PMCS/EVMS for CAMs and Project Managers

Jeffrey Kantor
LSST Data Management Project Manager

LSST All Hands Meeting
August 13 - 17, 2012
The LSST Program

- LSST Corporation founded in 2003 as non-profit to construct and operate LSST
- R&D phase funded by grants from NSF, DOE, and private donors
- Program recently became Center within Association of Universities for Research in Astronomy (AURA)
- Currently 37 member institutions
- Construction, commissioning phase is multi-agency program (NSF - lead, DOE, International, Private)
- LSST is a large program by NSF standards and falls under the rules for Major Research Equipment and Facilities Construction (MREFC)
- LSST Camera falls under the DOE rules for Major Item of Equipment (MIE) projects
Why have a PMCS/EVMS?

- Fundamentally about two questions:
  - How much is it going to cost?
  - How long is it going to take?
- All “large” federally funded programs require a process and system to manage this
- Funding agencies have started to require not-to-exceed estimates as early as Preliminary Design Review
- You have to plan to manage change (i.e. escalation) and allow for unplanned occurrences (i.e. risk/contingency)
- The bigger the project the more you need it
- It touches almost everyone in a leadership position, at least those involved in planning and status reporting
LSST Project Controls Process

- The LSST PMCS implements the project controls process in the LSST Cost Estimating Plan (document-313)

- LSST Cost Estimating Plan key sections:
  - Work Breakdown Structure
  - Basis of Estimate
  - Costing Methodology
  - Integration of Scope, Cost, and Schedule
  - Pricing Strategy
  - Labor Pricing
  - Risk as a Contingent Cost
  - Escalation
  - Schedule Contingency
  - Contingency Management
  - Software Estimation
LSST Work Breakdown Structure (WBS)

<table>
<thead>
<tr>
<th>WBS 1</th>
<th>Project Management Office</th>
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<tbody>
<tr>
<td>1.00</td>
<td>PMO Level 2 Milestones</td>
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<tr>
<td>1.01</td>
<td>LSST Program Management Office</td>
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<tr>
<td>1.02</td>
<td>LSST System Engineering</td>
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<td>1.03</td>
<td>LSST Science</td>
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<table>
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<tr>
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<td>DM Level 2 Milestones</td>
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<td>System Management</td>
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<tr>
<td>2.02</td>
<td>System Engineering</td>
</tr>
<tr>
<td>2.03</td>
<td>Alert and Calibration Productions</td>
</tr>
<tr>
<td>2.04</td>
<td>Data Release Production</td>
</tr>
<tr>
<td>2.05</td>
<td>Science User Interface and Analysis Tools</td>
</tr>
<tr>
<td>2.06</td>
<td>Science Data Archive and Data Access Services</td>
</tr>
<tr>
<td>2.07</td>
<td>Processing Middleware and Site Infrastructure</td>
</tr>
<tr>
<td>2.08</td>
<td>Communications and Base Site</td>
</tr>
<tr>
<td>2.09</td>
<td>Data Management System Integration and Test</td>
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<table>
<thead>
<tr>
<th>WBS 3</th>
<th>Camera</th>
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<tbody>
<tr>
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<tr>
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<td>System Management</td>
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<td>3.02</td>
<td>Systems Engineering and Design Integration</td>
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<td>3.03</td>
<td>Science Raft System</td>
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<td>Corner Raft System</td>
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<tr>
<td>3.05</td>
<td>Optics</td>
</tr>
<tr>
<td>3.06</td>
<td>Camera Body and Mechanisms</td>
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<tr>
<td>3.07</td>
<td>Cryostat</td>
</tr>
<tr>
<td>3.08</td>
<td>Control System and DAQ</td>
</tr>
<tr>
<td>3.09</td>
<td>Camera System Integration and Test</td>
</tr>
<tr>
<td>3.10</td>
<td>Camera Observatory Integration &amp; Test</td>
</tr>
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<table>
<thead>
<tr>
<th>WBS 4</th>
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<tbody>
<tr>
<td>4.00</td>
<td>T&amp;S Level 2 Milestones</td>
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<tr>
<td>4.01</td>
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<td>4.02</td>
<td>Telescope System Engineering</td>
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<tr>
<td>4.03</td>
<td>Summit Facilities and Infrastructure</td>
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<td>4.04</td>
<td>Dome</td>
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<td>4.05</td>
<td>Telescope Mount</td>
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<tr>
<td>4.06</td>
<td>Mirror Systems</td>
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<td>4.07</td>
<td>Wavefront and Alignment Sensing</td>
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<td>4.08</td>
<td>Calibration System</td>
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<td>4.09</td>
<td>Reflective Coating System</td>
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<td>4.10</td>
<td>Observatory Control System</td>
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<tr>
<td>4.11</td>
<td>Telescope Control System</td>
</tr>
<tr>
<td>4.12</td>
<td>Utilities and Support Equipment</td>
</tr>
<tr>
<td>4.13</td>
<td>Base Facility and Infrastructure</td>
</tr>
<tr>
<td>4.14</td>
<td>Telescope Integration and Test</td>
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<table>
<thead>
<tr>
<th>WBS 5</th>
<th>Education and Public Outreach</th>
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<tr>
<td>5.00</td>
<td>EPO Level 2 Milestones</td>
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<tr>
<td>5.01</td>
<td>System Management</td>
</tr>
<tr>
<td>5.02</td>
<td>EPO Database and Data Access Services</td>
</tr>
<tr>
<td>5.03</td>
<td>Infrastructure for Citizen Science</td>
</tr>
<tr>
<td>5.04</td>
<td>Classroom / Online Research Toolkit</td>
</tr>
<tr>
<td>5.05</td>
<td>Visualization including Science Museums</td>
</tr>
<tr>
<td>5.06</td>
<td>User Interfaces</td>
</tr>
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</table>

<table>
<thead>
<tr>
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<th>Commissioning</th>
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<tr>
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<td>Commissioning Level 2 Milestones</td>
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<td>6.01</td>
<td>Commissioning Management</td>
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<tr>
<td>6.02</td>
<td>System Integration &amp; Test</td>
</tr>
<tr>
<td>6.03</td>
<td>Science Verification</td>
</tr>
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</table>
Project Controls Roles/Responsibilities

- Project Managers define WBS structure and assign elements to Cost Account Managers (CAMs)
- CAMs are responsible for estimates in their WBS
- Technical experts in each area estimate effort, cost, schedule
- Each lowest level WBS element is composed of 1 – n activities, each activity is cost-estimated
- Estimation basis and team are documented in PMCS and in referenced quotes, models, documentation
- Estimate type is also captured in PMCS
  - For purchased elements, use catalog price (CP), vendor estimate (VE) or vendor quote (VQ)
  - For custom elements, use historical data (HD) or engineering estimate (EE)
- Estimates are developed in both Base Year and Then-Year $
- Standard typical costs (e.g. for travel) are used across projects
Integration of Scope, Cost, Schedule

- As the team defines tasks within the lowest-level elements of the WBS, several things are done simultaneously:
  - Each of the tasks is scheduled and inter-task dependencies are captured
  - Resources and units are assigned to all activities
  - The estimates are documented with a Basis of Estimate (BOE)
  - Loading curves are assigned as appropriate (linear is default)
  - Risk factors are assigned to provide basis for contingency estimation
  - Codes are assigned to document funding source, method of procurement, location of work, etc.

- Values are selected from a single database with WBS, activity, resource, and coding data dictionaries
  - This provides total integration of the cost estimate and the project schedule
  - Calculations are made to apply critical path method scheduling, cost escalation, and risk and contingency
  - The cost and resource loaded project schedule provides the means to analyze cash flow, resource levels, earned value, and what-if scenarios
Pricing strategy uses pricing groups

- LSSTC has 37 institutions, about 1/3 are participating in construction/commissioning project
- Each has multiple Labor and Non-labor resource categories
- Categories and rates fall into natural pricing groups
  - DOE-Lab, LSSTC, NOAO, University, (Premium – not used)
- Pricing groups are blended based on actual rates provided by institutions and weighted by institutional proportion of work
- PMCS has 58 Labor categories, 40 Non-labor categories
- Individual rates are captured for Direct, Labor Fringe, Indirect (for each of Labor, Travel, Materials, Subcontract)
- Rates are updated annually
- Labor estimates cover fully burdened rate at 1800 hours/year to account for off-project time
Risk as a contingent cost

- Contingency estimates based on a standardized risk analysis
- Complete set of standardized risk factors is part of the cost estimate for each activity

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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Risk Percent</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>4</td>
<td>2%</td>
</tr>
<tr>
<td>5</td>
<td>1%</td>
</tr>
</tbody>
</table>
Escala@on (aka inflation)

- Applied annually, but can apply at any granularity financial period
- Individual % for each type
  - Concrete
  - Construction
  - Energy
  - Engineering
  - Equipment
  - Steel
  - Travel
- Initially used OMB factors, but are too low by comparison with historical data
- Based on external review recommendations now using higher %s
**Software Estimation Process**

(UML + FPA + COCOMO + Actuals)

1. Architectural component counts are extrapolated from Use Cases, Activities, and the Domain Model during Analysis and Design.
2. The spreadsheet model maps the various technology component architecture categories to the traditional Function Point counting categories (including level of complexity decisions).
3. The model processes developer counts of component architecture categories as traditional category counts.

1. The Sizing Model is used to adjust Equivalent Function Points (EFP) to provide credit for software reuses (i.e., use of a framework, object-oriented inheritance).
2. The Sizing Model processes EFPs to Equivalent Kilo-Source Lines of Code (EKSLOC).

1. The Estimation Model accepts EKSLOC, constraints and rates, and a Development Process model to produce Schedule and Time-Phased Resource estimates.

Iterate with real data


Infrastructure Sizing is Requirements-driven

LSST Science and Project Sizing Inputs
LSE-81
Explanation:
LSE-82
[Dubois-Felsmann, Axelrod]

DM Compute Sizing
LDM-138
Explanation:
LDM-140
[Lim]

DM Storage & I/O Sizing
LDM-141
Explanation:
LDM-139
[Becla]

Network Sizing
LDM-142
Explanation:
LSE-78
[Lambert]

DM Site Specific Infrastructure Architecture/Design/Costs
LDM-144
Explanation:
LDM-143
[Freemon]

DM System Design
LDM-148
DM Applications Design
LDM-151
DM Middleware Design
LDM-152
DM Database Design
LDM-135

LSST Science Requirements
LPM-17
LSST System Requirements
LSE-29
Observatory System Specs
LSE-30
DM Subsystem Requirements
LSE-61
Community Access White Paper
Document-5373

DM System Design
LDM-148
DM Applications Design
LDM-151
DM Middleware Design
LDM-152
DM Database Design
LDM-135

DM Infrastructure Design
LDM-129

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Implementing PMCS II in Primavera

- Risk and Contingency
  - Added user defined fields for risk-based contingency factors and layouts for data entry
  - Created user defined fields for risk and contingency calculation results
  - Added global changes to calculate risk adjustments and contingency and store them in user defined fields

- Escalation and rates
  - Created resources.xls sheet to calculate direct, fringe, indirect and total burdened escalated rates by resource, pricing group, and escalation type (and total burdened rate in base-year)
  - Used SDK to import rates into Primavera
  - Created global changes to toggle between then-year and base-year total burdened rates, to calculate and store base-year values, and to calculate and store values for direct, fringe, indirect
  - Created reports to show then-year and base-year values

- WBS, Cost, and Basis of Estimates
  - Created Notebooks for WBS Definitions, Activity Scope, and Activity BOE
  - Created Cost Reports with full detail by activity
Example: Detailed Cost Report

**Activity Summary**

<table>
<thead>
<tr>
<th>Labor</th>
<th>Non-Labor</th>
<th>Materials/Supplies</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A, B, C) + I</td>
<td>(D, E, F2, G5, G6) + I</td>
<td>(G1 - G4, F1) + I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Cost Base</th>
<th>Estimated Contingency Cost</th>
<th>Total Cost w/Contingency</th>
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<tbody>
<tr>
<td>$161,024</td>
<td>$0</td>
<td>$421,565</td>
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<tr>
<td>$582,589</td>
<td>$233,036</td>
<td>$815,625</td>
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**Risk Assessment and Contingency Calculation**

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<tr>
<th>Risk Factors</th>
<th>Risk Multipliers</th>
<th>Risk Adjustments</th>
<th>Total Risk Multiplier</th>
<th>Override Multiplier</th>
<th>Estimated Contingency Amount</th>
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<tr>
<td>Technical</td>
<td>8</td>
<td>0.02</td>
<td>0.16</td>
<td></td>
<td></td>
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<tr>
<td>Cost</td>
<td>8</td>
<td>0.02</td>
<td>0.16</td>
<td></td>
<td></td>
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<tr>
<td>Schedule</td>
<td>8</td>
<td>0.01</td>
<td>0.08</td>
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**Labor Costs Detail (A B, C) + I**

<table>
<thead>
<tr>
<th>Exp Code</th>
<th>NSF Code</th>
<th>Resource ID - Price Group</th>
<th>Resource Description</th>
<th>Cost Basis</th>
<th>Labor Hours</th>
<th>Direct Labor</th>
<th>Fringe</th>
<th>Indirect Cost</th>
<th>Total Burdened Labor Cost</th>
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<tbody>
<tr>
<td>LST-University</td>
<td>DM Sr. Technician</td>
<td>HD</td>
<td>1050</td>
<td>$75,492</td>
<td>$26,422</td>
<td>$59,110</td>
<td>$161,024</td>
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**Materials/Supplies Costs Detail (G1 - G4, F1)**

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<tr>
<th></th>
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<tr>
<td>CEDE-LSST-NOAO</td>
<td>Local Area Network</td>
<td>HD</td>
<td>371</td>
<td>$408,782</td>
<td>$0</td>
<td></td>
<td></td>
<td>$408,782</td>
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<tr>
<td>MNS-LSST-NOAO</td>
<td>Shipping to Chile</td>
<td>HD</td>
<td>5</td>
<td>$4,958</td>
<td></td>
<td>$441</td>
<td></td>
<td>$5,400</td>
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<tr>
<td>CIND-LSST-NOAO</td>
<td>Capped Indirect</td>
<td>HD</td>
<td>3</td>
<td></td>
<td></td>
<td>$7,383</td>
<td>$7,383</td>
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</tr>
</tbody>
</table>

*Cost Basis: CP-Catalog Price CR-Cost Relationship EE-Engineering Estimate HD-Historical Data VQ-Vendor Quote VE-Vendor Estimate*

- Each costed activity has 2 pages
- First page is summary activity information, including WBS, risk and contingency information, and resource estimates
Example: Detailed Cost Report

**Statement of Work**

Activity Scope:

Prior to Construction, during R&D phase the detailed design was performed, the RFPs written, vendor responses reviewed and vendor selected. The equipment will be acquired in just-in-time yearly acquisitions, to minimize cost. The detailed acquisition schedule is documented in the Estimation of Infrastructure Costs document-6284.

In this activity the following are performed:

- Acquire/Accept from Vendor at Archive Center
- Configure Hardware and Software at Archive Center
- Burn In Test at Archive Center
- Package and Ship to La Serena
- Unpack and set up at Base Facility

**Basis of Estimate**

Labor Basis:

- 15 years AURA experience in deploying, managing, maintaining data communications at CTIO.
- 22 years NCSA experience in deploying, managing, maintaining data communications at NCSA.

Non-Labor Basis:

- Vendor quotes, refer to Estimation of Infrastructure Costs document-6284 and related quotes.

Travel Basis:

- All travel is costed in WBS element 02.01 System Management.

- Second page is description of basis of estimate and scope of activity
- External documents are referenced here
Each month we are required to submit a report to NSF including details on schedule, earned value, and contingency.

Note: Camera team already has DOE-certified PMCS/EVMS at SLAC for DOE reporting.
Earned Value Management

- Earned Value Management (EVM) is the process of defining and controlling a program/project so that program objectives are met, such as:
  - Deliveries on-time
  - Programs on-cost
  - Profit met for company goals

Our Earned Value Management System (EVMS) is what we use to schedule, plan and monitor performance to both schedule and cost.

**Planning:**
- What work *will* you perform? How many? How much work?
- When *will* you perform it?
- How much *will* you spend to perform it?

**Monitoring:**
- What work *did* you perform? How many? How much work?
- When *did* you perform it?
- How much *did* you spend to perform it?
How does the EVMS do this?

- Captures an integrated “baseline plan” (technical scope, schedule, budget)
- Measure the work accomplishment to that baseline plan
- Capture actual costs spent to complete the work
- Identify situations not previously recognized/planned
  - Work performed early? On schedule? Late?
  - Costs for work accomplished were less than? On? More than budgeted?
- Performance traceability to organizations and to deliverable products
EVM Key Terminology

• **Budgeted Cost for Work Scheduled (BCWS)**
  
  – The time-phased, “planned value” of the work **to be accomplished** (e.g., one widget planned to cost $100)

• **Budgeted Cost for Work Performed (BCWP)**
  
  – The “planned value” of the work that **has been accomplished**
  
  – Synonymous with *Earned Value* (e.g., one widget *earns* $100 when accomplished)

• **Actual Cost of Work Performed (ACWP)**
  
  – The costs actually incurred and recorded in accomplishing the **work performed** (e.g., the costs [labor and non-labor] spent to produce the widget)

• **Budget at Completion (BAC)**
  
  – The total authorized budget for accomplishing the work
  
  – Total BCWS = BAC
EVM Key Terminology (cont.)

- **Schedule Variance (SV)**
  - $BCWP - BCWS$

- **Cost Variance (CV)**
  - $BCWP - ACWP$

- **Estimate To Complete (ETC)**
  - A time-phased estimate of costs to complete all remaining work from a point in time to completion

- **Estimate At Completion (EAC)**
  - The actual costs (ACWP) to date plus the estimated cost to complete (ETC) all authorized work

- **Variance At Completion (VAC)**
  - The difference between the BAC and the EAC
Performance Measurement/EV

“Budget Versus Actuals”
Overrunning Cost Or Ahead Of Schedule?

Actual Cost

$ $ $

Time

Total Budget

Time Now

Ahead of Schedule?

Budget

Cost Overrun?

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Next Step - Implementing EVMS and Reporting

- LSST Earned Value Management System leverages ATST
  - Cobra integrated with Primavera
  - Cobra becomes “system of record”, maintains baselines
- LSST system will retain ability to do “what-if” scenarios in Primavera while not modifying the baseline in Cobra
- Key questions for LSST: What level/type of EV milestones?
  - Process, deliverable/milestone, and/or time driven
  - EV in context of algorithm evolution in Data Management
  - DOE and NSF EV reporting, combined or integrated?
ATST has interfaced the AURA accounting system to COBRA and set up an NSF monthly reporting package.
ATST has also set up the tool set for monthly reporting
Example of ATST monthly CPR report and earned value chart

<table>
<thead>
<tr>
<th>WBS</th>
<th>CURRENT PERIOD</th>
<th>CUMULATIVE TO DATE</th>
<th>AT COMPLETION</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>PLANNED</td>
<td>EARNED</td>
<td>ACTUAL</td>
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<td>$139</td>
<td>$294</td>
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<td>$20</td>
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<td>$1,888</td>
<td>$911</td>
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**Notes:**
- BAC: Baseline Actual Cost
- EAC: Estimated Actual Cost

Additional chart showing budget, actuals, and performed values.
PMCS/EVMS Schedule

- Pre-PDR PMCS (prior to August 2011)
  - Update Final Design and Construction/Commissioning Plans in Primavera to “PDR-ready” (all subsystems)
- Post-PDR PMCS (October 2011 – June 2012)
  - Update for Cost and JIM Reviews, NSB briefing
- Pre-construction EVMS Pilot
  - Phase 1 - Set up EV reports with Final Design Phase projects in Primavera and CAS (July – 2012 – December 2012)
  - Phase 2 - Pilot Cobra with Final Design Phase Schedule, train PMs and CAMs (December 2012 – July 2013)
  - Phase 3 - Implement and operate “full” system with separate NSF, DOE EV reporting (November 2013 – July 2014)
- (Phase 4 - Implement combined NSF, DOE EV reporting only if required by funding agencies)