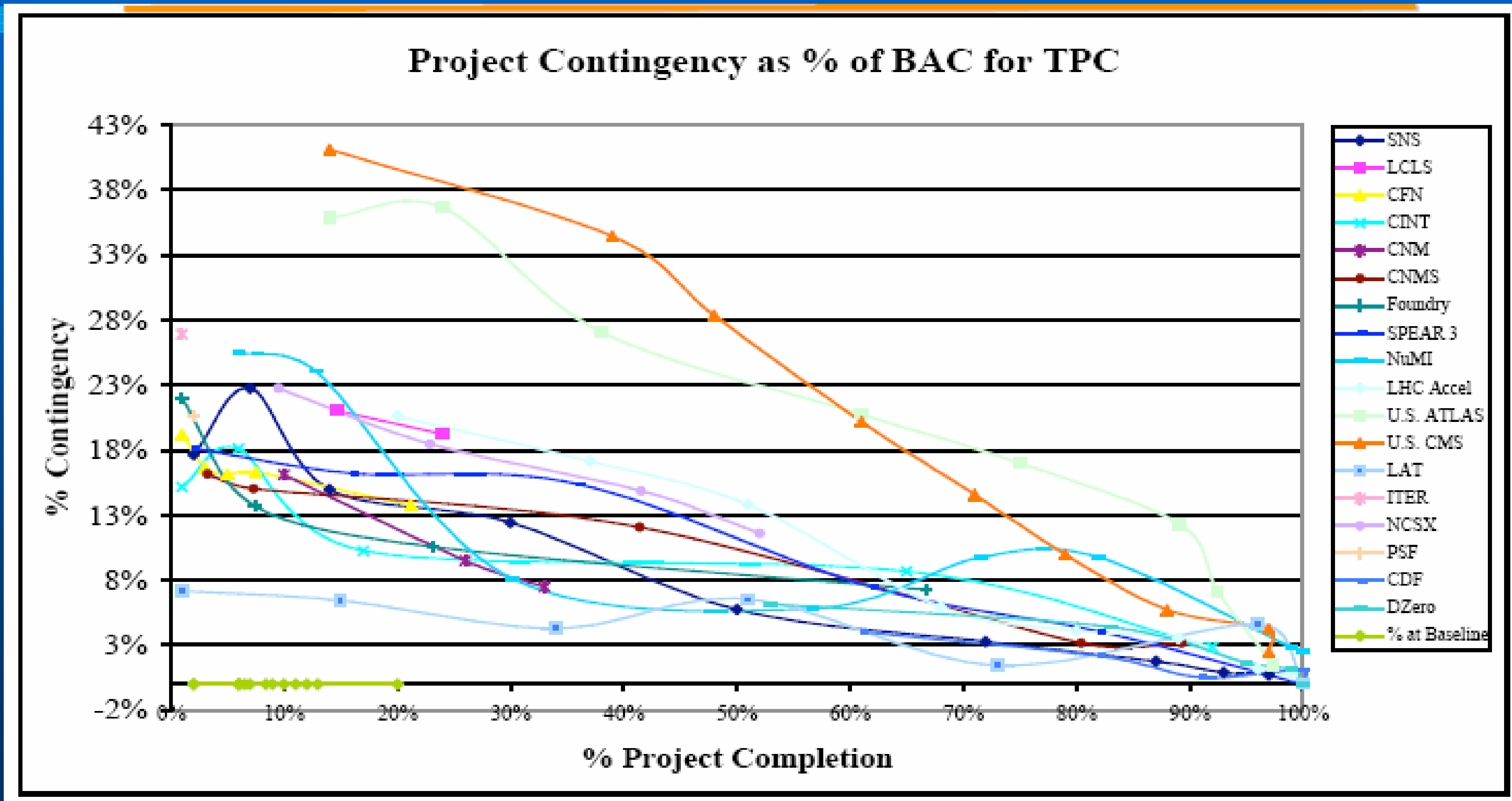
Contingency Experience of Recent DOE Office of Science Projects



Project
Science

Cost Baseline

- **Original full cost estimate (in base year $) including the separate pool of contingency funds is entered into a database and maintained throughout the life of the Project as the Cost Baseline**
- **All Project cost performance is measured monthly against the Cost Baseline in order to detect cost deviations as early as possible**
- **New Estimate to Complete is used after reestimate but original Cost Baseline is preserved in database**
- **Define time spread of costs using inflation factors in Cost Baseline for later use with schedule**

Project Science

Schedule

Schedule - Basic

- **Project Management defines a set of useful major project milestones and requests development of lower level detailed schedules to conform to top level milestones. These top level milestones define the overall project strategy and priorities and the attention of project staff.**
- **Subproject structure organized to agree with Work Breakdown Structure and integrated together following WBS**
- **Prepare Integrated Project Schedule consisting of all linked schedules for each subproject in total Project**

LIGO Facility Milestones

MILESTONE NAME	WASHINGTON LATE DATE	LOUISIANA LATE DATE
Initiate Site Development	03/14/94	08/07/95
Beam Tube Final Design Review	04/21/94	common
Select A/E Contractor	11/15/94	common
Complete Beam Tube Qualification Test	01/16/95	common
Select Vacuum Equipment Contractor	03/28/95	common
Complete Performance Measurement Baseline	04/28/95	common
Initiate Beam Tube Fabrication	01/22/96	common
Initiate Slab Construction	02/05/96	01/06/97
Initiate Building Construction	06/11/96	01/06/97
Joint Occupancy	09/02/97	03/30/98
Accept Tube and Cover	03/16/98	09/28/98
Beneficial Occupancy (Accept Buildings)	03/16/98	09/28/98
Accept Vacuum Equipment	03/16/98	09/28/98
Initiate Facility Shakedown	03/16/98	09/28/98

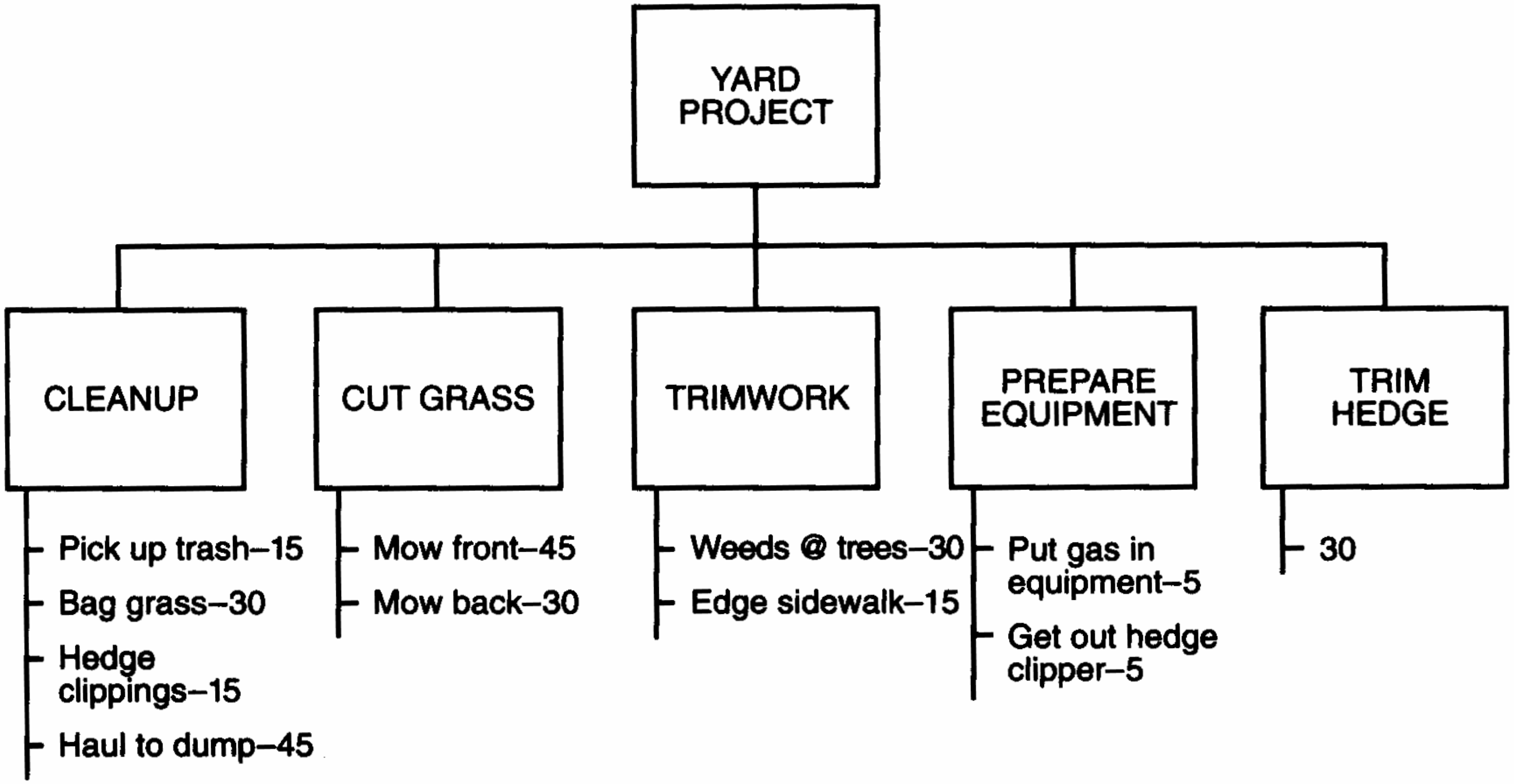
Project Science

Schedule - Bottom up

- Detailed schedules developed in same manner as cost estimate
  - follow WBS
  - developed by responsible task leaders
  - basis recorded in standardized manner
  - schedule risks considered in developing details
  - technical estimate made of each task duration and dependence on other tasks
- Detailed schedule development is closely related to development of cost estimate detail

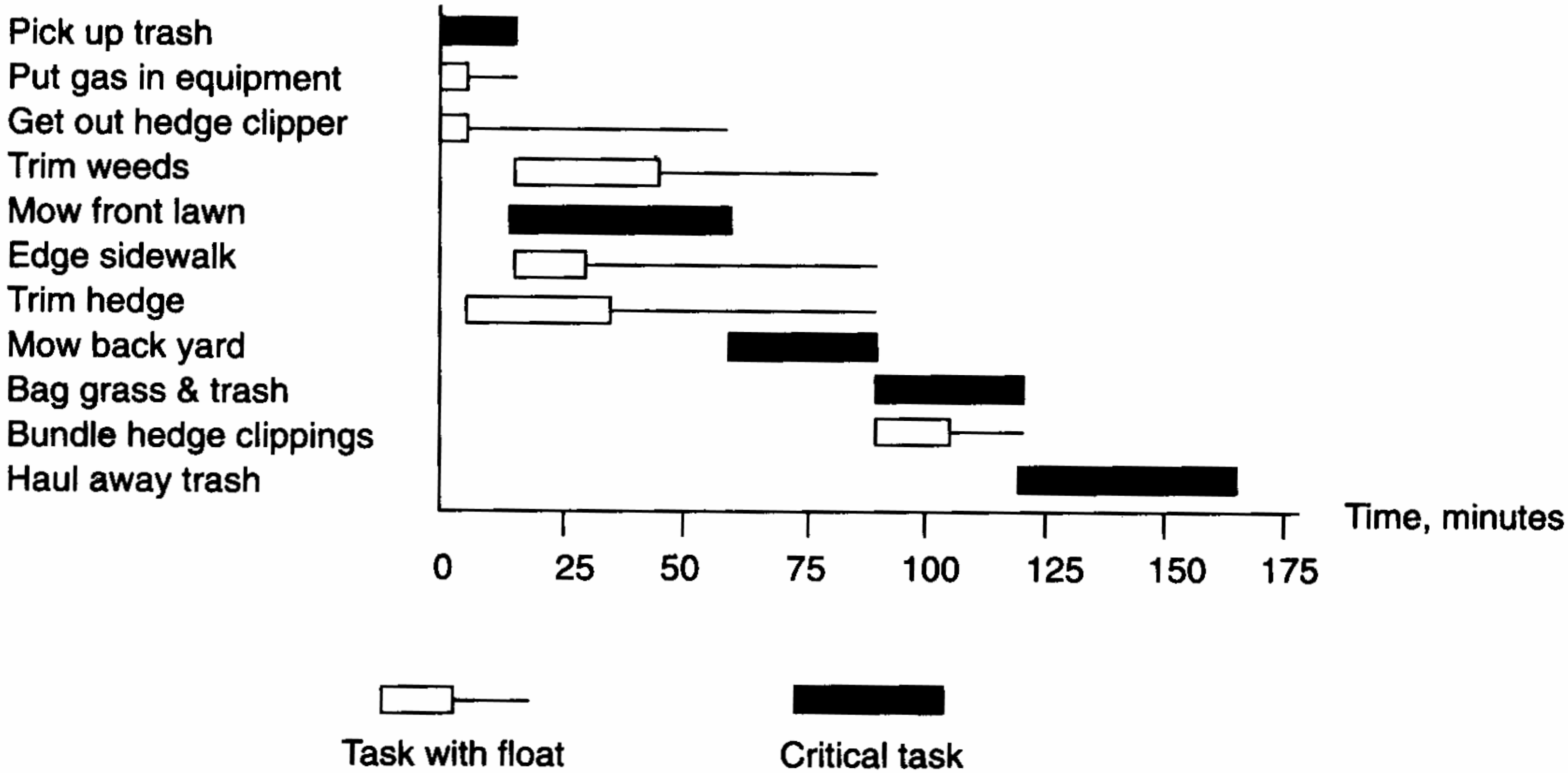
Project Science

Figure 5-3. Work breakdown structure for yard project.



* **Fundamentals of Project Management** ,
James P. P. Lewis, 2nd ed., 148pp, **ISBN:**
0814471323, AMACOM, February 2002

Figure 6-4. Bar chart schedule for yard project.



* **Fundamentals of Project Management** ,
James P. P. Lewis, 2nd ed., 148pp, **ISBN:**
0814471323, AMACOM, February 2002

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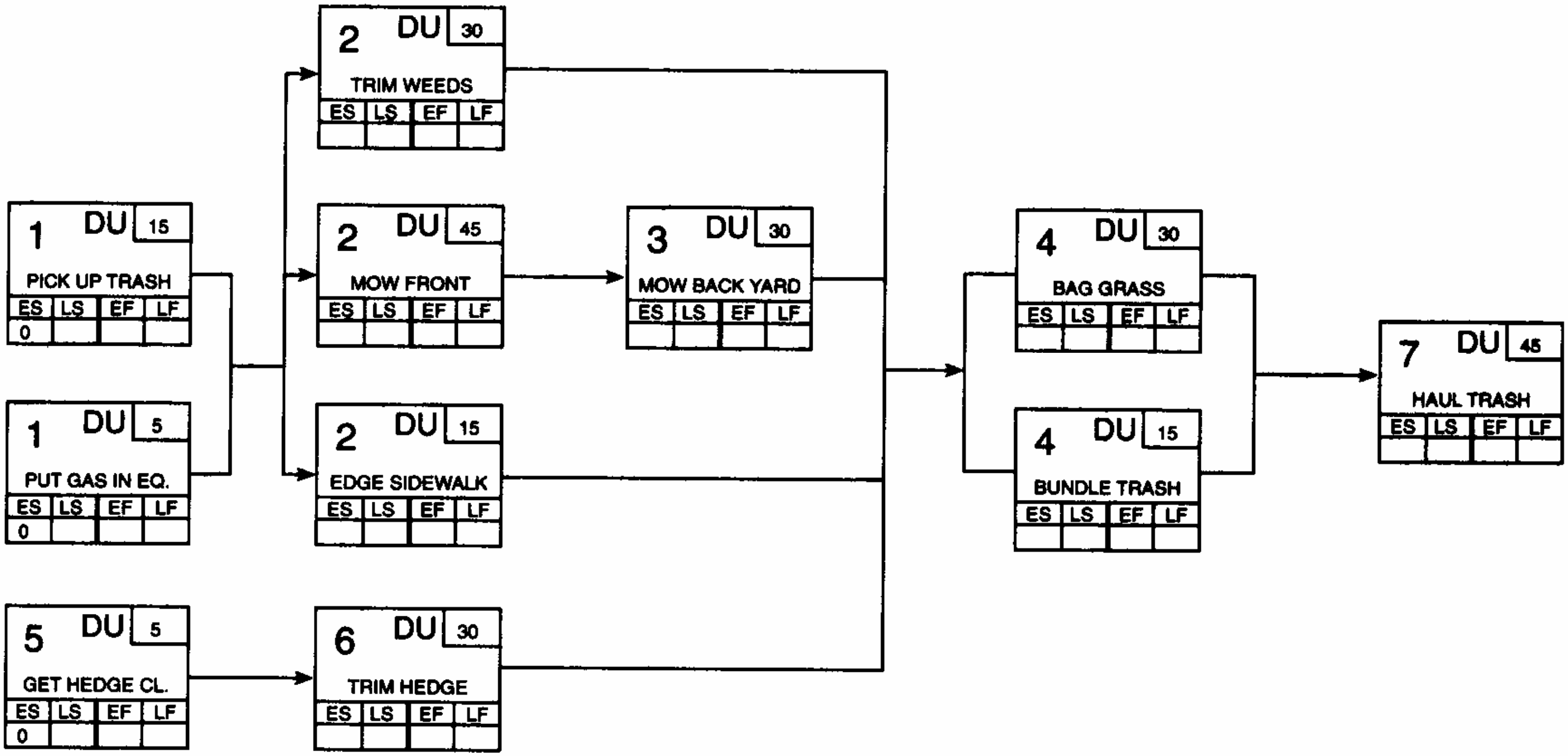
Figure 5-4. CPM diagram for yard project.



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Cost Book Summary COC Pathfinder

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CostBook Activity Sheet Summary

for WBS Number LIGO.4.06.4.1 -- Pathfinder
(Amounts Include Staff Benefits, GRA Benefits, and Indirect Cost)

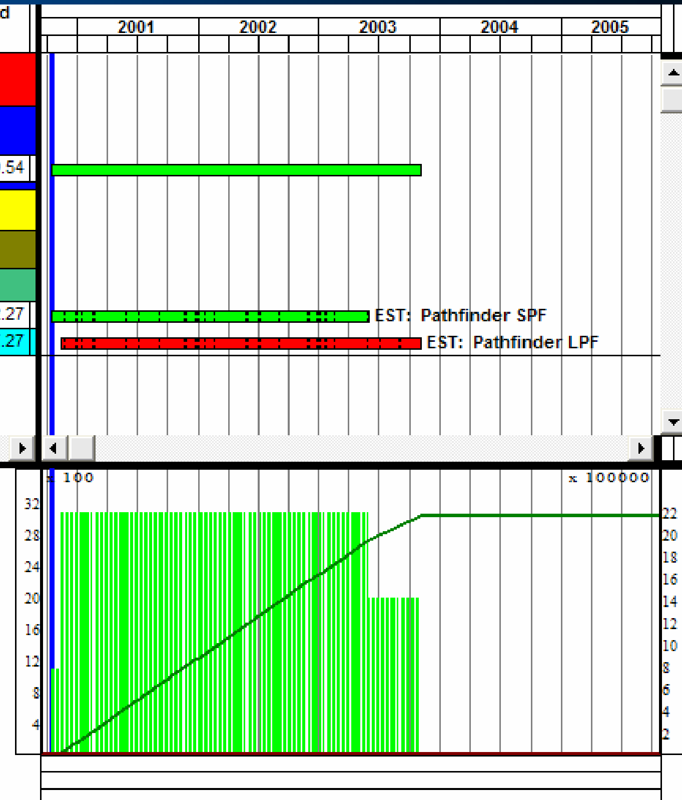
WBSNo: LIGO.4.06.4.1 - Pathfinder

COF40641A - EST: Pathfinder SPF	$490,276.25
COF40641B - EST: Pathfinder LPF	$833,015.50
WBS Total:	**$1,323,291.75**
Report Total:	**$1,323,291.75**
Report Contingency at 63.40%:	**$839,007.79**
Total Plus Contingency:	**$2,162,299.54**

Done Internet

Schedule Summary COC Pathfinder

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish		Late Start	Late Finish	Total Float	Budgeted Cost
LIGO									
LIGO.4 Advanced LIGO Construction									
Subtotal		762*	18OCT00	03NOV03		12OCT01	20MAR07	841	2,162,299.54
LIGO.4.06 Core Optics Components (COC)									
LIGO.4.06.4 COC Fabrication									
LIGO.4.06.4.1 Pathfinder									
CO-F40641A	EST: Pathfinder SPF	654*	18OCT00	02JUN03		29SEP05	20MAR07	949	696,192.27
CO-F40641B	EST: Pathfinder LPF	742*	15NOV00	03NOV03		12OCT01	03NOV03	0	1,466,107.27



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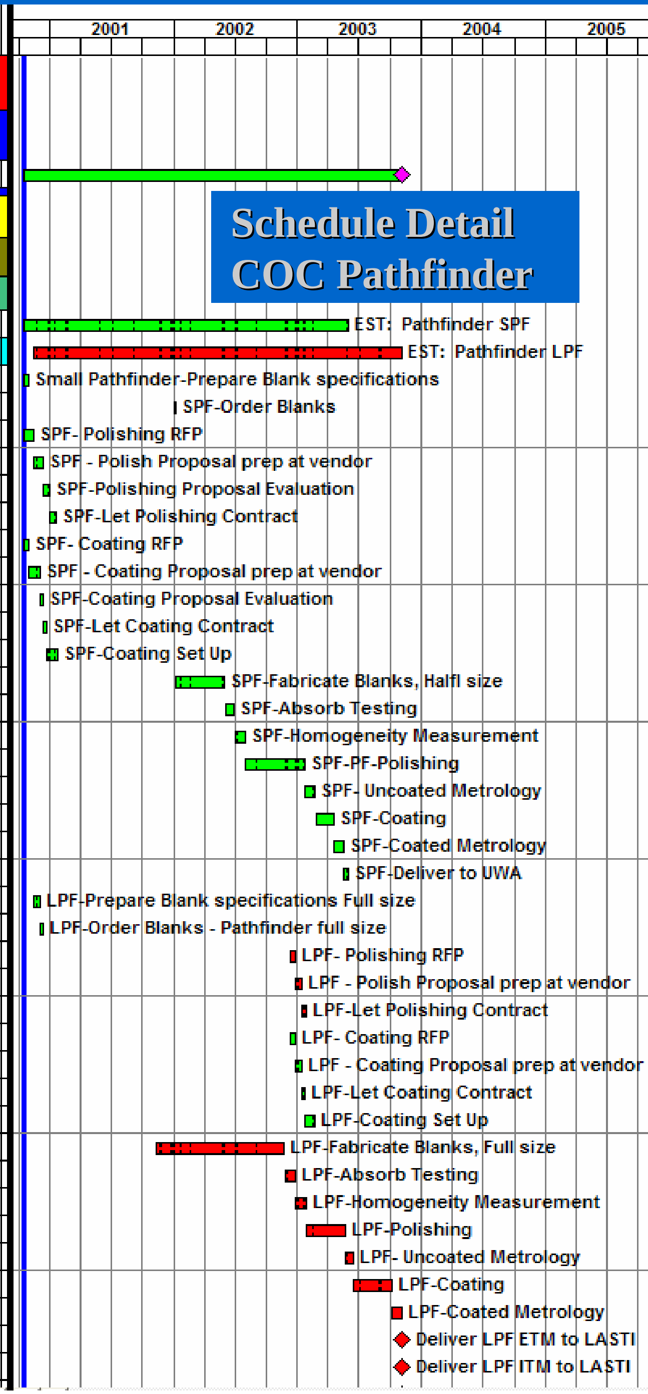
Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Late Start	Late Finish	Total Float	Budgeted Cost
LIGO								
LIGO.4 Advanced LIGO Construction								
Subtotal		762	18OCT00	03NOV03	12OCT01	20MAR07	841	2,162,299.54
LIGO.4.06 Core Optics Components (COC)								
LIGO.4.06.4 COC Fabrication								
LIGO.4.06.4.1 Pathfinder								
CO-F40641A	EST: Pathfinder SPF	654*	18OCT00	02JUN03	29SEP05	20MAR07	949	696,192.27
CO-F40641B	EST: Pathfinder LPF	742*	15NOV00	03NOV03	12OCT01	03NOV03	0	1,466,107.27
CO-D50540	Small Pathfinder-Prepare Blank specifications	10	18OCT00	31OCT00	29SEP05	12OCT05	1,238	0.00
CO-P50550	SPF-Order Blanks	5	02JAN02*	08JAN02	13OCT05	19OCT05	949	0.00
CO-P50560	SPF- Polishing RFP	20	18OCT00	14NOV00	21FEB06	20MAR06	1,333	0.00
CO-P50570	SPF - Polish Proposal prep at vendor	20	15NOV00	14DEC00	21MAR06	17APR06	1,333	0.00
CO-P50580	SPF-Polishing Proposal Evaluation	10	15DEC00	02JAN01	18APR06	01MAY06	1,333	0.00
CO-P50590	SPF-Let Polishing Contract	10	03JAN01	17JAN01	02MAY06	15MAY06	1,333	0.00
CO-P50600	SPF- Coating RFP	10	18OCT00	31OCT00	31AUG06	14SEP06	1,468	0.00
CO-P50610	SPF - Coating Proposal prep at vendor	20	01NOV00	30NOV00	15SEP06	12OCT06	1,468	0.00
CO-P50620	SPF-Coating Proposal Evaluation	10	01DEC00	14DEC00	13OCT06	26OCT06	1,468	0.00
CO-P50630	SPF-Let Coating Contract	5	15DEC00	21DEC00	27OCT06	02NOV06	1,468	0.00
CO-T50640	SPF-Coating Set Up	20	22DEC00	24JAN01	03NOV06	04DEC06	1,468	0.00
CO-F50650	SPF-Fabricate Blanks, Halfl size	100	09JAN02	31MAY02	20OCT05	20MAR06	949	0.00
CO-Q50660	SPF-Absorb Testing	20	03JUN02	28JUN02	21MAR06	17APR06	949	0.00
CO-Q50670	SPF-Homogeneity Measurement	20	01JUL02	29JUL02	18APR06	15MAY06	949	0.00
CO-F50680	SPF-PF-Polishing	120	30JUL02	23JAN03	16MAY06	02NOV06	949	0.00
CO-Q50690	SPF- Uncoated Metrology	20	24JAN03	21FEB03	03NOV06	04DEC06	949	0.00
CO-T50700	SPF-Coating	40	24FEB03	18APR03	05DEC06	05FEB07	949	0.00
CO-Q50710	SPF-Coated Metrology	20	21APR03	16MAY03	06FEB07	06MAR07	949	0.00
CO-H50720	SPF-Deliver to UWA	10	19MAY03	02JUN03	07MAR07	20MAR07	949	0.00
CO-D50740	LPF-Prepare Blank specifications Full size	10	15NOV00	30NOV00	12OCT01	25OCT01	227	0.00
CO-P50750	LPF-Order Blanks - Pathfinder full size	10	01DEC00	14DEC00	26OCT01	08NOV01	227	0.00
CO-P50760	LPF- Polishing RFP	10	11DEC02	26DEC02	11DEC02	26DEC02	0	0.00
CO-P50770	LPF - Polish Proposal prep at vendor	10	27DEC02	13JAN03	27DEC02	13JAN03	0	0.00
CO-P50780	LPF-Let Polishing Contract	10	14JAN03	28JAN03	14JAN03	28JAN03	0	0.00
CO-P50790	LPF- Coating RFP	10	11DEC02	26DEC02	10APR03	23APR03	80	0.00
CO-P50800	LPF - Coating Proposal prep at vendor	10	27DEC02	13JAN03	24APR03	07MAY03	80	0.00
CO-P50810	LPF-Let Coating Contract	5	14JAN03	21JAN03	08MAY03	14MAY03	80	0.00
CO-T50820	LPF-Coating Set Up	20	22JAN03	19FEB03	15MAY03	12JUN03	80	0.00
CO-F50830	LPF-Fabricate Blanks, Full size	260	09NOV01*	22NOV02	09NOV01	22NOV02	0	0.00
CO-Q50840	LPF-Absorb Testing	20	25NOV02	26DEC02	25NOV02	26DEC02	0	0.00
CO-Q50850	LPF-Homogeneity Measurement	20	27DEC02	28JAN03	27DEC02	28JAN03	0	0.00
CO-F50860	LPF-Polishing	80	29JAN03	21MAY03	29JAN03	21MAY03	0	0.00
CO-Q50870	LPF- Uncoated Metrology	15	22MAY03	12JUN03	22MAY03	12JUN03	0	0.00
CO-F50880	LPF-Coating	80	13JUN03	06OCT03	13JUN03	06OCT03	0	0.00
CO-Q50890	LPF-Coated Metrology	20	07OCT03	03NOV03	07OCT03	03NOV03	0	0.00
CO-H50900	Deliver LPF ETM to LASTI	0		03NOV03		03NOV03	0	0.00
CO-H50930	Deliver LPF ITM to LASTI	0		03NOV03		03NOV03	0	0.00



Schedule - Integration

- **Project Management integrates detailed schedules and reviews all schedule ties between subprojects with those developing detailed schedules**
- **Identify all Critical Paths (paths through schedule with no extra time (slack))**
- **Test alternate approaches to Critical Path**
- **Test alternate project strategies**
- **Attempt to build schedule slack in critical operations**
- **Develop menu of “work arounds” for anticipated schedule risks**

Project Science

Project Science

Performance Measurement Baseline

Performance Measurement Baseline

- **Cost Baseline and Integrated Project Schedule are held by Project Management**
- **Create PMB by loading costs for each task into schedule task**
  - **select flat, growing, falling, bell curve, or progress payment cost profile for each task**
  - **select an appropriate level in WBS for combining costs and schedule tasks. Goal is performance measurement by Project Manager, with lower level flexibility left to task leaders**
  - **match to likely funding profile from funding source**
    - **"Technically paced" or "funding paced"**
- **Load into database as Budgeted Cost of Work Scheduled**

Project Science

Schedule Cost Sheet Detail COC Pathfinder

Cost

D2*

Resource	D2*	E1*	EN*	G5*	OT*	SC*	Z-RISK	Z-RISK	Z-RISK	Z-RISK
Cost Acct/Category	12-40641-14E	12-40641-14I	12-40641-14L	12-40641-14C	12-40641-14L	12-40641-14L	12-40641-14C	12-40641-14E	12-40641-14I	12-40641-14L
Driving	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Curve										
Budgeted cost	43010.00	2075.00	28518.75	400085.00	11187.50	5400.00	168035.70	18064.20	871.50	18944.62
Actual this period	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Actual to date	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percent expended	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent complete										
Earned value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cost to complete	43010.00	2075.00	28518.75	400085.00	11187.50	5400.00	168035.70	18064.20	871.50	18944.62
At completion	43010.00	2075.00	28518.75	400085.00	11187.50	5400.00	168035.70	18064.20	871.50	18944.62
Variance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Budget Summary

D2*

Resource	Cost Acct/Category	Driving	Curve
D2*	12-40641-14E	☐	
E1*	12-40641-14I	☐	
EN*	12-40641-14L	☐	
G5*	12-40641-14C	☐	

	Units	Cost	Total Units	Total Cost
Units per day	0.00			
Res Lag/Duration	0			
% Complete/Expended		0.0	0.0	0.0
Budgeted amount	1.00	43010.00	800.00	696192.27
Planned value	0.00	0.00	0.00	0.00
Earned value	0.00	0.00	0.00	0.00
Actual to date	0.00	0.00	0.00	0.00
To complete	1.00	43010.00	800.00	696192.27
At completion	1.00	43010.00	800.00	696192.27
Variance	0.00	0.00	0.00	0.00

Project Science

Tracking and controlling performance

- **Require contractors to report costs and schedule progress monthly to Task Leaders responsible for contract**
- **Task Leaders report cost and schedule progress to Project Management each month**
  - **Only this system used by Task Leaders for performance measurement**
  - **Must be implemented so as to be truly useful**
- **Progress measured by standardized methods and accumulated as Earned Value**

Project Science

Earned Value reporting

- **Monthly measurement of progress in each task accumulated as Earned Value**
  - **% Complete**
  - **Milestones Completed**
  - **Progress Payments Earned**
  - **Level of Effort**

Project Science

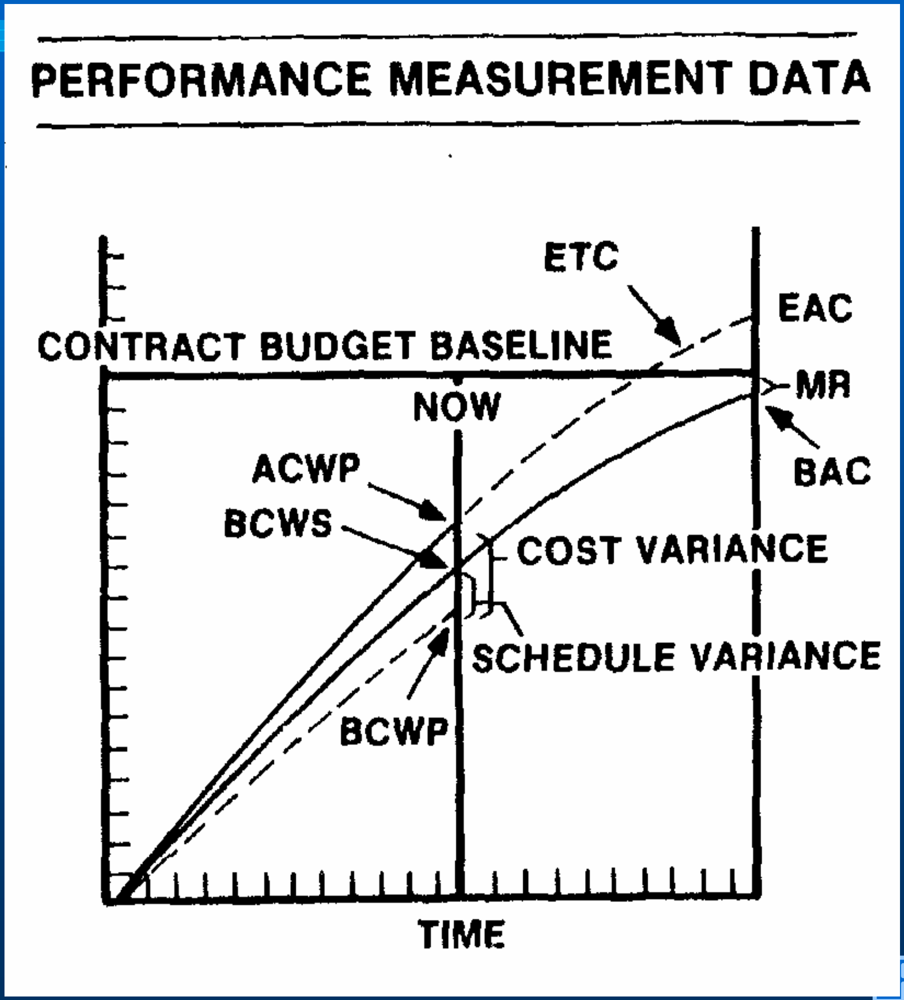
Performance and variances

- Budgeted Cost of Work Scheduled (BCWS)
- Budgeted Cost of Work Performed (BCWP)
  - earned value
- Actual Cost of Work Performed (ACWP)
- Cost Performance Index (CPI) = BCWP/ACWP
- Schedule Performance Index (SPI) = BCWP/BCWS
- Cost Variance (CV) = BCWP - ACWP
- Schedule Variance (SV) = BCWP - BCWS

(All units are in $)

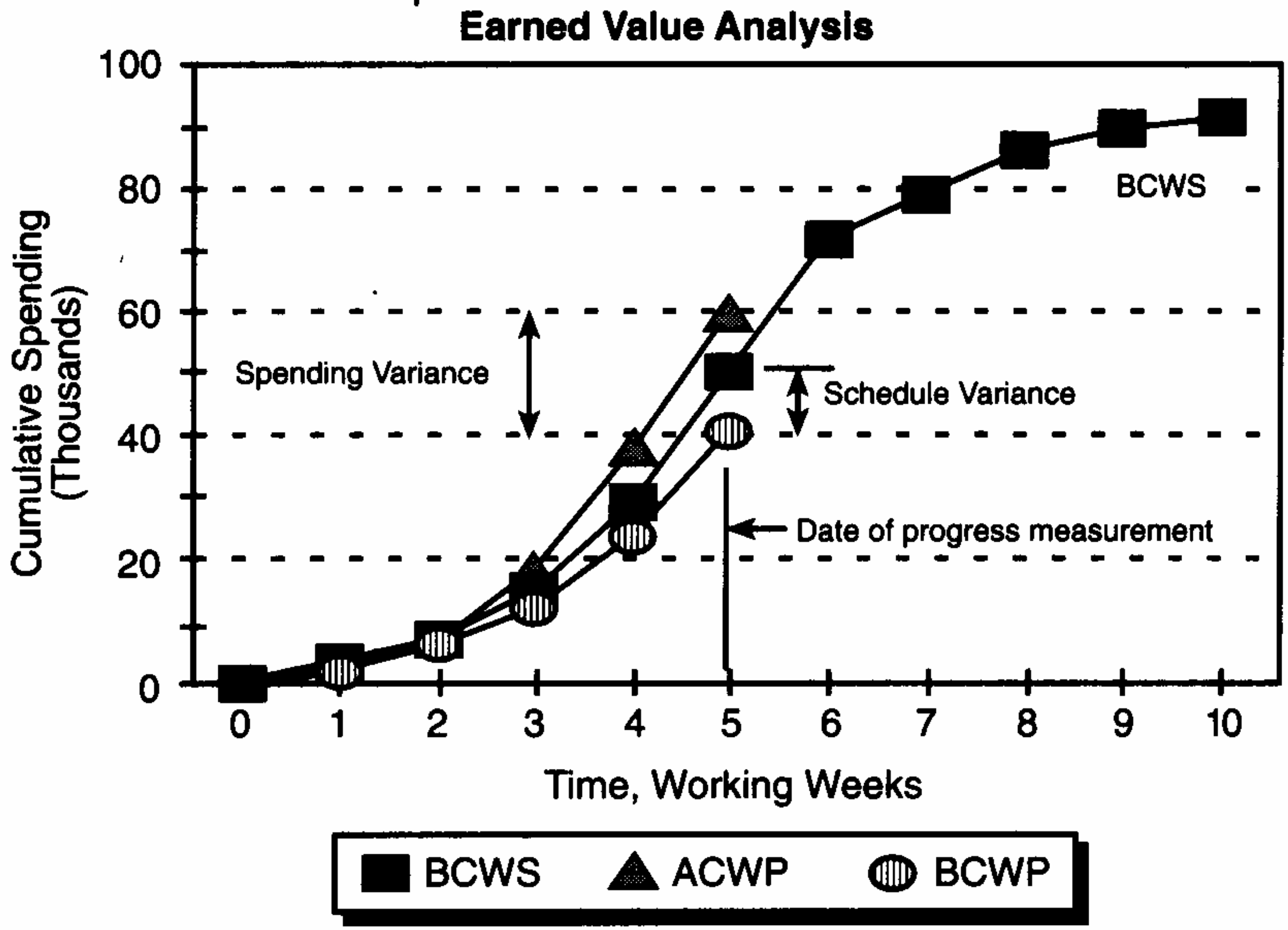
Project Science

Performance Measurement display



Project Science

Figure 8-4. Earned value analysis—behind schedule, overspent.



Science

Figure 8-6. Earned value analysis—behind schedule, spending on target.

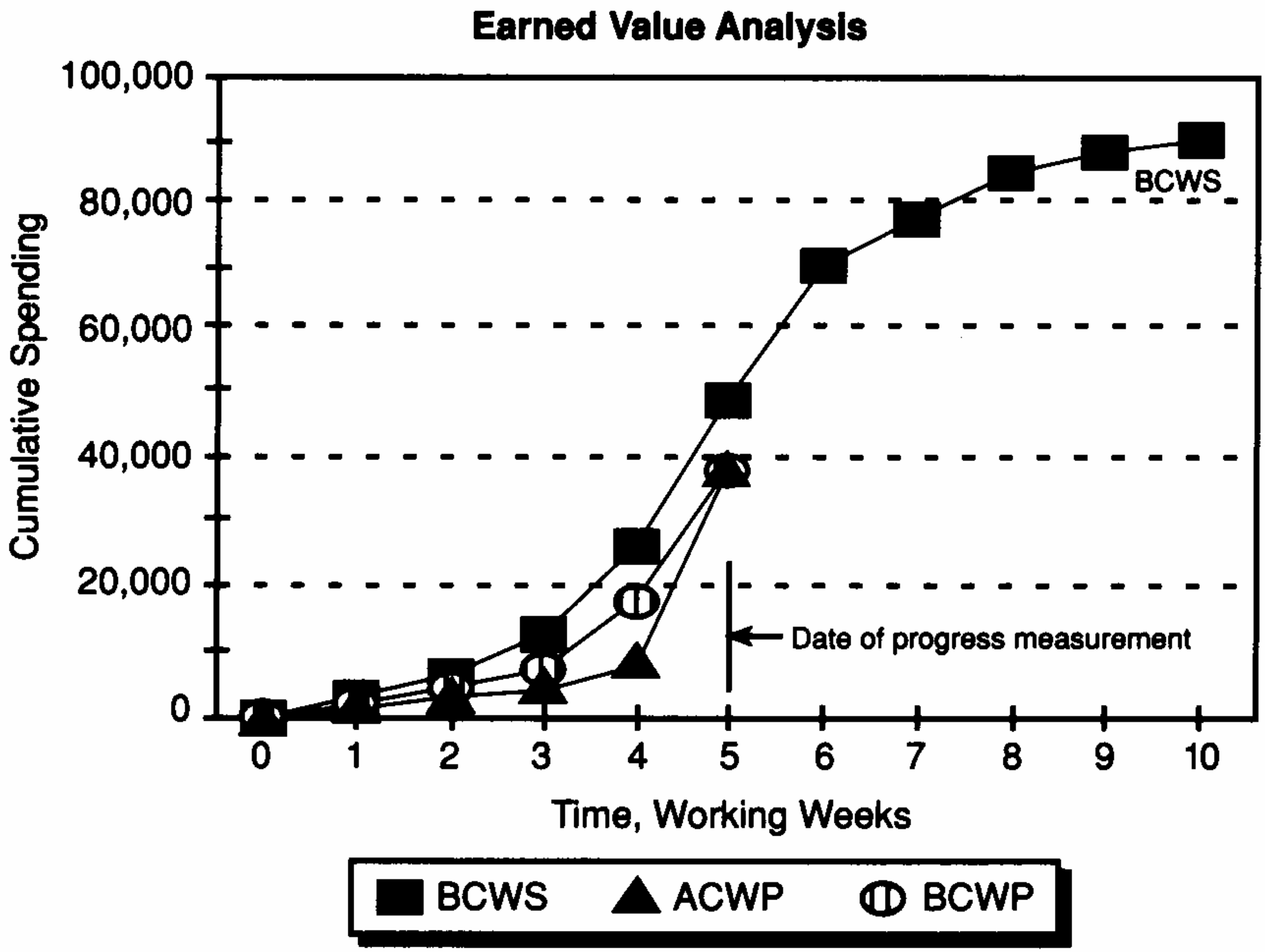
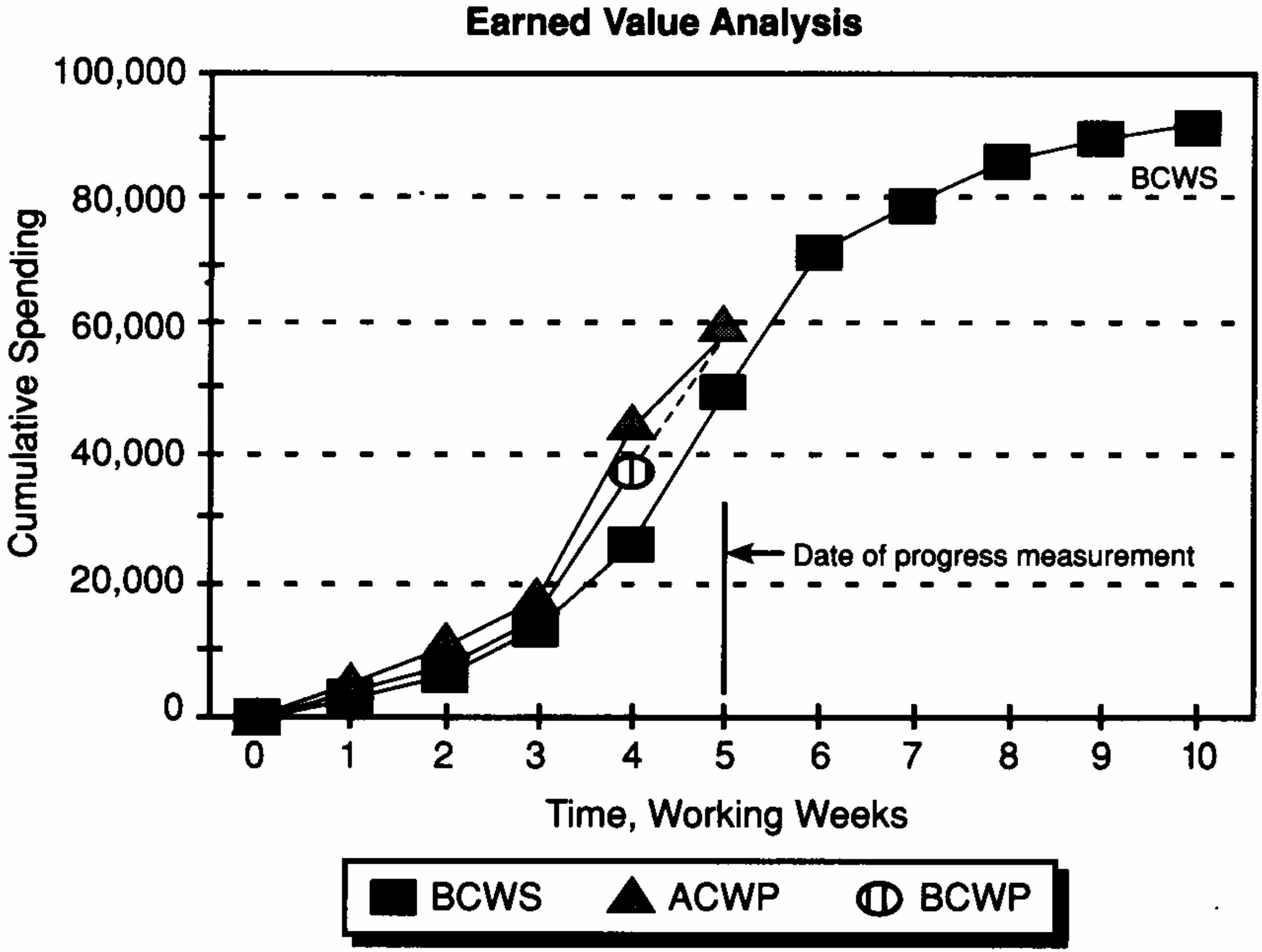
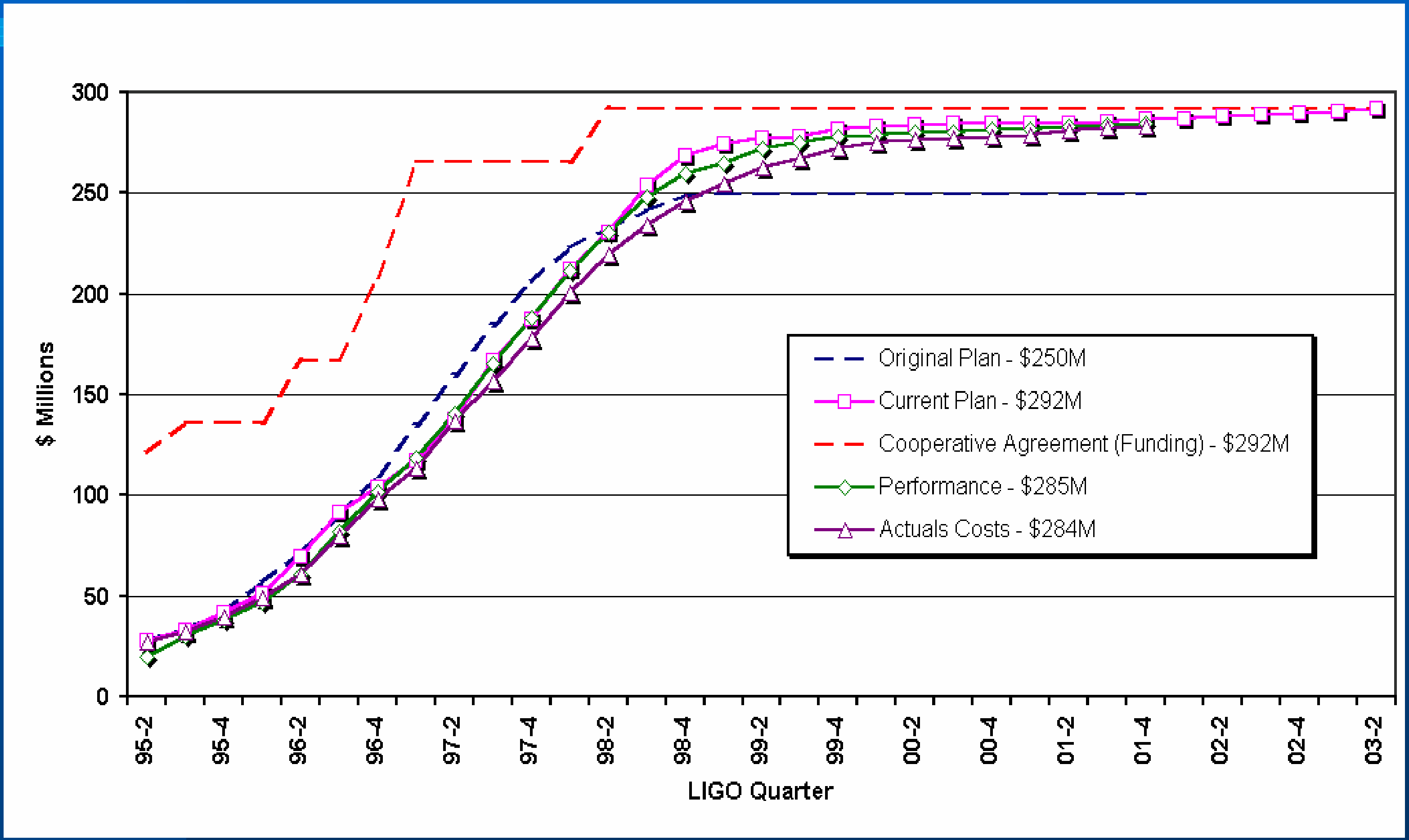


Figure 8-5. Earned value analysis—ahead of schedule, spending on target.



LIGO Cost Schedule Status



Project Science

Looking ahead

- More details of the linear project
- Complex Projects
- Environmental and Affected Cultural Planning
- Case studies of forming projects
- Case studies of projects in progress
- Cyberinfrastructure
- Projects as communities
- Funding and Governance Issues
- “Almost big” projects
- Discussion, discussion, discussion...

Project Science