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# Activity-Based Budgeting and Cost Estimating for Operations

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NSF Large Facilities Workshop 2018

# Break-out Session Goal

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Walk through the LIGO Laboratory cost estimating process to provide ideas and generate discussion. We can all benefit from learning from each other about how to evaluate and comply with NSF LFM requirements.

# LIGO Lab Structure

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- The LIGO Laboratory is managed by Caltech with one subaward to MIT, exclusively funded by NSF (Cooperative Support Agreement). New 5 year CSA starting Oct 1, 2018
- Four sites including the observatories and campuses
  - » Caltech – Pasadena, CA
  - » MIT – Cambridge, MA
  - » LIGO Hanford Observatory (LHO) – Richland, WA
  - » LIGO Livingston Observatory (LLO) – Livingston, LA
- Directorate located at Caltech and MIT
- Business Office located at Caltech and LHO

# LIGO Cost Estimating Plan

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- Cost Estimating Plan (CEP)
  - » Large Facilities Manual Section 4.2.2.1
    - How will the “Cost Model Data Set” will meet the various needs of the project. The “Cost Model Data Set” is the cost data used as input to software tools and/or project reports to organize, correlate, and calculate different project
    - Must describe how the Recipient will implement the guidelines contained in the GAO Cost Estimating and Assessment Guide.
    - The CEP should also typically include a narrative and sufficient detail explaining the ground rules and assumptions, roles and responsibilities, practices, systems, and calculations used to develop the cost estimate.
    - The CEP should describe the expected cost estimating methodology at each stage (e.g., expert opinion, analogy, parametric, or engineering build-up).
    - Recipients should also discuss their own independent estimates and reviews, if any, planned to validate the project estimate.

# LIGO Cost Estimating Plan, cont

- **Cost Model Data Set** Section 4.2.2.1; it is used as input to software tools and/or project reports to organize, correlate, and calculate different project management information.
  - » Cost Estimates
  - » Staffing Levels
  - » Rate tables/inputs
  - » Basis of Estimates (BOE)
  - » Rules, Assumptions
  - » Risk Assessments
  - » Chart of Accounts
  - » Sorting ID and codes
- ❖ *Important to note that terminology within your own organization may vary; this is why it is important to describe in the CEP*

# LIGO Cost Estimating Plan Elements

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- Cost Estimating Plan (CEP), Elements
  - » Development of categories for what approach to use for estimating costs
    - Determined it would be most practical to develop estimate using 4 different cost categories: Labor; Travel; Property Life Cycle Maintenance Projects (PLMP); all other direct costs
  - » Development of how indirect costs, staff benefits allocations, and escalation will be handled
    - Chose to use budgeting software to calculate these items
    - Benefit: Budget manager developing cost estimate focuses on estimating direct cost only. Does not confuse the cost estimate, especially when developing a 5 year budget

# LIGO Cost Estimating Plan

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- Development of new WBS structure
  - » Activity based, rather than functional based. Goal is to budget and report cost incurred against activities.
  - » Identification of high level primary activities, aligned with Scientific goals
- Direct Labor
  - » Labor mapping templates issued to functional group leads to map staff to new WBS structure. Majority of labor based on current staffing, with exception of proposed additional staff positions.
- Travel
  - » Travel template developed with categories of travel and staff names. The functional group leaders were asked to complete the template for each of their employees.
    - LIGO Conference Travel was not included in this template. Estimated by Conference Committee Chair.

# LIGO CEP, cont

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- Property Life Cycle Maintenance
  - » Independent assessment and facilities software.
- Other Direct Costs
  - » A master workbook template was developed and assigned to the proposal section lead
  - » Within template, individual worksheets at lowest level WBS elements to capture all non-labor expenses, other than travel.
- MIT Subaward
  - » MIT developed a budget and it was integrated into the O&M activity based costing structure
- Final Budget
  - » All direct costs from all BOE sources compiled and uploaded into BudgetPak.
  - » All allocations are set-up in BudgetPak and are applied to direct costs through programmed calculations, including MIT.



# GAO 12 Steps of High Quality Cost Estimating Process

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- Step 1: Define estimate's purpose
  - Step 2: Develop estimating plan
  - Step 3: Define program characteristics
  - Step 4: Determine estimating structure
  - Step 5: Identify ground rules and assumptions
  - Step 6: Obtain data
  - Step 7: Develop point estimate and compare it to an independent cost estimate
  - Step 8: Conduct sensitivity analysis
  - Step 9: Conduct risk and uncertainty analysis
  - Step 10: Document the estimate
  - Step 11: Present estimate to management for approval
  - Step 12: Update the estimate to reflect actual costs and changes
- ❖ For more in-depth information attend session “Cost Estimating for NSF Facility Operations – Reasonable Application of GAO Good Practices

# Development of Activities Based WBS

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- The LIGO Laboratory has always utilized a Functional WBS.
- Management decision made to transition to Activities Based WBS

## Why?

- Benefits
  - » Costing and monitoring of activities, which involves tracing resource consumption and costing final outputs. Resources are assigned to activities and activities to cost objects.
  - » Business office can provide reports to Management and to NSF that reports against operational and scientific objectives
  - » Budget managers assigned to specific activities
  - » Distinguish the cost of running the Laboratory (maintaining and running the Observatory) from the cost of improving the detector
  - » Set priorities based on the amount of funding available

# Development of Activities Based WBS

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- Potential Disadvantages

- » Cost of implementation and managing
- » Potentially creates a disconnect from those who own the resources and those who have responsibility (execution and financial) of activity
  - Example: Not all work taking place at Observatory will be the direct responsibility of the Observatory Site Head, even though Observatory Site Head is responsible for all on-goings at the Site.

- Mitigating Disadvantages

- » Create an Organizational Breakdown Structure (OBS) that lays on top of WBS. Goal is to not have confusion about communication.
  - Make sure there are clear paths of reporting and how conflicts will be handled
- » Don't go too far down into the details.
  - Example: Want to know how much Control Room Operations cost but do not want to try to capture how much a Black Hole Merger versus a Binary Neutron Star Merger costs
- » Think about cost versus benefit.

# Gathering Data for Basis of Estimate

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- Biggest lesson learned: developing comprehensive tools that tie everything together is priceless
  - » This takes careful thought, analysis, and time – *give yourself time!!!*
- We needed our tools to:
  - » Gather all the information needed for basis of estimates to follow LFM and GAO guidelines
  - » Tie all the way from the top of the WBS roll-up structure down to the very bottom level any way the data is looked at (by activity, 1030 code, cost categories, etc)
  - » Document each cost
  - » Be user friendly for non-Excel users, non-accountants to use
  - » Be standardized for use across varying activities (LIGO has over 100)
  - » Leverage software capabilities to allow very small business staff to manage large amounts of details

# Estimating & Reporting Tools

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- Developed a different tool for each of the 4 different cost categories of our Cost Estimating Plan: Labor; Travel; Property Life Cycle Maintenance Projects (PLMP); all other direct costs
- Made sure each one would gather needed information so it could be combined into a single document later (excluding labor)
- Used BudgetPak software by Xlerant to bring it all together and complete indirect cost allocations and staff benefits allocations
  - » Allowed us to remove these from basis of estimate templates, so didn't have to train estimators on how to calculate these correctly



# Tools to Estimate & Allocate Labor

UnitDescription	Abbott, Benjamin P	Abbott, Richard	Bork, Rolf Georg	Etzel, Todd	Sanchez, Luis Enrique	Grand Total
<b>Sub-Activity</b>						
ALTS.CDS.10.50: Control & Data Systems	-	-	10.00		-	10.00
ALTS.DSD.10.50: Det System Develop R&D	10.00	10.00	-		10.00	30.00
ALTS.EE.10.50: Electronics Engineering	70.00	70.00		60.00	70.00	270.00
LOPS.CTRL.10.50: Control-room operation and monitoring						-
LOPS.CDS.10.50: CDS maintenance and operation	-	-	70.00	-		70.00
LOPS.CDS.10.51: Electrical and electronics infrastructure and instrumentat	10.00	10.00		20.00	10.00	50.00
LOPS.CDS.10.53: Information technology M&O, sitewide			-			-
LOPS.CDS.10.54: Control room configuration and support						-
LOPS.CDS.10.55: Remote access support						-
LOPS.CDS.10.56: Software fault monitoring, diagnosis, reporting, analysis			20.00			20.00
LOPS.EE.10.50: Electronics Engineering	10.00	10.00		10.00	10.00	40.00
LOPS.FAC.LBSH.50: Electronics Lab						-
LOPS.FAC.LBSH.54: CDS Electronics Shop				10.00		10.00
LOPS.FAC.LBSH.57: 40m Lab						-
LOPS.MGMT.10.50: Management						-
	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>500.00</b>

# Tools to Estimate Travel

- Created a matrix and had supervisors estimate number of trips by employee for each category of travel, both foreign & domestic

Employee	Reasons for Travel	# of Domestic Trips19	# of Domestic Trips20	# of Foreign Trips19	# of Foreign Trips20
Abbott, Benjamin P	Project #1 meetings and work	2.00	2.00	1.00	
Abbott, Benjamin P	Project #2 meetings and work				
Abbott, Benjamin P	Conferences and Workshops	1.00			1.00
Abbott, Benjamin P	Detector Related Work for regular operations				
Abbott, Benjamin P	Employee Recruitment & Development				
Abbott, Benjamin P	NSF Reviews	1.00	1.00		
Abbott, Benjamin P	Outreach				
Abbott, Benjamin P	Specialty Training & Certifications		1.00	1.00	
Abbott, Benjamin P	Supplier Management				

# Tools to Estimate Other Direct Costs

- » NSF LFM has a sample BOE, but it is for construction, not operations
- » Also needed a format we could link to gather all the data in a single tab

Figure 4.2.3-2 Construction Cost Book Sheet Sample Format

Activity Summary						Year			
Estimate: WBS Element: Activity:		Funding Source: WBS Description:		Estimator Name, Date		Estimated By: Date: FY of Estimate			
Personnel Costs Detail: Equipment, Travel, Participant Support Costs Detail		Materials/Supplies, Publication, Consultants, Computer Services, Subawards, Other Costs Detail		Total Base		Contingency: Total W/Contingency			
$A = B + C + I$		$ID = E + F + I$		$(G1 + G2 + G3 + G4 + G5 + G6) + I$		\$0.00      \$0.00      \$0.00			
Personnel Costs Detail (A + B + C) + I									
Exp Code	NSF Code	Resource ID - Price Group	Resource Description	Cost Basis	Labor Hours	Direct Labor	Fringe	Indirect Cost	Total Burdened Labor Cost
Label NSF Budget Category Codes, e.g., A for Senior Personnel, D for Equipment, G.5 for Subawards		Provide Labor Resource Descriptions, e.g. Manager, Mechanical Engineer, Electrical Technician			Provide associated Fringe and Indirect Costs				
Cost Basis: CP-Catalog Price CR-Cost Relationship CE-Engineering Estimate HD-Historical Data VQ-Vendor Quote VE-Vendor Estimate									
Equipment, Travel, Participant Support Costs Detail (D + E + F) + I									
Exp Code	NSF Code	Resource ID - Price Group	Resource Description	Cost Basis	Material Units	Direct Material	Indirect Cost	Total Burdened Material Cost	
Provide Other Direct Cost Resource Descriptions, e.g. Concrete, Design Consultants, Computer Software, Construction Contracts		Show Direct Cost Calculations with Labor Hours and Material Units							
Cost Basis: CP-Catalog Price CR-Cost Relationship CE-Engineering Estimate HD-Historical Data VQ-Vendor Quote VE-Vendor Estimate									
Materials/Supplies, Publication, Consultants, Computer Services, Subawards, Other Costs Detail (G1 + G2 + G3 + G4 + G5 + G6) + I									
Exp Code	NSF Code	Resource ID - Price Group	Resource Description	Cost Basis	Material Units	Direct Material	Indirect Cost	Total Burdened Material Cost	
Provide Equipment, Travel, and Participant Cost Resource Descriptions, e.g. Specialized Equipment, Foreign Travel		Provide Cost Basis Code for estimate methodology, e.g., expert opinion, analogy, parametric, or engineering build-up							
Cost Basis: CP-Catalog Price CR-Cost Relationship CE-Engineering Estimate HD-Historical Data VQ-Vendor Quote VE-Vendor Estimate									
Risk Assessment and Contingency Calculation (G6)									
Risk:	Risk Factors		Risk Multipliers		Risk Adjustments		Total Risk Multiplier:		
Task/Item:							Override Multiplier:		
Cost:							Estimated Contingency Amount:		
Sub-code:							\$0.00		
Provide associated Risk number from Risk Management Plan in PEP, Calculations, and Estimated Contingency Amount									
Statement of Work									
Describe the scope of the specific activity and clarify any items not included and covered elsewhere									
Basis of Estimate									
Provide a narrative explaining the approach to the estimate and any assumptions, research, sources, references, calculations, etc.				Directly attach, reference, or electronically link to any additional supporting information and references, e.g., drawing numbers, technical specification sections, technical requirements, catalog price sheets, vendor quotes, labor rate sources, RSM means tables, etc.					
Provide Source Data and Calculations for the Basis of Estimate, e.g., Labor Rates and Unit Prices referencing Source Material									





# Basis of Estimate templates

<b>PTA Name</b>	<b>LOPS.FAC.LBSH.52: Vacuum Lab</b>							
<b>Statement of Work</b>	Vacuum Lab (Vacuum Preparation and Contamination Control Supplies): 1. Vacuum Preparation - The Vacuum Preparation Lab at Caltech provides an equitable share of support to LLO, LHO, LASTI and the 40m with cleaning, vacuum baking and RGA qualification for UHV parts. 2. Contamination Control Supplies - Contamination Control Supplies are required to support the 8 ISO Class 5 cleanroom and 5 flow-bench facilities at Caltech used for e.g. during optic cleaning, inspection and assembly as well as component testing, inspection and assembly.							
<b>Basis of Estimate Narrative</b>	1. Vacuum Preparation - All estimated costs are for maintenance (repair) and expendables during operation – no fabricated equipment is anticipated and no equipment acquisition is anticipated (other than possibly component replacement if repair is not feasible). 2. Contamination Supplies - The costs listed for contamination supplies are based on catalog pricing and the 2017 spend in support of the areas listed above.							
<b>Estimator Name</b>	Feicht, Romel, McCormick			<b>5yr running total</b>				
<b>Date</b>	7/17/2017		<b>All locations combined:</b>					
			LOPS.FAC.LBSH.52.CIT					
			LOPS.FAC.LBSH.52.HAN					
			LOPS.FAC.LBSH.52.LIV					

Expenditure Type	Resource Description	Estimating Technique	Price per Unit	Tax Rate	Tax Rate	No. of Units FY19	No. of Units FY20	Direct Costs FY21	Direct Costs FY22	Reference
Equipment Maintenance	Vac Prep: Turbo pumps Repair / Replacement	Vendor Quotes		Pasadena	0.095		1			<a href="#">Based on 2017 pricing from</a>
Equipment Maintenance	Vac Prep: Roughing pumps repair /	Vendor Quotes		Pasadena	0.095		1			<a href="#">Based on 2017 pricing from</a>
Supplies - Allocable	Vac Prep: Hand Tools / Misc.	Expert Judgment		Pasadena	0.095	1	1			Engineering estimate
Supplies - Allocable	Vac Prep: Hardware	Expert Judgment		Pasadena	0.095	1	1			Engineering estimate
Supplies - Allocable	Copper CF seals for 16" vacuum bake oven	Vendor Quotes		Pasadena	0.095	20	20			<a href="#">Based on 2017 pricing from</a>
Supplies - Allocable	Copper CF seals for 10" vacuum bake oven	Vendor Quotes		Pasadena	0.095	55	55			<a href="#">Based on 2017 pricing from</a>
Supplies - Allocable	Copper CF seals for 4.50 CF vacuum flange	Vendor Quotes		Pasadena	0.095	5	5			<a href="#">Based on 2017 pricing from</a>
Supplies - Allocable	Copper CF seals for 2.75 CF vacuum flange	Vendor Quotes		Pasadena	0.095	10	10			<a href="#">Based on 2017 pricing from</a>
Supplies - Allocable	Copper wire seals for 27" wire seal ovens	Vendor Quotes		Pasadena	0.095	10	10			Based on 2017 pricing from
Supplies - Allocable	Vacuum plumbing replacement parts	Expert Judgment		Pasadena	0.095	18	18			Engineering estimate
Supplies - Allocable	Bottles of dry nitrogen (200 / 300 bottle size)	Vendor Quotes		Pasadena	0.095	17	17			<a href="#">Based on 2017 pricing from</a>
Supplies - Allocable	cleanroom cleaning services	Expert Judgment		Pasadena-non	0	1	1			Engineering estimate
Supplies - Allocable	laminar flow bench maintenance	Expert Judgment		Pasadena	0.095	1	1			Engineering estimate
Supplies - Allocable	Cleanroom HEPA maintenance	Expert Judgment		Pasadena	0.095	1	1			Engineering estimate
Supplies - Allocable	Electronics and Cleaning Equipment Repair &	Expert Judgment		Pasadena	0.095	1	1			Engineering estimate
Supplies - Allocable	Rolls of Hi Vacuum Foil (thick)	Expert Judgment		Pasadena	0.095	6	6			Engineering estimate
Supplies - Allocable	cleanroom wipes (valutek wet) pack of 50	Analogy Estimating		Pasadena	0.095	6	6			<a href="#">VQ144-FY17 Actuals (based</a>

# Basis of Estimate Dissemination

- Created a tab for each lowest level WBS element, then split these up into workbooks by proposal section, with a tab for each lowest-level WBS
- Assigned workbooks to proposal section leaders to gather information from relevant budget managers
- Posted these in our Document Control Center, which is where the updated ones were also turned in; access can be given to cost reviewers and budget managers
  - [Final](#) (BOE-Facilities Labs and Shops-Oram.xlsx, 700.3 kB)
  - [Final](#) (BOE-Facilities Maintenance-Oram.xlsx, 515.8 kB)
  - [Final](#) (BOE-Facilities PLMP-Oram.xlsx, 1.0 MB)
  - [Final](#) (BOE-Gravitational-wave Data Science-Weinstein.xlsx, 77.6 kB)
  - [Final](#) (BOE-LIGO-India Support-Raab.xlsx, 267.8 kB)
  - [Final](#) (BOE-Lab Mgmt and Business Serv-Hansen.xlsx, 268.8 kB)
  - [Final](#) (BOE-Vacuum Supplement-Hansen.xlsx, 300.1 kB)
  - [Final](#) (BOE-Vacuum Systems-Feicht.xlsx, 697.1 kB)

# BOE Data Management

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- Using formulas, gathered data from each tab into a single consolidating tab in each workbook
- Took data from consolidating tab of each workbook into a single document, and added info from Travel BOEs as well
- This gives us a data set we can build pivot tables from to answer all kinds of questions and manage the data
  - » Which kind of estimating technique is used the most?
  - » What equipment have budget managers requested?
  - » What is the sum of all expenditure type “Supplies”?
  - » Which WBS elements are missing a statement of work?
  - » Who did the estimating on a particular WBS element?
  - » Which vendor quotes haven’t been linked yet?

# Budget Iterations and What-Ifs

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- » Once we had a draft budget, we went through cycles of reviewing and proposing adjustments to arrive at our final budget
- » Developed a flexible worksheet tool that allowed real-time what-if changes to be made on the spot in meetings, so we could immediately see the approximate effect of proposed adjustments
- » Lessons learned on this tool:
  - Add columns for proposed changes, and keep original budget so you can calculate variance
  - Add a column for labeling changes, each change with its own label
    - Examples: What if we remove a clean & bake lab, that includes an employee, supplies, and travel? (Label A) ; What if we reduced travel by 10% lab-wide except for travel for detector upgrades? (Level B)
    - Both examples have reductions in travel, and we needed to be able to differentiate impacts of each adjustment

# Budget Adjustments

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- Once adjustments are chosen:
  - » Any final adjustments must only be done at the very bottom level on the BOE templates, then implemented up through the process. Otherwise your direct tie is no longer there, and your BOE is no longer valid.
  - » When budgets are built on the details, it takes longer to make changes, and NSF needs to allow time for that
  - » Can no longer just make a 10% reduction across the board; budget is built on details. To enact a 10% reduction, budget managers must go to their individual BOE documents and remove or reduce specific line items that add up to approximately 10%
- This approach generates much better budget manager buy-in, because they have made the decisions about what is in their budget or what has been cut

# Reporting Tools

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- Gather all budget and employee data in one single document
  - » Budget lines at the lowest WBS element and expenditure type
- Assign extra identifiers to all the data (using cross-walks and look-up formulas) – this is priceless
  - » 1030 code (assigned by expenditure type and employee position)
    - Makes for very easy 1030 preparation and reporting
  - » Each roll-up level of the WBS structure, so the budget could be rolled up and analyzed at any level
  - » Employee FTE amounts, names, titles, and classifications for FTE analysis within each category and lab-wide
    - Easily answer questions like, “how many post-docs are working on this particular project, and how much is that costing?”

# Reporting Tools

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- » Proposal section, so each section of the proposal can easily be tied to the budget for that scope of work
- » Expenditure categories, or cost profiles, so these could be analyzed in groups rather than all the individual expenditure types
- » Geographic location (based on lowest level of WBS structure)
  - CIT/MIT/HAN/LIV/OFF; This way we can tell how much is estimated at each observatory, how much is the MIT subaward, etc
- » Institutional categories required to pass institutional approvals for proposal submission
  - Used for indirect calculations: on-campus, off-campus, fabrication, MIT (based on lowest level of WBS structure)
  - Expenditure types by inclusion or exclusion of MTDC
  - Allows for easy report preparation to answer any questions institution has about budget for proposal, shows compliance with their rules

Questions?



# Speaker Information

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