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LIGO - the Evolution of a Project Management Process

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Abstract and Speaker Biography
This presentation examines the challenges facing the project management team of the National Science Foundation's Laser Interferometer Gravitational wave Observatory (LIGO) project at the California Institute of Technology. The team was faced with the challenge of concurrently defining and implementing a functional performance measurement system in only a few short months.

A successful performance measurement system must meet internal and external requirements. In this case, the customer, NSF had a vision of a performance measurement system, but no clear guidelines or criteria defining one. Likewise, Caltech had imposed no clear guidelines either. The LIGO scientific team chose to bring in a project controls team with extensive experience in implementing controls systems on large DOD/DOE/NASA projects. The project controls team decided to borrow the best ideas of C/SCSC (Cost/Schedule Control Systems Criteria). The approach was to implement a system which embodies the spirit of the law rather than keeping to the letter.

You can satisfy all external and internal requirements and still not meet your needs. Most importantly, the LIGO scientific team needed a system they could have confidence in. They needed a system which could turn reams of raw data into the information essential for management. Finally they needed a system which could evolve, offering them desktop capability (information at their fingertips). The project controls team worked hands on with the scientific staff to develop a CPE (Continuous Process Evolution) approach which drew from the maturity of well established systems and offered the flexibility to grow with the program.

Mark Patlan is President of Applied Integration Management, a management consulting company providing project management services on a number of large government contracts. He has led the design and development of integrated cost/schedule systems for programs in aerospace, defense, and energy. Felix Fernandez has over twenty years experience in planning and scheduling on large DOD and NASA programs. Felix is the project controls lead at the LIGO project. He is responsible for guiding the development of the system for the LIGO scientific and management teams and the cultivation of a performance measurement attitude.

Presentation

Program Overview

LIGO is a $365M project initially approved by congress in 1991 with full funding authorized in the fall of 1994. The project objective is to provide physicists, by the year 2001, with two observatories capable of detecting and measuring the gravitational waves predicted by Albert Einstein within the Theory of General Relativity. Gravitational waves are ripples in the fabric of space-time caused by turbulent and/or cataclysmic motion of distant astronomical bodies (i.e. neutron stars, blackholes, supernovas). The project is funded by a grant from the National Science Foundation (NSF) and was awarded to the California Institute of Technology (Caltech) with scientific support from the Massachusetts Institute of Technology (MIT). The laser interferometers, which will perform the subatomic measurements, will be designed and developed by the Caltech and MIT scientific team. The interferometers will be housed in two environmentally controlled facilities designed and constructed by A&E and construction companies with technical oversight and quality assurance provided by the Caltech project management and specialist from the Jet Propulsion Laboratory.

The LIGO observatories are two "L" shaped facilities located 3000 kilometers apart with sites in Hanford, Washington and Livingston, Louisiana. Each arm of the "L" shaped facility will house a 1 meter diameter steel tube that will extend 4km and be maintained in a constant vacuum. The corner building will house the laser light source, vacuum equipment, laboratory and office space. At both ends of each of the 4km vacuum beam tubes, suspended test masses will reflect the laser light and measure the exact distance between the masses. Variations in the distance between masses from arm to arm and from site to site will analyzed and used by physicists to demonstrate the existence of gravitational waves.

Program Management Challenges

NSF required implementation and demonstration of a functional performance measurement system in only a few short months. Caltech offered a project team with extensive scientific abilities, but limited project management experience. A successful performance measurement control system (PMCS) had to meet internal and external requirements.

External Requirements

NSF had a vision of a performance measurement system, but no formal requirements (such as DOD Mil-Std or DOE 4700 criteria.) Therefore, the project controls team was faced with concurrently defining and implementing the system requirements and processes.

Internal Requirements

Caltech had no institutional guidelines or infrastructure to support a PMCS implementation. Internal processes were not defined to provide guidelines for the development of cost and schedule planning. The integration of cost and schedule planning with financial (actual costs) data had not previously been a requirement at the institute. Once again, the project controls team was required to concurrently define, implement, and train internal management on the management system.

Schedule Challenges

Facilities work (over 50% of program) is accomplished by outside subcontractors - always a management challenge. Rather then contracting with one major construction contractor, Caltech was going to review all tasks to be accomplished at each site and structure individual subcontracts based on evolving requirements. Schedules for the civil construction at each of the two sites are still evolving as contract structures and strategies are determined. Until subcontracts can be negotiated and finalized, most civil construction schedule tasks are "best guess" placeholders.

Two of the major equipment contracts would be Fixed Price contracts worth an estimated $40M each. Because of the risk to the project, schedules had to be developed with comprehensively defined significant progress milestones.

Detector and R&D work (internal effort) had to be resource loaded due to scientific resource (manpower) constraints. Qualified experimental physicists with experience in this very specialized field are limited. Therefore careful consideration had to be given to tasks assignments and priorities.

Tools used during the early phase of program deemed were inadequate for maintaining a PMCS. The selection and the implementation of the tool had been accomplished by members of the scientific team and upon further review of the long term requirements it was determined that the scheduling tool change should be the first step in the implementation of the new PMCS.

Cost Challenges
Caltech had an NSF approved cost estimate which would serve as the basis for the performance measurement baseline. However, the cost estimate had some quirks which would have to be addressed before it would be useful:

- The cost estimate contained a priced detail list of materials (most of which would be provided by subcontractors).
- Labor estimates were based on man-months by fiscal year (rather then man-hours tied to a schedule.)
- The cost book was in constant FY94 dollars w/ escalation calculated below the line.
- The cost book contained fully-burdened rates (not separated by direct and indirect costs.)
- Cost book time-phasing was based on commitments rather than planned dates.

Management Requirements
The Caltech scientific team needed a system which could turn reams of raw data into information to augment management. In addition, LIGO wanted a system which could evolve to desktop capability - offering the scientific team information at their fingertips.

Meeting the Challenge
The Caltech scientific team chose to bring in a project controls team with extensive experience in implementing controls systems on large DOD/DOE/NASA projects. The project controls team combined extensive experience in project planning/scheduling, cost control/performance measurement, and database management.

External Success
The Caltech project controls team decided to borrow the best ideas of C/SCSC (Cost/Schedule Control Systems Criteria). The approach was to implement a LIGO project management system which embodied the best of earned value systems.

The Caltech project team implemented well-developed management procedures (previously used on other projects) for:

- scope authorization and responsibility assignment
- baseline scheduling methodologies
- work package planning
- progress procedures and reporting
- change management

The procedures were tailored to the needs of the LIGO project and documented in the system description.

Internal Success
Internal success can be measured by the level of understanding that is evolving on the part of the previously inexperienced scientific team members. Schedule and budget databases are updated monthly, status is reviewed by the combined team at mid-month and tabular and graphic output is used to support presentations, work around assessments and change request documentation. The new systems have gained acceptance and a positive attitude toward performance measurements, its applications and its benefits, is being demonstrated by the most reluctant of the scientific team members.

Schedule Success
During an early evaluation of the original schedule database, it was noted by the project control team that sometimes unconventional methods were used to define and constrain tasks and activity relationships. Because the schedule database was also going to provide the basis for calculating performance measurement, a decision was made to reconstruct the database and to reassess each activity and relationship. During the updating process, efforts were made to include progress milestones and/or tasks which could be quantifiably statused. Tasks were cross-referenced to the work package

numbers and performance measurement techniques were considered as tasks were defined. The database was successfully updated and reconstructed and confidence was established in the new database and the new scheduling tool. For all the internal scientific tasks, where qualified resources were limited and constraining, resource loading in the original schedule database was preserved and verified.

Cost Success

Since the cost estimate was not in a format useful for the LIGO PMCS, a custom routine was developed to electronically transfer the estimate to the cost system, where it could be edited. The transfer routine had to simultaneously revise data when transferring from the old system to the new:

- A resource hierarchy was defined to summarize detailed estimate line items to higher levels.
- Man-months were converted to man-hours for planning.
- Estimate dollars were calculated into direct and indirect amounts.
- The estimate was time-phased according to the current plan.

Once the Caltech controls team demonstrated traceability between the new estimate and the old, the cost estimate was revised to current expectations and presented to the NSF.

After the cost estimate was revised and approved, it was run through another custom routine. The estimate-PMB routine combined the estimate with labor resource-loaded schedules (for in-house effort) to produce a performance measurement baseline, which was vertically integrated with the schedule. In addition, the estimate-PMB conversion routine generated links between cost workpackages/milestones and their corresponding schedule activities, to ensure that cost performance was derived directly from schedule progress.

Finally, another custom routine was developed to automate integration with the Caltech financial system. The actual costs routine takes a periodic actual costs feed from finance and allows posting of actual costs against individual workpackages and cost elements.

Management Success

Because it was essential that management have access to a system which could turn reams of data into useful management information in a timely manner, the Caltech controls team selected cost and schedule systems which were based on commercial database systems. This allows the team to present data quickly from flexible cost/schedule reporting systems, or to quickly get data from the system into analysis tools such as spreadsheets or visual query tools.

Conclusions

The successful implementation of Caltech's LIGO PMCS demonstrates that a successful management system can be implemented in a short-time given:

- top management commitment and buy-in
- a focused understanding of the project requirements
- well-developed and documented management processes/procedures
- a skilled and experienced planning, cost, and systems team
- close involvement and education of the technical team
- continuous review of management systems and procedures

The ongoing success of the system requires commitment by top management and the technical team through out the life of the project.

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Program Overview

- Laser Interferometer Gravitational-wave Observatory, at $365M, is the largest project funded by a grant from the National Science Foundation (NSF)
- The project was initially approved by congress in 1991 with full funding authorized in the fall of 1994

Program Overview

- LIGO is a physics research project with an objective of searching for the gravitational waves predicted by Einstein within the Theory of General Relativity
- Gravitational waves are ripples in the fabric of space-time caused by turbulent or cataclysmic motion of large astronomical masses

Program Overview

- picture of neutron stars

Program Overview

- The project was awarded to the California Institute of Technology with scientific participation by the Massachusetts Institute of Technology
- The Caltech and MIT team is responsible for R&D and design/development of the laser interferometers

Program Overview

- picture of 40 meter

Program Overview

- Caltech, with engineering support from JPL, is responsible for technical oversight and quality assurance of the development of the observatory facilities
- Two facilities will be designed/constructed, by subcontractors, that will provide the appropriate vacuum environment for the interferometers to perform sub-atomic measurements

Program Overview

- aerial picture of Hanford

Program Overview

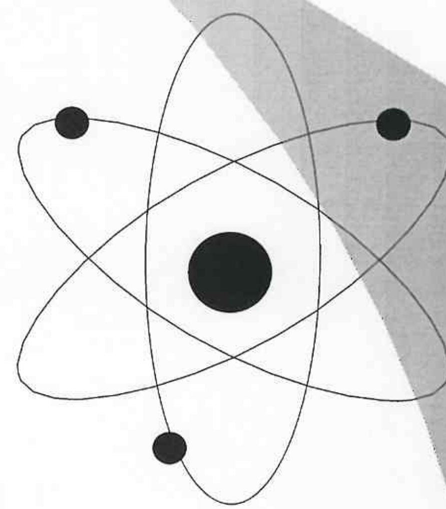
- aerial picture of Livingston

Program Overview

- sketch of equipment within facility

Program Management Challenges

- NSF required a functional performance measurement system in only a few short months.
- Caltech offered extensive scientific abilities, but limited project management experience.



External Requirements

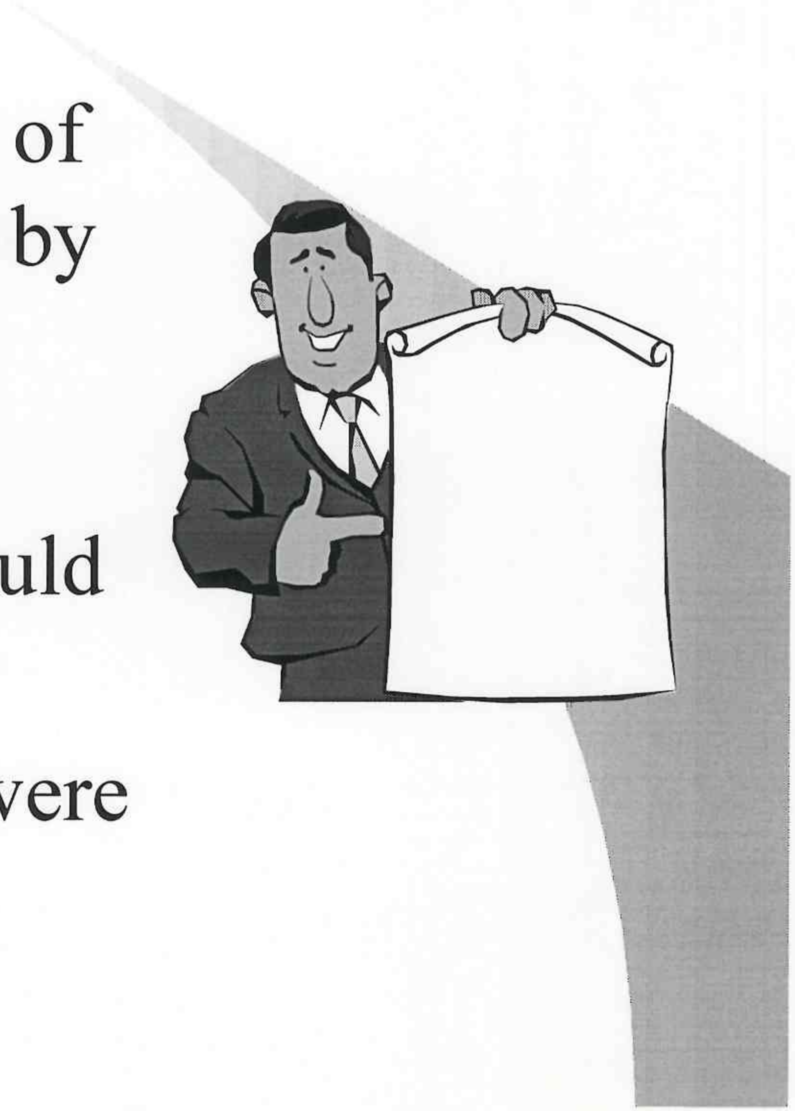
NSF had a vision of a performance measurement system, but no formal requirements.

Internal Requirements

Caltech had no institutional guidelines or infrastructure to support a PMCS implementation.

Schedule Challenges

- Facilities work (over 50% of program) is accomplished by outside subcontractors.
- Two major equipment contracts ($40M each) would be fixed price.
- Detector and R&D work were internal and resource constrained.

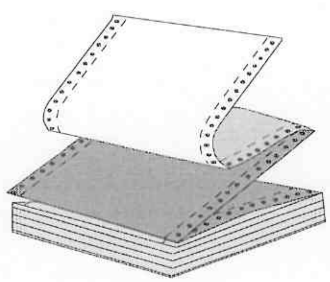


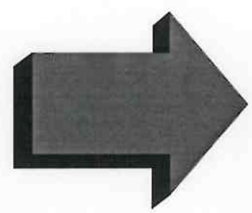
Cost Challenges

- Cost estimate contained priced detail list of materials.
- Labor estimates were based on man-months by fiscal year.
- Cost book was constant FY94 dollars.
- Cost book was fully-burdened rates.
- Cost book was time-phased by commitments.

Management Requirements

System needed to turn data into information.





Meeting the Challenge

- Extensive experience implementing controls for DOD/DOE/NASA.
- Extensive experience in project planning/scheduling, cost/performance measurement, and database management.

External Success

- Borrow the best of earned value (C/SCSC).
- Implement well-developed, tried-and-tested management procedures.

Internal Success

Internal success is measured by the level of understanding, acceptance, and use by the technical team.

Schedule Success

- Reassess each activity and relationship.
- Include progress milestones or quantifiable tasks.
- Cross-reference to the performance measurement system.
- Verify and preserve resource loading.

Cost Success

- Simultaneously revise and transfer the estimate.
- Vertical integration between cost and schedule.
- Derive performance from schedule progress.

Management Success

Cost/schedule systems based on commercial database products.

Conclusion - success factors:

- Top management commitment and buy-in
- Focused understanding of project requirements
- Developed/documented procedures
- Skilled controls team
- Close involvement/education of technical team
- Continuous review of systems