Project Science

Managing Big Science Projects: Avoiding the Near Death Experience

Many large science projects experience serious cost and schedule overruns. These frequently lead to cancellation or to the near-death experience of being reorganized and replanned. This talk will describe the cultural contrasts between scientific research and the culture of big projects. It will define the ideal linear project and the perspectives and techniques needed to manage such a project. Finally, it will survey the real world complexities that make nearly all projects more complex and strategies to deal with these complexities. Examples of these techniques will be drawn from high-energy physics projects, LIGO and the Thirty Meter Telescope project.

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Managing Big Science Projects: Avoiding the Near Death Experience

Gary H Sanders
Thirty Meter Telescope Project

SLAC

September 18, 2013

LIGO – a centralized scientific tool

Livingston Observatory
Louisiana
One interferometer (4km)

Hanford Observatory
Washington
Two interferometers
(4 km and 2 km arms)

The near death experience lurks…

- **Too many large scientific projects get into trouble**
  - **Trouble is diagnosed at vulnerable times**
  - **Projects are frequently reorganized**
  - **Some projects are canceled or they fail**
- **The "review-cry-coach-review-cry-coach-fire-reorganize-review…" cycle as a learning tool**
  - **There has to be a better way**
- **Spread case-based experience of scientist/managers to those in emerging projects**
- **Make the scientist-specific cultural setting visible**

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This Talk

- Culture
- Big science is different from small science
- Management goals in big science
- The “linear project”
- Complex projects
- Structuring the linear project
- New kinds of projects

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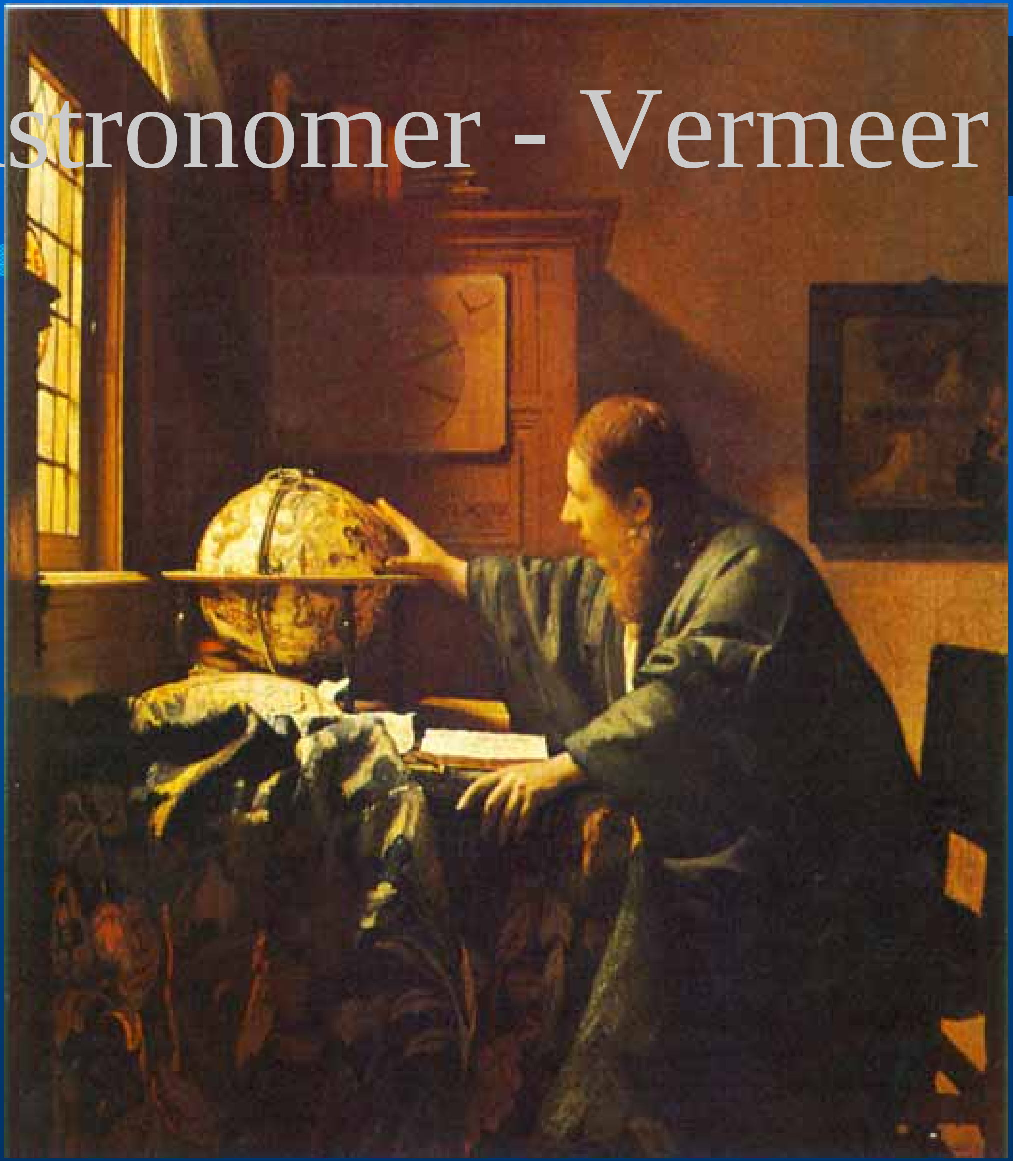
Sociology

The Astronomer - Vermeer



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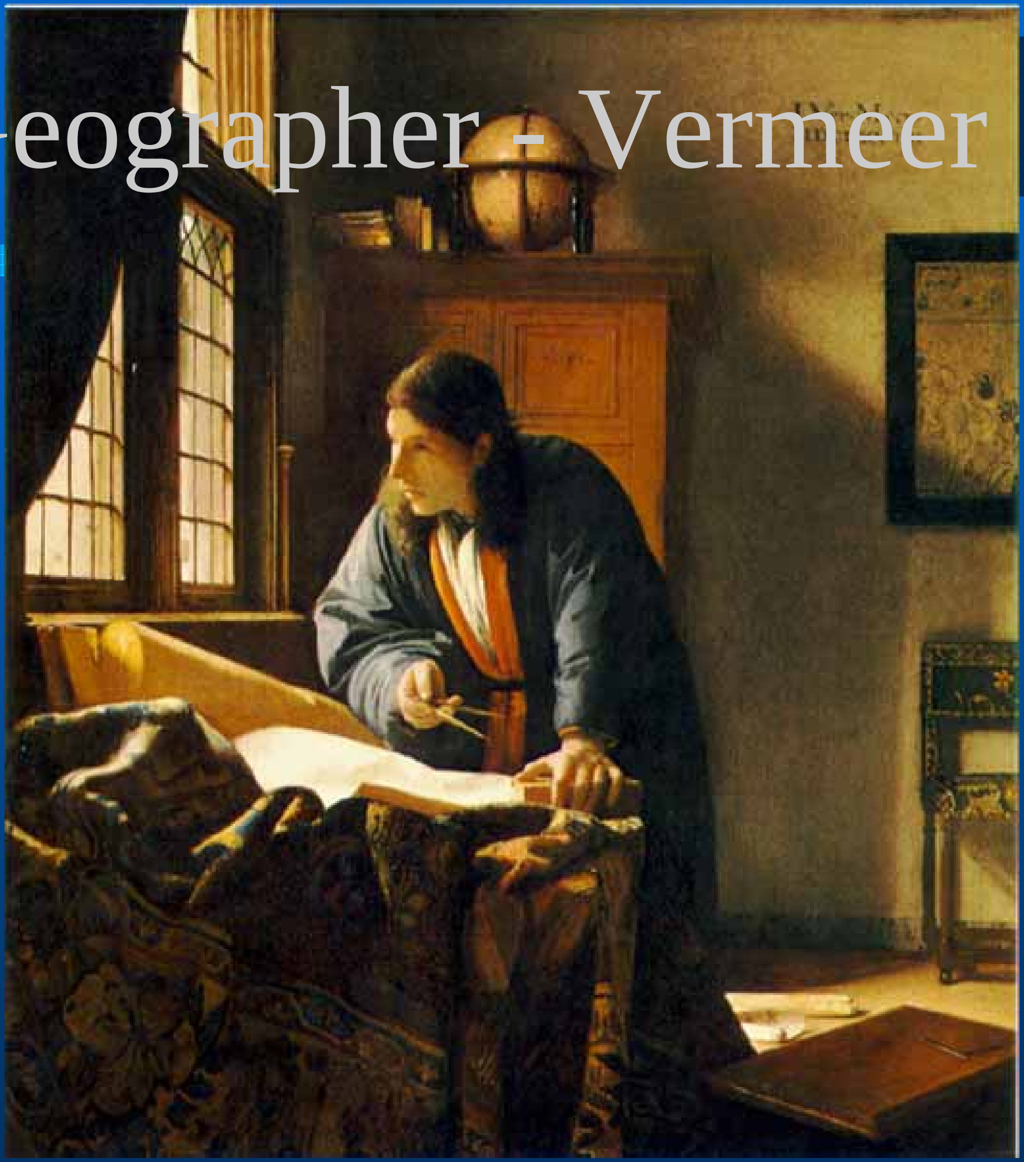
The Geographer - Vermeer



The Collaborators – A Caltech "forgery"

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Previous

Next

UBIQUITOUS EXPERTISES (Harry Collins et al., Cardiff)

DISPOSITIONS: Interactive Ability / Reflective Ability

SPECIALIST	*UBIQUITOUS TACIT KNOWLEDGE*			*SPECIALIST TACIT KNOWLEDGE*	
EXPERTISES	Beer-mat Knowledge	Popular Understanding	Primary Source Knowledge	Interactional Expertise	Contributory Expertise

Polimorphic / *Mimeomorphic*

META-	*EXTERNAL (Transmuted expertises)*		*INTERNAL (Non-transmuted expertises)*		
EXPERTISES	Ubiquitous Discrimination	Local Discrimination	Technical Connoisseurship	Downward Discrimination	Referred Expertise

META-CRITERIA	Credentials	Experience	Track-Record

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"Expertises" – Harry Collins

- **Contributory expertise – the knowledge that enables a participant to advance a field**
- **Interactional expertise – knowledge sufficient to understand the subject matter of a field and to support communicating intelligently with contributory experts in the field**
- **Referred expertise – Expertise of a contributory or interactional nature in one field that is applied usefully in a new field**

Interacting in little circles

Contributory expertise

Lone researcher

Tacit knowledge

Community and shared history

Expertise narrowly defined

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Collaborators

Lone researcher 1

Tacit knowledge

Community and shared history

Expertise narrowly defined

Lone researcher 2

Tacit knowledge

Community and shared history

Expertise narrowly defined

Contributory expertise

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Projects

Lone Project Manager
Tacit knowledge
Community and shared history
Expertise narrowly defined

Lone researcher
Tacit knowledge
Community and shared history
Expertise narrowly defined

Lone engineer
Tacit knowledge
Community and shared history
Expertise narrowly defined

Contributory expertise

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Project Science as a culture

- **Theoretical scientists**
- **Experimental scientists**
- **Project scientists**

Three distinct cultures and temperaments

Three distinct "expertises"

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Project Management and Management of Operating Organizations

- **Project management**
- **Operating management**

Two distinct cultures, temperaments, "expertises" and management goals

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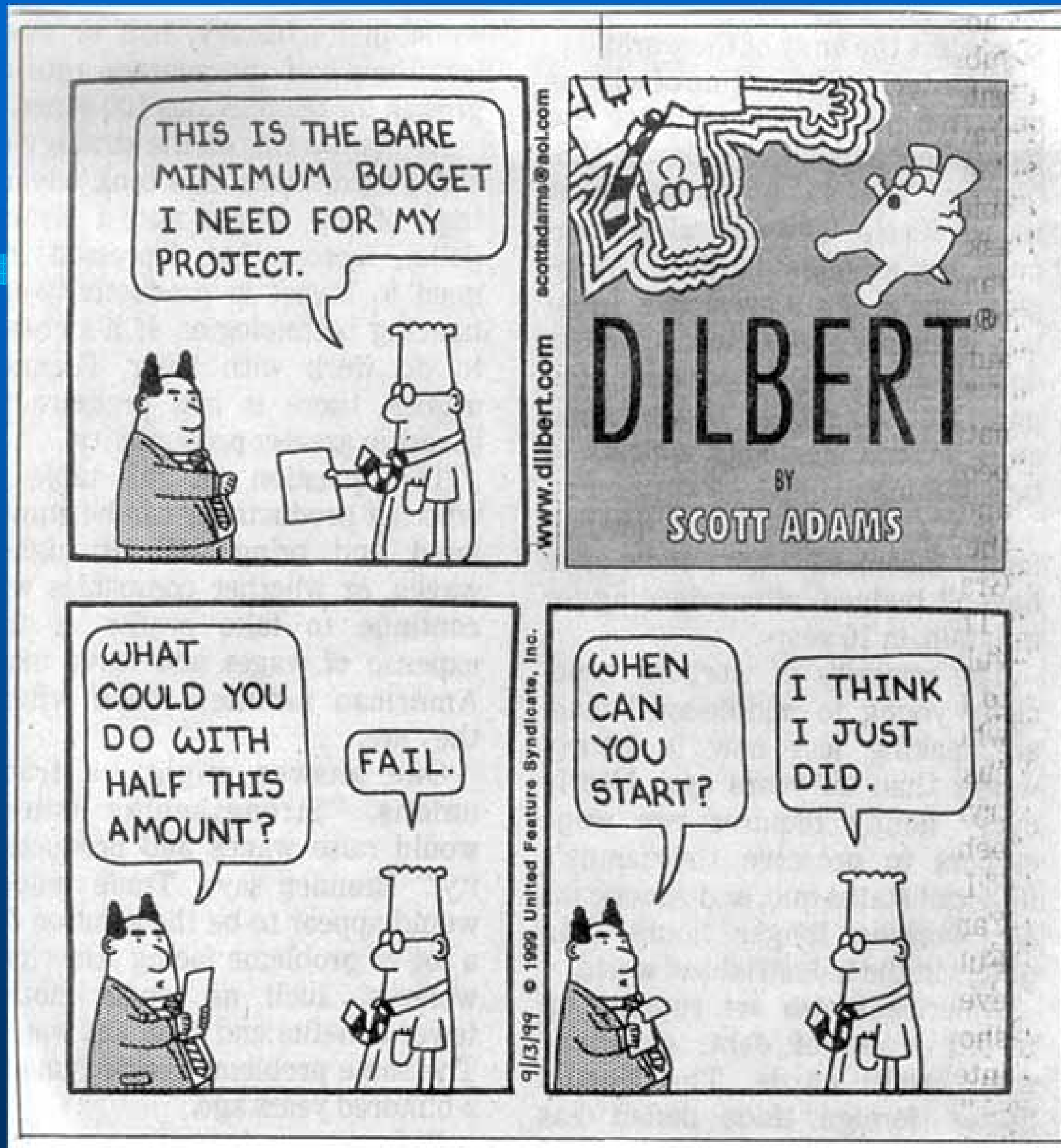

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The training and filtering of scientists

- Undergraduate study – reading and problem sets
  - Selects productive problem solvers
- Graduate study – Apprentice research under an advisor
  - Absorb the advisor's techniques and values
- Early postdoctoral career – Independent contributor to research
  - Show independence, innovation, creativity, analytical and technical mastery, focus, teaming in small teams
- Midcareer – Mentor in research
  - Confidence, mastery, emergence as a leader in a research field, strong focus, tenacious, competitive, seeker of "truth"

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Work-motivation of scientists

- **Among the most stable of work-motivations throughout one's career* are the need for:**
  - **Achievement**
  - **Affiliation**
  - **Power**
- **The selection process for scientists prefers achievement**
- **Big science requires teams and members who value affiliation and power**

* McClelland,D.,Motives, Personality and Society, New York: Praeger 1984

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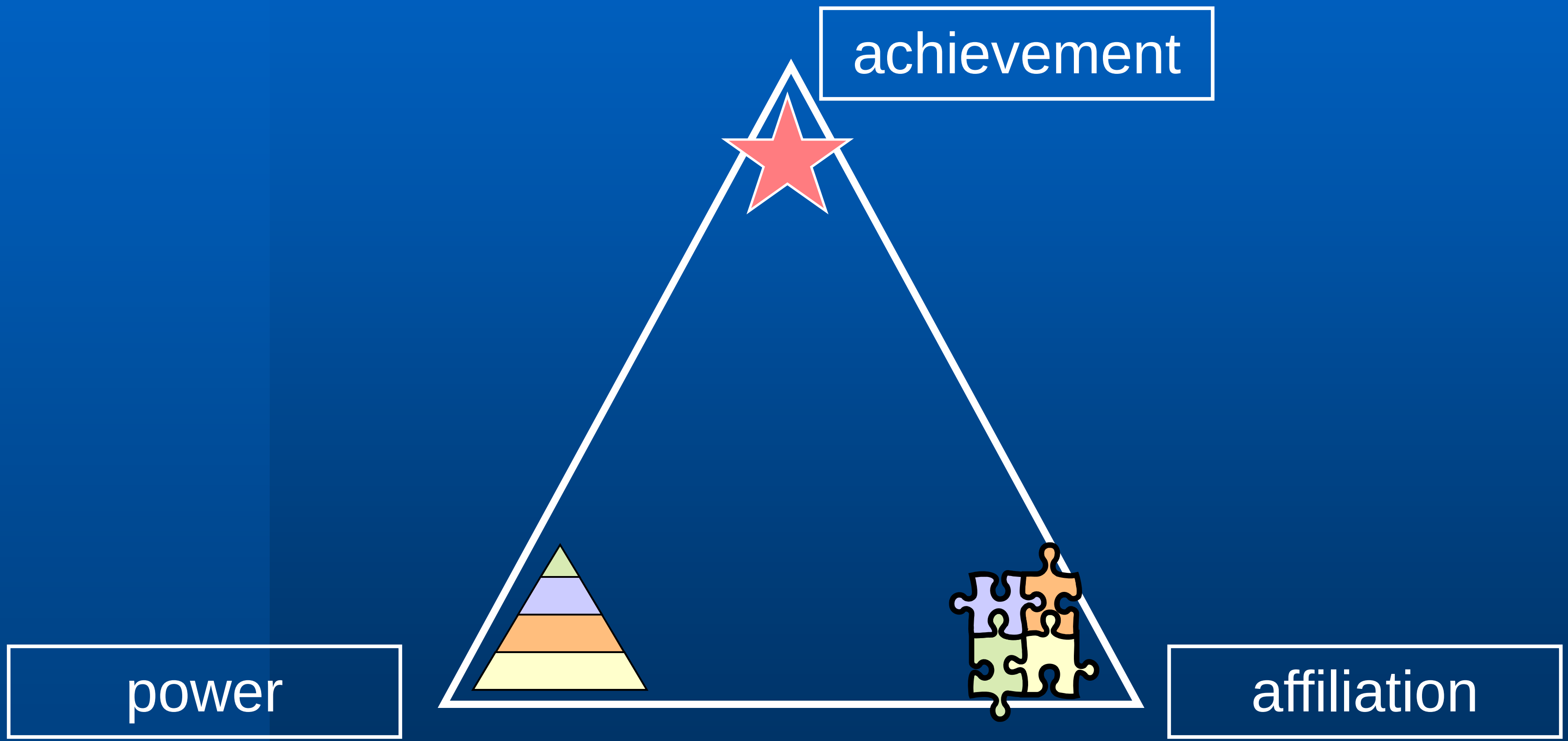
Work motivation mapping



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The project manager's motto – the project mindset

"le mieux est l'ennemi du bien."
Voltaire, 1764

"Il meglio e l'inimico del bene"
– Boccacchio, 14th century

"the better is the enemy of the good enough"

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Small Science vs. Big Science

Attribute	Small Science	Big Science
Decisions made by	scientists, creators, inventors	managers, directors, delegated
Design flexibility	flexible, creative	fixed, baselined
Fabricated by	in-house craftwork, "make"	industrial approach, "buy"
Team composition	predominantly scientists	scientists, engineers, accountants, PMs
Visibility of project	private	public
Project process	opaque	transparent
Success defined by	scientists, creators, inventors, peers	managers, reviewers, sponsors, peers

From discussions with Harry Collins

Big science is public

- Everything about the conduct of big science must be transparent to the public
- This is an ethical imperative
  - You are consuming resources that could make a difference to:
    - The public
    - Other recipients of the private support
    - Other scientific opportunities
- Your project's resources are not an entitlement
- You must be prepared to be on "60 Minutes"

"YouTube"

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The "Linear" Project

The “Linear” Project: An Ideal

- Before we can create and manage a real world project we must be able to isolate the “ideal” project inside the real project
- What are the identifying features of the ideal project?
  - The project that can be managed in a straightforward “linear” manner

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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

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Managing complex (nonlinear) projects

- Most real world projects are not linear projects
- Nonlinear projects are managed with great management attention to nonlinear attributes
  - Diffuse goals steered towards project goal
  - Multiple resource bases coordinated through negotiation and consensus building rather than real control
  - Project replanning places heavy burden on leadership and erodes focus on and respect for project plan
  - Project is distracted by reinventing and rejustifying itself

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Managing complex (nonlinear) projects

- Most nonlinear projects are managed without reference to a simple linear plan
  - How it could be
  - The most important things that should be managed for project success are the linear attributes
  - Nonlinear aspects are taken for granted and an accommodation is made and not seen as a complication
  - This accommodation is a slippery slope
- Projects must strive to achieve a linear model as much as possible in order to minimize risk

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Generic nonlinearities/complications...

- **Major project replanning is caused by:**
  - **Project goals unstable**
  - **Politics interfere with project progress**
    - **project either follows politics or**
    - **tries to operate adaptively in the lee of the political winds**
  - **Sponsor attention or support varies within term of project**
  - **Annual funding does not follow either:**
    - **funding profile dictated by technical pace of project or**
    - **funding profile agreed to in a funding limited plan**

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…Generic nonlinearities/complications…

- Institutional setting of project poor
  - Operating laboratory management imperatives influence decision making, resource allocation, funds management
    - Project managers create, execute, dismantle
    - Operating lab managers conserve and adjust
    - Transient vs. continuous management
  - Host institutional culture and support infrastructure not matched to project
  - Institutional setting fragmented among disparate institutions

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…Generic nonlinearities/complications…

- **Project team members suffer cultural mismatch**
  - **traditional "small science" vs. "big science" gap**
  - **values system not matched to project science**
    - **project science not matched to traditional graduate student education, nor to tenure evaluation process**
    - **projects are successful because the contributions of many types of team members are combined, thus contributions must be matched to project needs and not just to academic meritocracy**
  - **team members do not respect the systems and processes of large projects**
  - **dysfunctional information sharing, information structure**
    - **Promotes fragmentation into small islands or "stovepipes" often along scientist/nonscientist lines**

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...Generic nonlinearities/complications

- **Resources management decentralized**
  - **European model with independent institutes each controlling own budget and resources**
- **Scientific creativity without formal change management**
- **Project unable to "heal" or to confront surprise**

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Organizing the Linear Project

Organizing the Linear Project

- Project stages
- Baseline
- Work Breakdown Structure (WBS)
- Organization
- Cost Estimate and Risk
- Schedule
- Performance Measurement

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Distinct stages in a project…

- **Definition to Reference Design**
- **Reference Design to Baseline Definition**
- **…to Final Design and Commitment**
- **… to Industrialization**
- **Execution and Performance Measurement**
- **Integration and Plan to Completion**
- **Endgame**

Manage obligations

Manage costs

"broke and done on the same day"

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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

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When to start defining the “baseline”?

- **On day 1 with pencil sketch?**
- **…**
- **After conceptual reference design defined?**
- **…**
- **When sponsor makes full commitment?**
- **…**
- **At Final Design Review?**
- **…**
- **When “as-built” drawings are completed?**

When to “baseline”?

- **This question is very much misunderstood**
- **Don’t delay**
  - **This leads to irresponsible softness in project team commitment to the reference design**
  - **“After all, we aren’t baselined yet, so…”**

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Reference Design to Baseline Definition

- **Put reference design under early configuration control as interim baseline**
  - **Grow a culture of disciplined work that fosters commitment to timely decisions**
    - **Team commits to "strawman"**
    - **Team learns process of orderly change**
    - **Team learns that work can now move forward**
    - **Team learns hierarchy of technology options and design choices**
      - **Baseline choice with fallback option and decision date**
      - **Equal options with decision date**
      - **Firm baseline choice with no option**
    - **Sponsor must recognize what this is**

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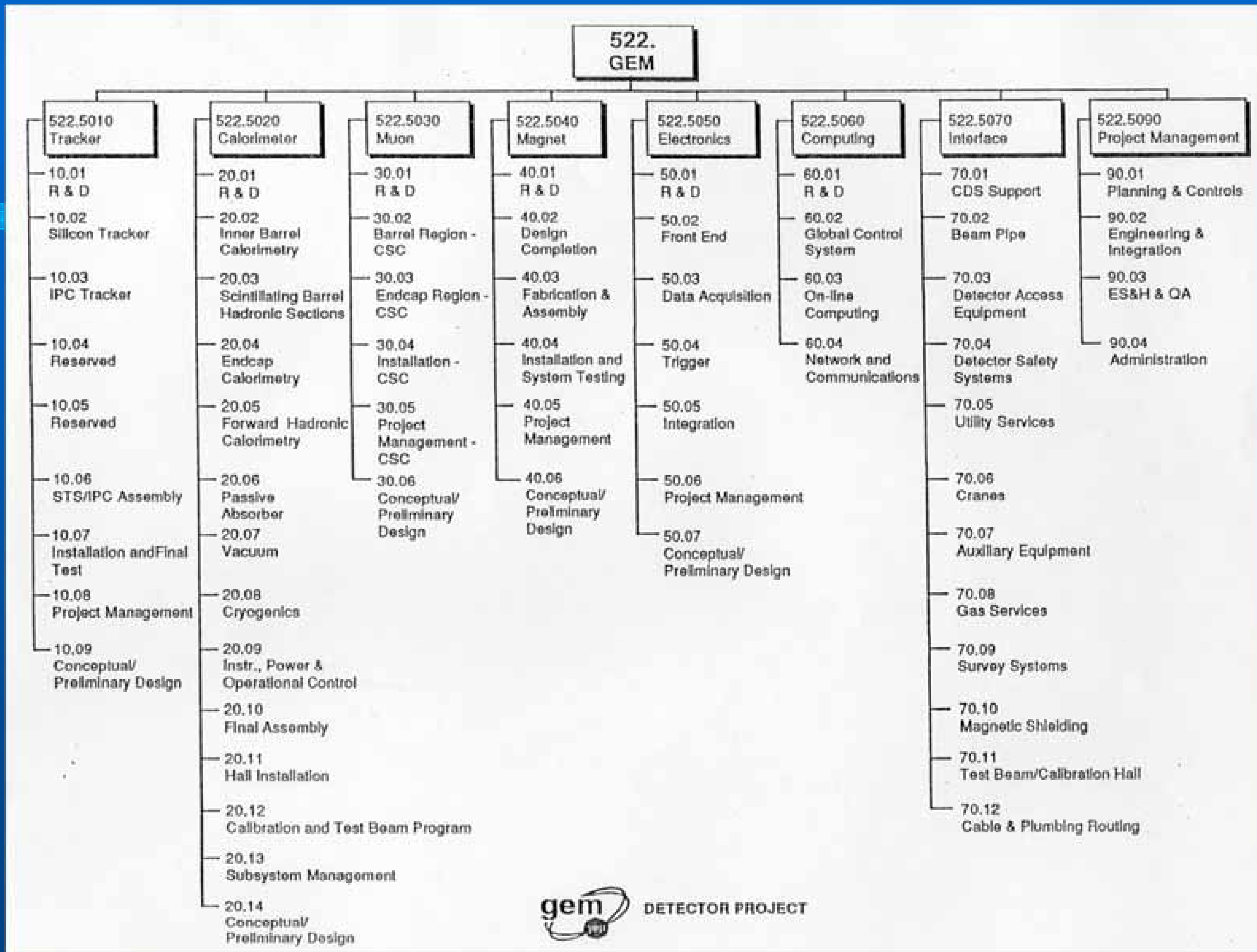
Work Breakdown Structure (WBS)



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Work Breakdown Structure (WBS)

- Detector
  - Tracker
  - Calorimeter
    - Cryostat
    - Electronics
      - Readout
        - Front End Op Amp
    - Support Structure
  - Muon Subsystem
  - Solenoidal Magnet
  - Project Management
    - Project Controls
    - System Engineering
    - Subcontracts
    - QA
    - ES&H
    - Documentation

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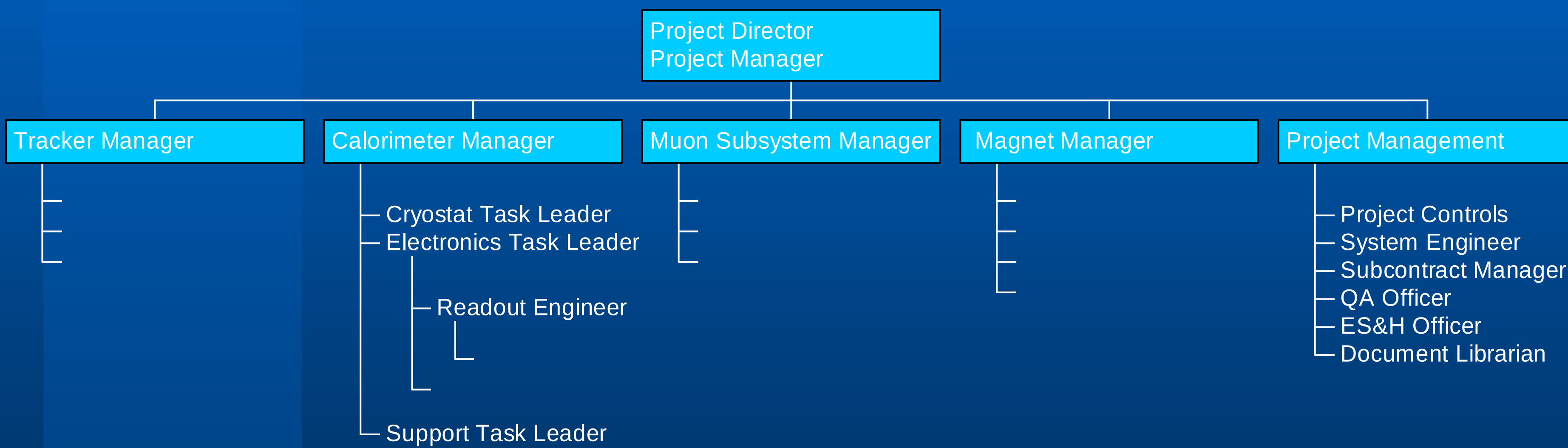
Project Organization



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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

ACDS # (Obsolete) Example

Task Name		$0
WBS Number		*e.g., 1.1.4.45*
Estimator		*Name*
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			**Multipliers for Contingency**			**FE Band**
Technical Risk	8	*(1, 2, 3, 4, 6, 8, 10, or 15; see definition)*	Technical Multiplier	2	*(2 or 4 are valid)*	
Cost Risk	10	*(1, 2, 3, 4, 6, 8, 10, or 15; see definition)*	Cost Multiplier	1	*(1 or 2 are valid)*	
Schedule Risk	8	*(2, 4 or 8; see definition)*	Calc. Contingency:	34%	*(Estimator may override)*	

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 & Travel Costs (in $K)

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

GEM COST ESTIMATE SUMMARY

FY93 U.S. Dollars

4/20/93

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

LINE ITEM	ITEM CODE	ITEM DESCRIPTION	QUANTITY	UNIT MEAS	COST BASIS	MATERIAL: UNIT COST	MATERIAL: TOTAL MAT'L,$	LABOR: CRAFT/ TEAM	LABOR: HOURLY RATE	LABOR: MH/ UNIT	LABOR: TOTAL HOURS	LABOR: UNIT COST	LABOR: TOTAL LABOR,$	TOTALS: 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

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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 inpact on vessel installation schedule.

Misc Comments:

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

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TMT
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:	$3,634
						Nonlabor Subtotal:	$594,739

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 provid acceptable performance.
Cost	3	2%	Most components quoted by vendor or catalog prices.
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

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), AIG, 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/PSPR 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	U/M	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

Priced Estimating Data Report — *TMT.BUS.CST.06.074.REL01* — *TMT Program Confidential Data* — *Monday, September 11, 2006* — *Page 239 of 318*

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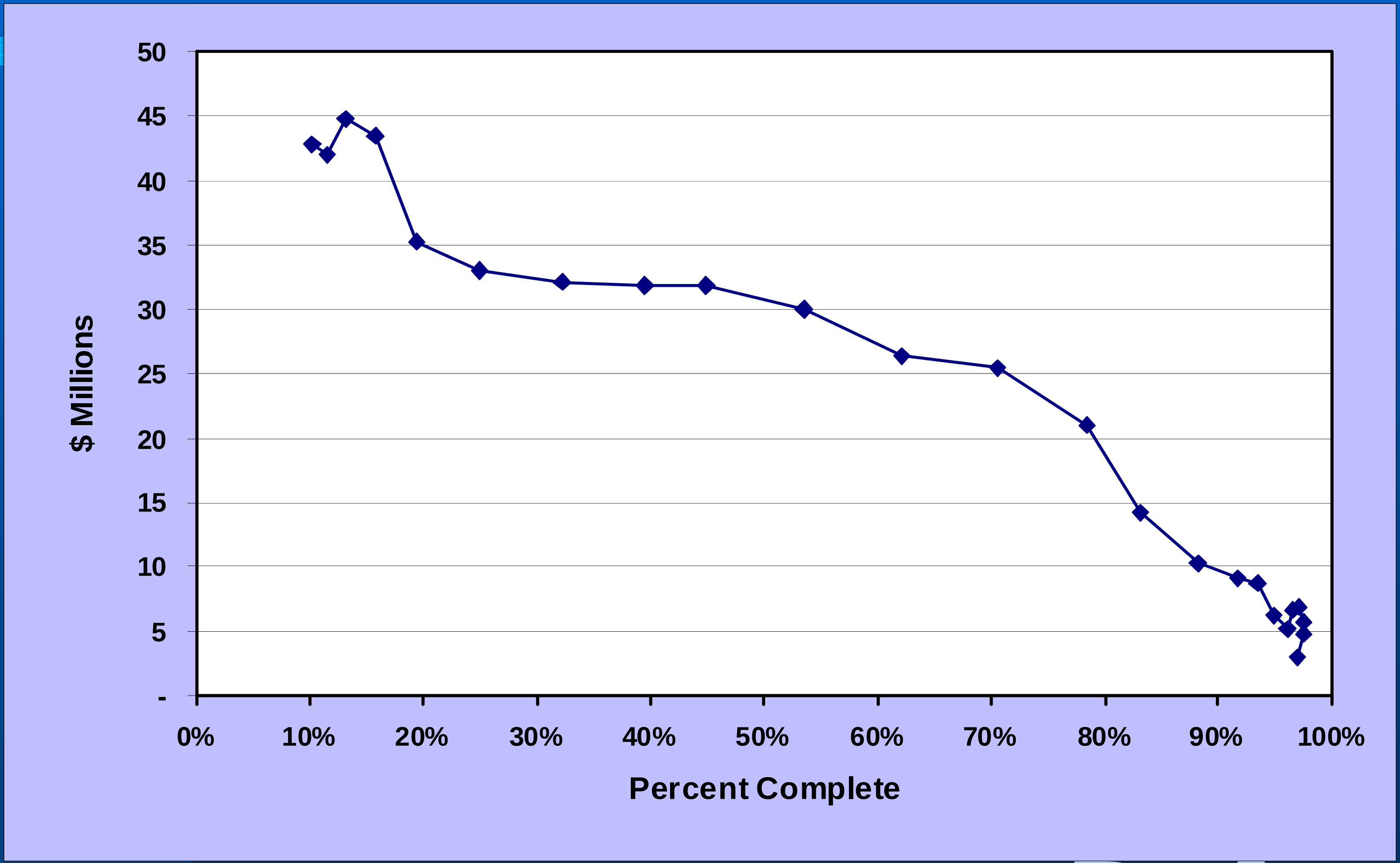
Cost Estimate - Risk analysis

- **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**

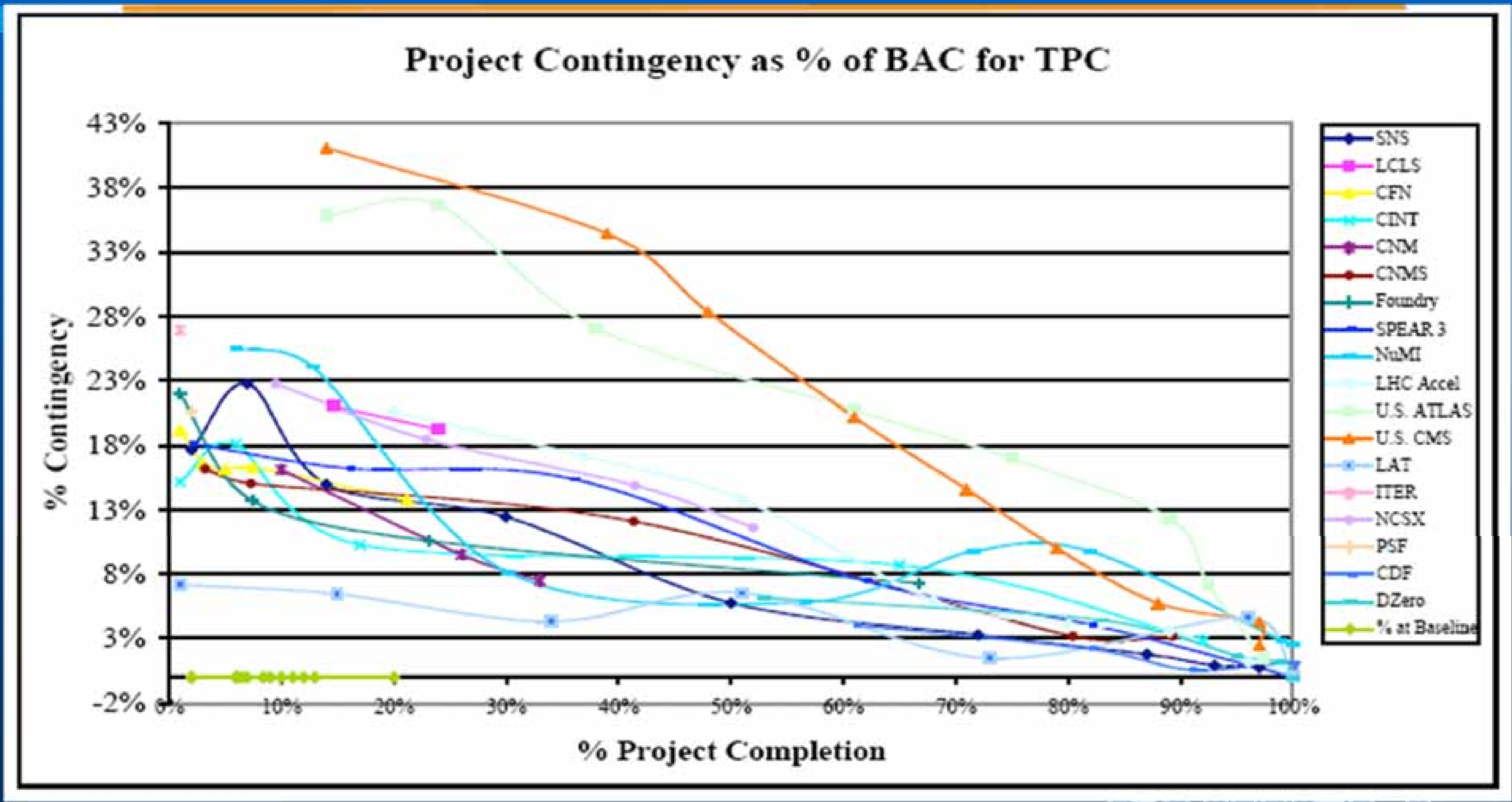
Project Science

(%Contingency used)/(% Project complete)



Project Science

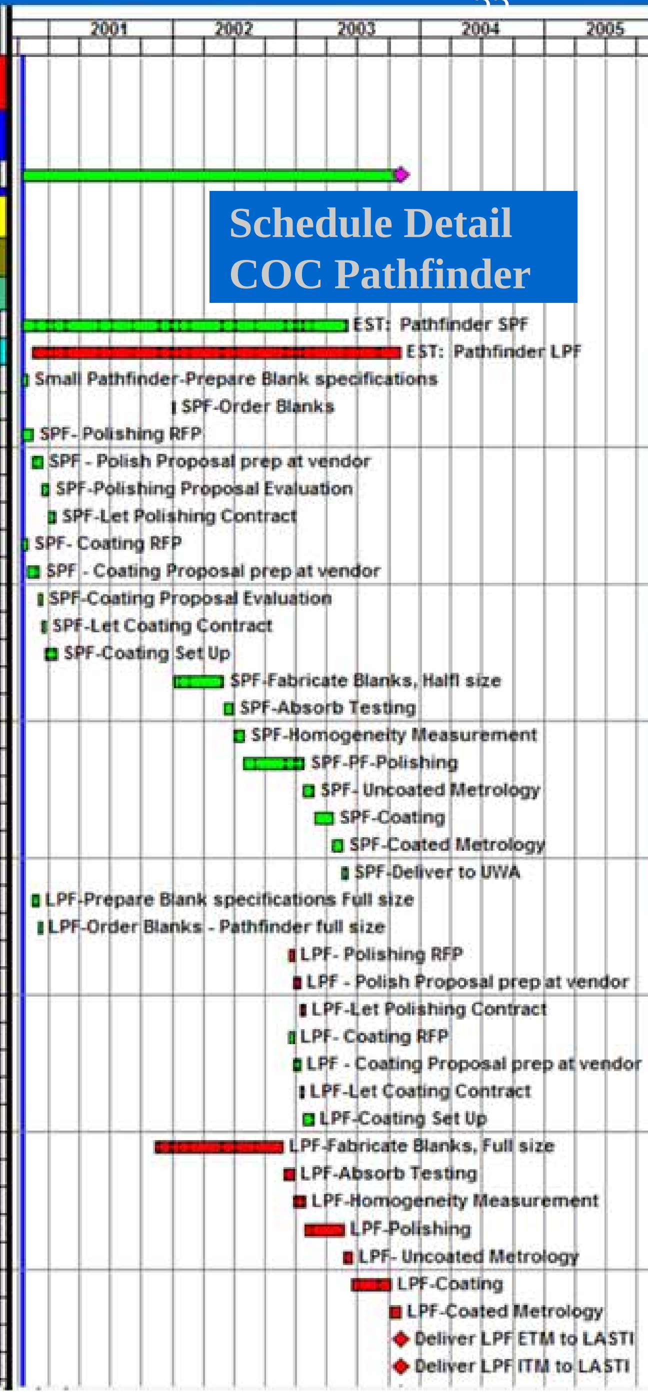
Contingency Experience of Past DOE Office of Science Projects



Project Science

Schedule Detail 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
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

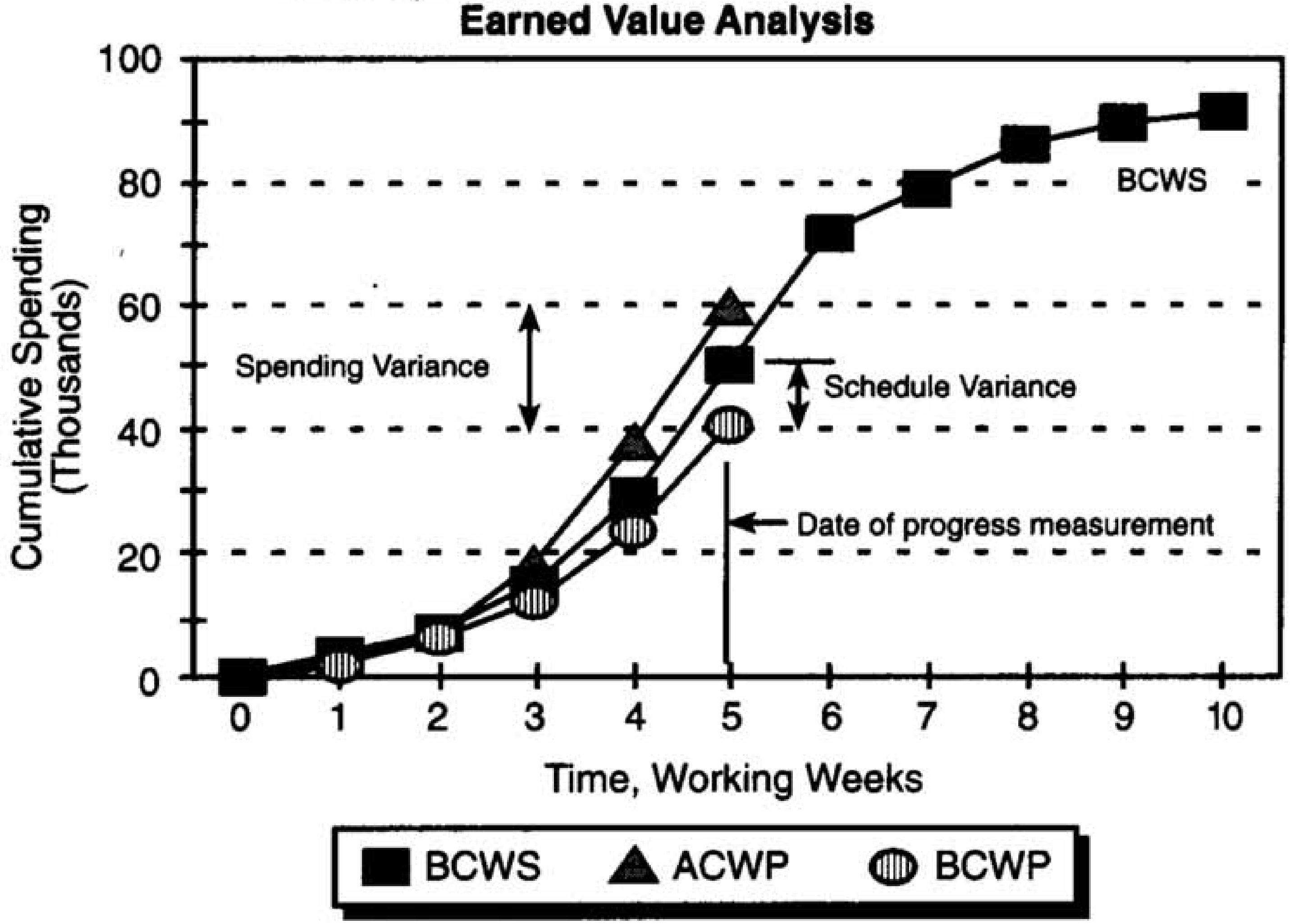


Schedule - Integration

- **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

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



Science

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

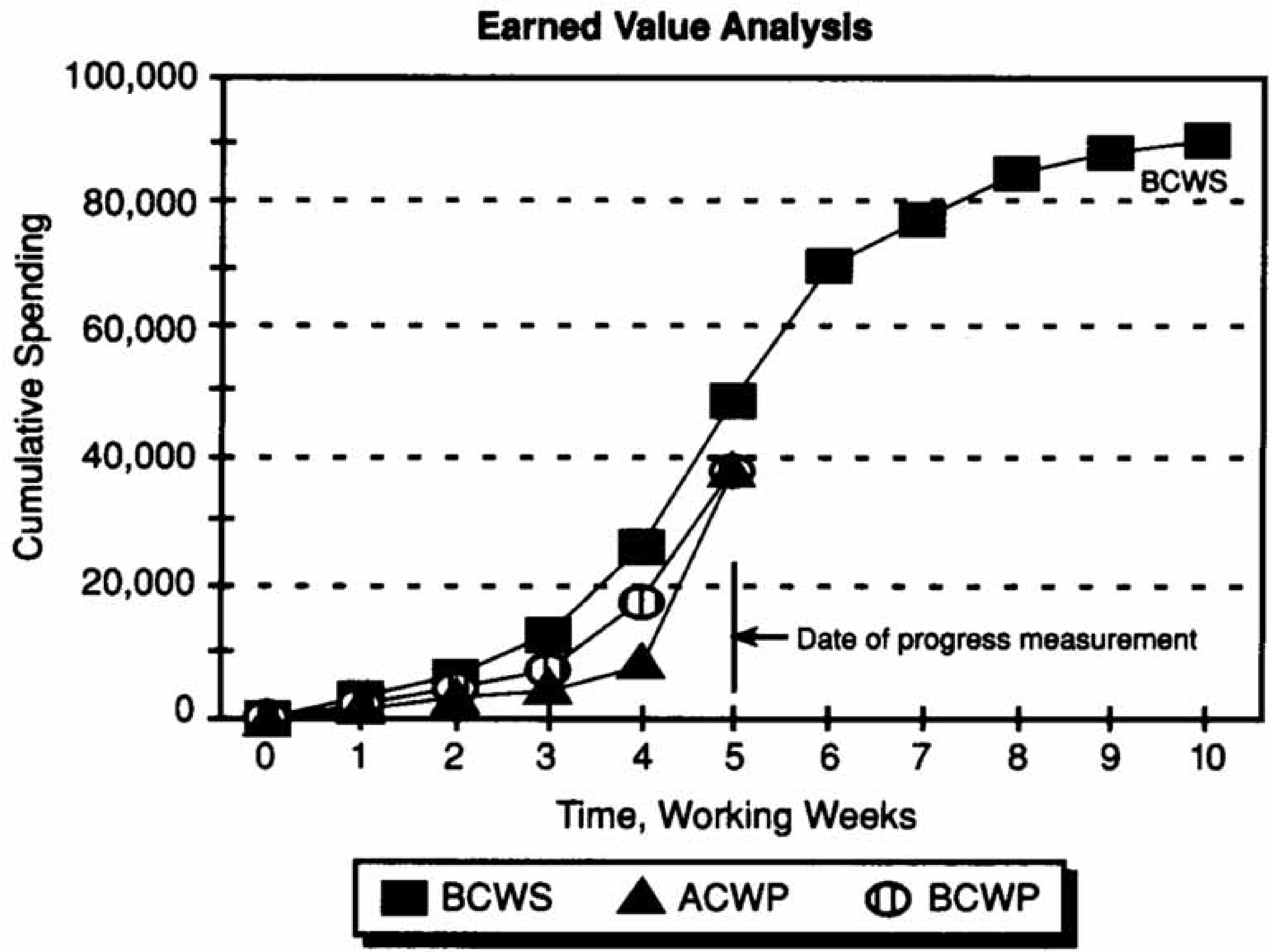
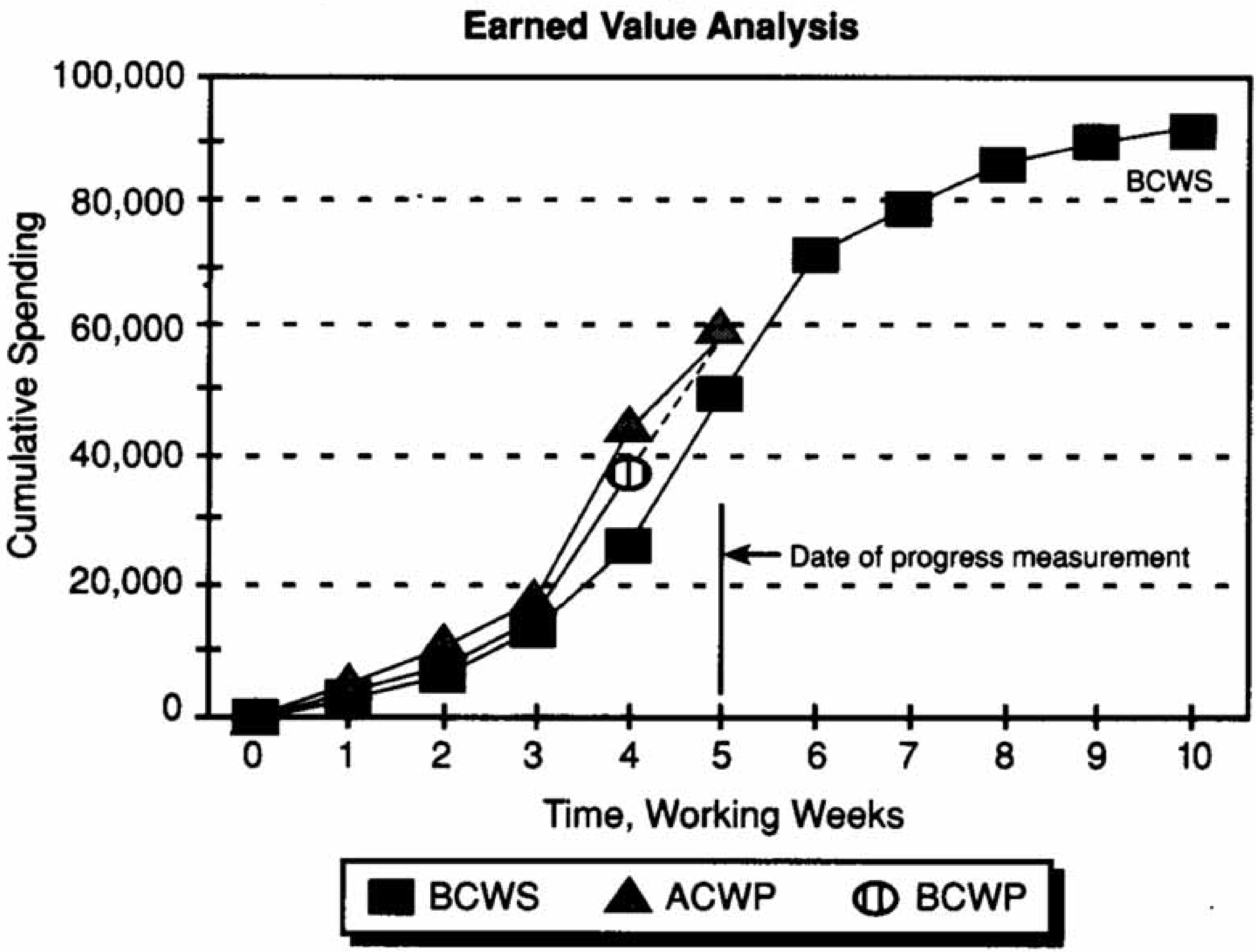
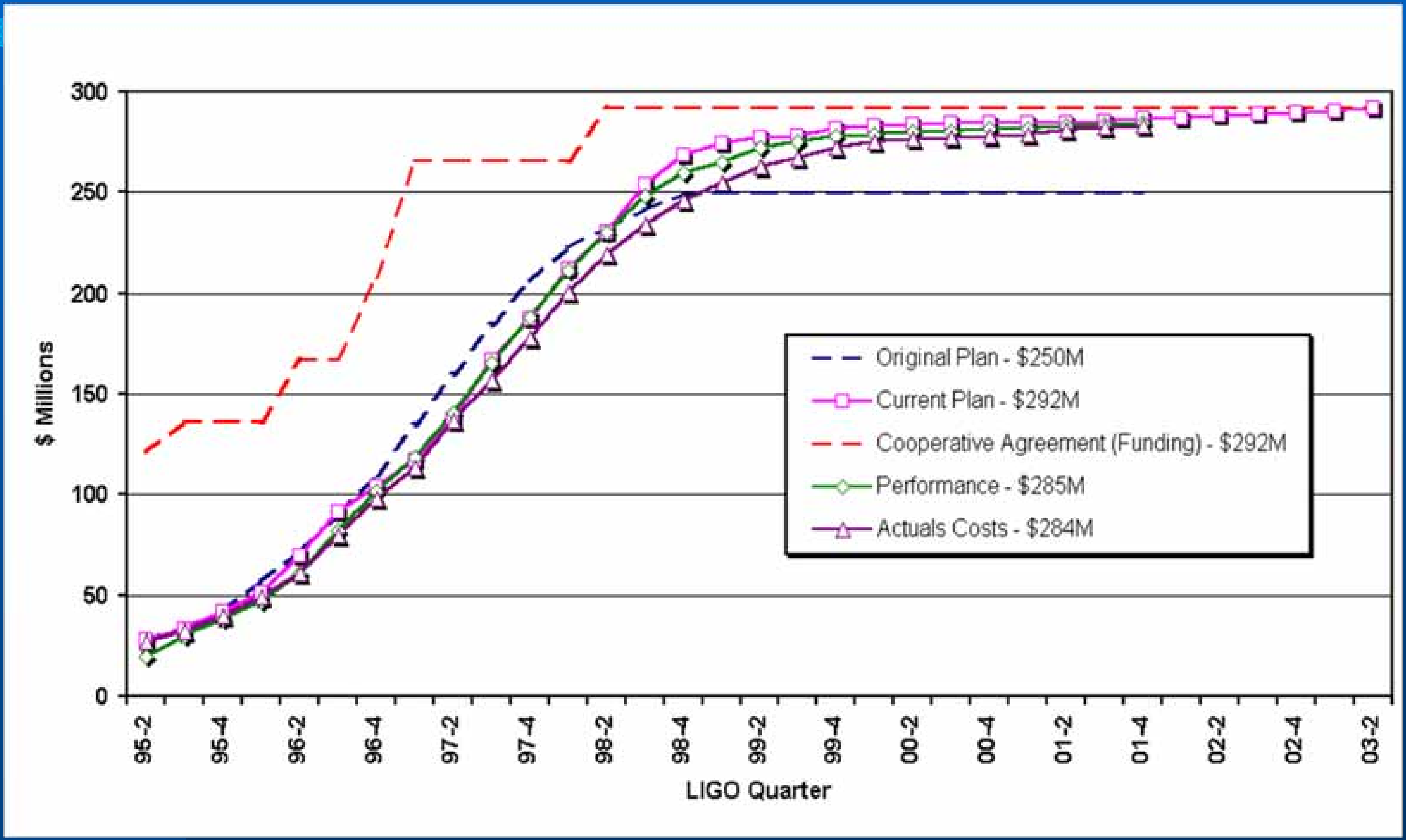


Figure 8-5. Earned value analysis—ahead of schedule, spending on target.



LIGO Cost Schedule Status



Project Science

LIGO – a centralized scientific tool

Livingston Observatory
Louisiana
One interferometer (4km)

Hanford Observatory
Washington
Two interferometers
(4 km and 2 km arms)

Project configurations

- Linear projects – LIGO (1994 – 2001)
- Composite operating+project setting - NuMI
- Multiple support sources - TMT
- Collaborative projects – Keck, LSST
- Global projects – ALMA, ITER, ILC, SKA
- Bottom-up collaboratories – NEES, Earthscope, NEON, OOI
- "Almost big" science – CDMS II, Borexino

Project Science

Lessons for Big Science Projects

- **Manage culture at the individual and group level**
- **Structure the linear project inside your real project and make sure that you are managing both the linear attributes and the complications adequately**
- **On day one, start to structure everything progressively as if it is a project**
- **Big science is different from small science**
- **http://www.projectscience.org for case studies**

Project Science