LIGO

Summary Remarks: Management of LIGO

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LIGO

This Presentation

- **Introduction to LIGO**
- **How we have managed LIGO**
- **How NSF has managed LIGO**

- Responses to Advance Questions

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LIGO Scope and Costs

- The Laser Interferometer Gravitational Wave Observatory (LIGO) is:
  - » a joint project of Caltech and MIT
  - » construct and operate two observatories with 4 km interferometers
  - » detect gravitational waves
  - » initiate ground-based gravitational wave astronomy
- LIGO is supported through the NSF Division of Physics/Gravity Program
  - » Construction cost $292 million (Major Research Equipment)
  - » Commissioning, early operations and R&D cost $79 million
  - » This funding covers 1994 - 2001

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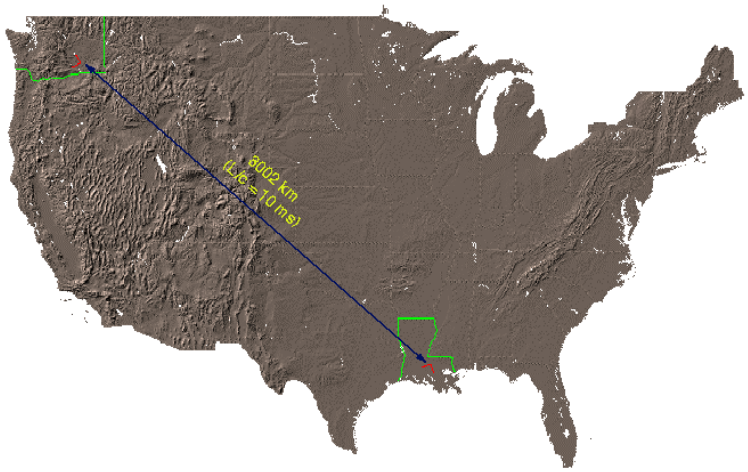
Long Baseline Interferometry



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LIGO Observatories

LIGO (Washington)

LIGO (Louisiana)

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LIGO Vacuum System

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LIGO 4 km Beam Tubes

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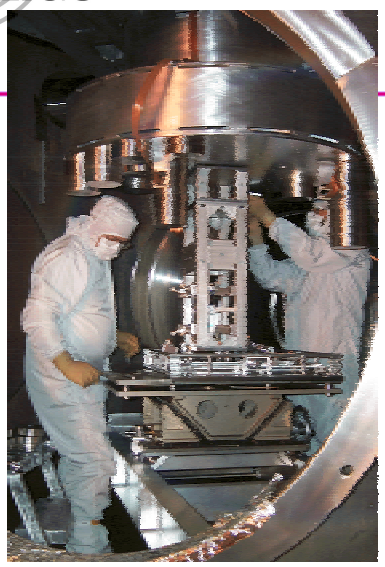
Optics Installation



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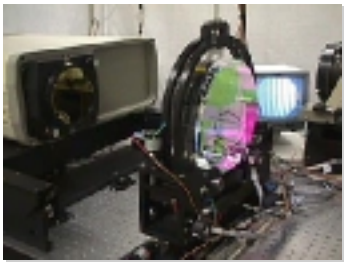
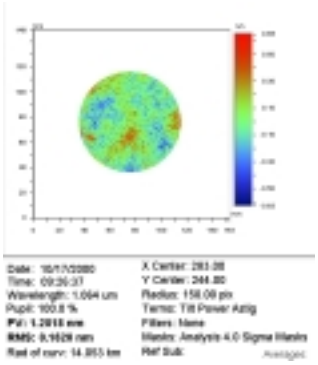
LIGO Fused Silica Optics





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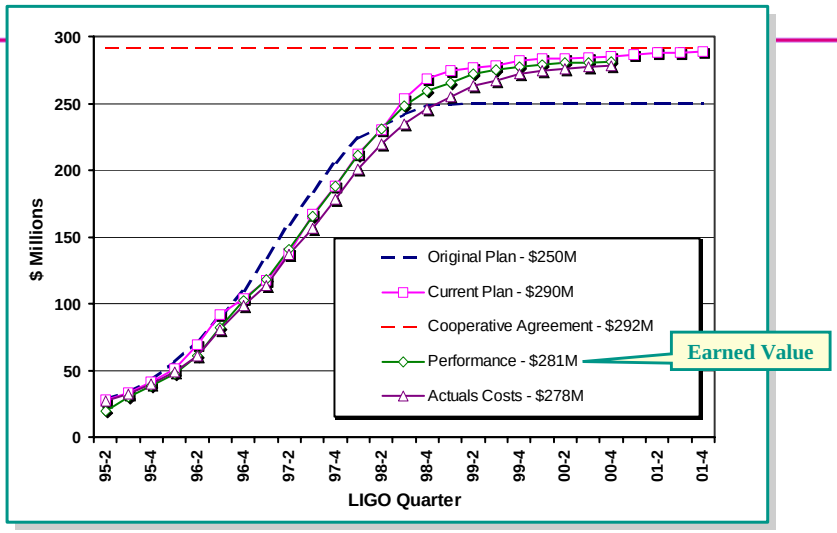
LIGO Schedule

1996	Construction Underway	(mostly civil)
1997	Facility Construction	(vacuum system)
1998	Interferometer Construction	(complete facilities)
1999	Construction Complete	(interferometers in vacuum)
2000	Detector Installation	(commissioning subsystems)
⇨ 2001	Commission Interferometers	(first coincidences)
2002	Sensitivity studies	(initiate LIGO I Science Run)
2003+	LIGO I data run	(one year integrated data at $h \sim 10^{-21}$)
2006+	Begin 'advanced' LIGO installation	

Cost Schedule Performance



Features of the LIGO Construction Project

- University (Caltech+MIT) managed, no national laboratory
- Two green field sites
- Carried out as two major subprojects
  - » 2/3 of the project constructs buildings, clean labs, vacuum system designed for ultimate terrestrial detectors
  - » 1/3 of project constructs initial detectors

LIGO Features of the LIGO Construction Project

- Organized and executed like a bridge building project
  - » Product oriented Work Breakdown Structure (WBS)
  - » Scope and technical configuration defined and controlled
  - » Cost and schedule integrated into a performance measurement baseline with earned value analysis
  - » Contingency funds managed centrally through a Change Control Board
  - » Organization matches WBS
    - – Subsystem managers responsible to deliver products
  - » Subcontractors managed rigorously
  - » Scientists fully integrated and aware of Voltaire's maxim **"le mieux est l'ennemi du bien"**
    - – Scientists did not destabilize project but were also the source for project repair and workaround
- Big Science culture new to NSF and to Caltech/MIT scientists

LIGO What LIGO Team Has Done

- Construction
  - » Executed a ~$300 technical construction project
  - » Adapted big science methods from DOE to an NSF project
- Operating a scientific program
  - » Organized a ~30 institution, ~300 scientist international collaboration to carry out the
    - – observational science and
    - – advanced R&D

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What NSF Has Done

- Through the Gravity Program, NSF has adapted elements of the same DOE model to an NSF environment to create an oversight function for LIGO
- Cooperative Agreement and Project Management Plan created the formal framework
- A **dedicated** program officer led the oversight and structured NSF review
- Semiannual project reviews during construction used a **standing** committee with slowly varying membership to provide review of progress
- Program officer employed an internal multidisciplinary team to coordinate NSF reviews and approvals with periodic meetings
  - » Gravity program, grants and agreements, legal, public affairs, government affairs, property management, budget,…

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Responses to Questions

"womb to tomb“ – Planning, Construction, Operations, …

- 1994 National Science Board recognized need to transition from construction to operation of LIGO. They authorized:
  - » Preconstruction R&D - $20 million – through FY 1999
  - » Construction - $272 million (Major Research Equipment) – through FY 1999
  - » Early operations and commissioning - $69 million – FY 1997 – 2001
- NSF Physics has done well in working with LIGO to assure a smooth transition from construction to early operations
  - » DOE high-energy physics experience in NSF program office and LIGO management provided the template

“…resources to advance the science…”

- LIGO was created as a capability
  - » LIGO is not a single attempt to observe with the initial interferometers
  - » 2/3 of investment is in the site, special buildings and vacuum system
    - – these are designed to house detectors whose sensitivity is close to the terrestrial limits
- 1996 NSF McDaniel panel on use of LIGO led to:
  - » LIGO community organized as a LIGO Scientific Collaboration (LSC) to carry out science
  - » LIGO Laboratory created to operate LIGO and manage program
  - » funding for R&D toward next generation detectors
    - – NSF has provided $10.2 million to LIGO – FY 1997 – 2001
    - – LIGO community also funded at additional ~$4 million/year
    - – NSF funds universities and LIGO Lab provides review and program integration and infrastructure
- 2002 – 2006 program for initial science run and R&D under review at NSF now
- NSF Physics/Gravity and LIGO have managed an appropriate balance between facility imperatives and scientific advancement

LIGO "…strengths…weaknesses… supporting…astronomy…"

- LIGO is an NSF Physics/Gravity activity
  - » LIGO provided first very large project example for NSF
  - » LIGO and NSF management of LIGO has been successful in project execution
- NSF LIGO experience has not been **formally** spread across NSF
- NSF management consciously encouraged LIGO model in managing ALMA
- ALMA is being managed by NSF/AST and NRAO in a manner consistent with LIGO approach
  - » LIGO experience was "borrowed" by NSF/AST and by NRAO
  - » Oversight committee includes experienced LIGO and NASA managers

LIGO Other agencies/NSF outside of Astronomy

- DOE Office of Science has
  - » experience and an established methodology for certifying and assessing large projects
    - – Temple/Lehman review process
  - » established national laboratories with project experience
  - » scientific communities with experience
- LIGO applied **selected** elements of this methodology borrowing from DOE and national laboratory practices
- NSF/LIGO model not formally described to or employed by other NSF programs, even in Physics Division

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Some Observations

- NSF has no established internal standards and processes defining how to develop large projects, assess readiness for construction, measure project performance and transition to operation
  - » Panels advise NSF on these questions for each project individually
  - » Panels are used in different ways by different program officials
  - » Program officials also have full-time jobs administering grant programs
  - » Leads to “approve-review-coach-review-flunk-review-flunk-fire-reorganize-review…” syndrome
    - – Poor substitute for community and agency understanding of big science
- MRE process has no established progression to incubate candidate projects to readiness for construction
- Involvement of the scientific stakeholders in big projects varies greatly in different fields
  - » Particle physicists are very involved in their large projects
  - » Astronomers are less involved during design resolution and construction