LIGO II and Advanced R&D Overview

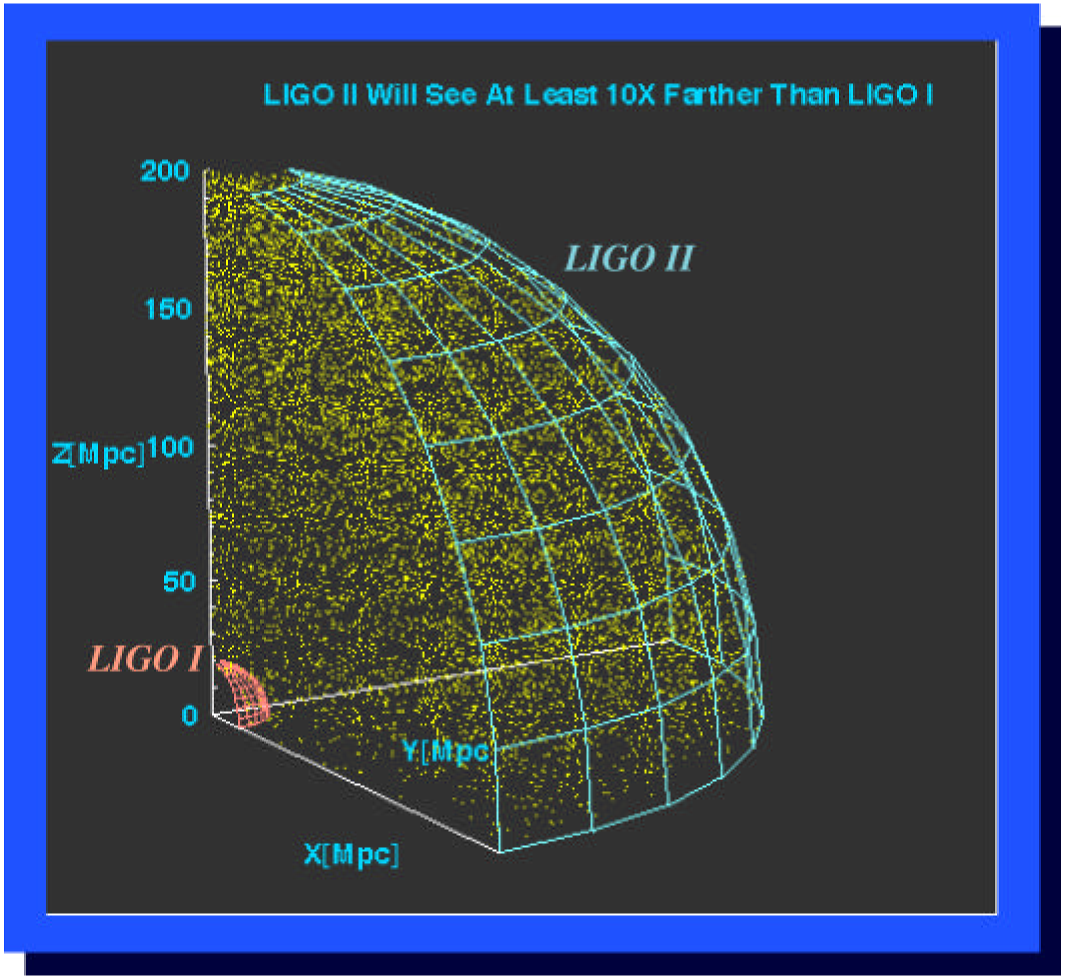
Gary Sanders

Caltech

PAC8 Meeting

May 2000

LIGO II Reach



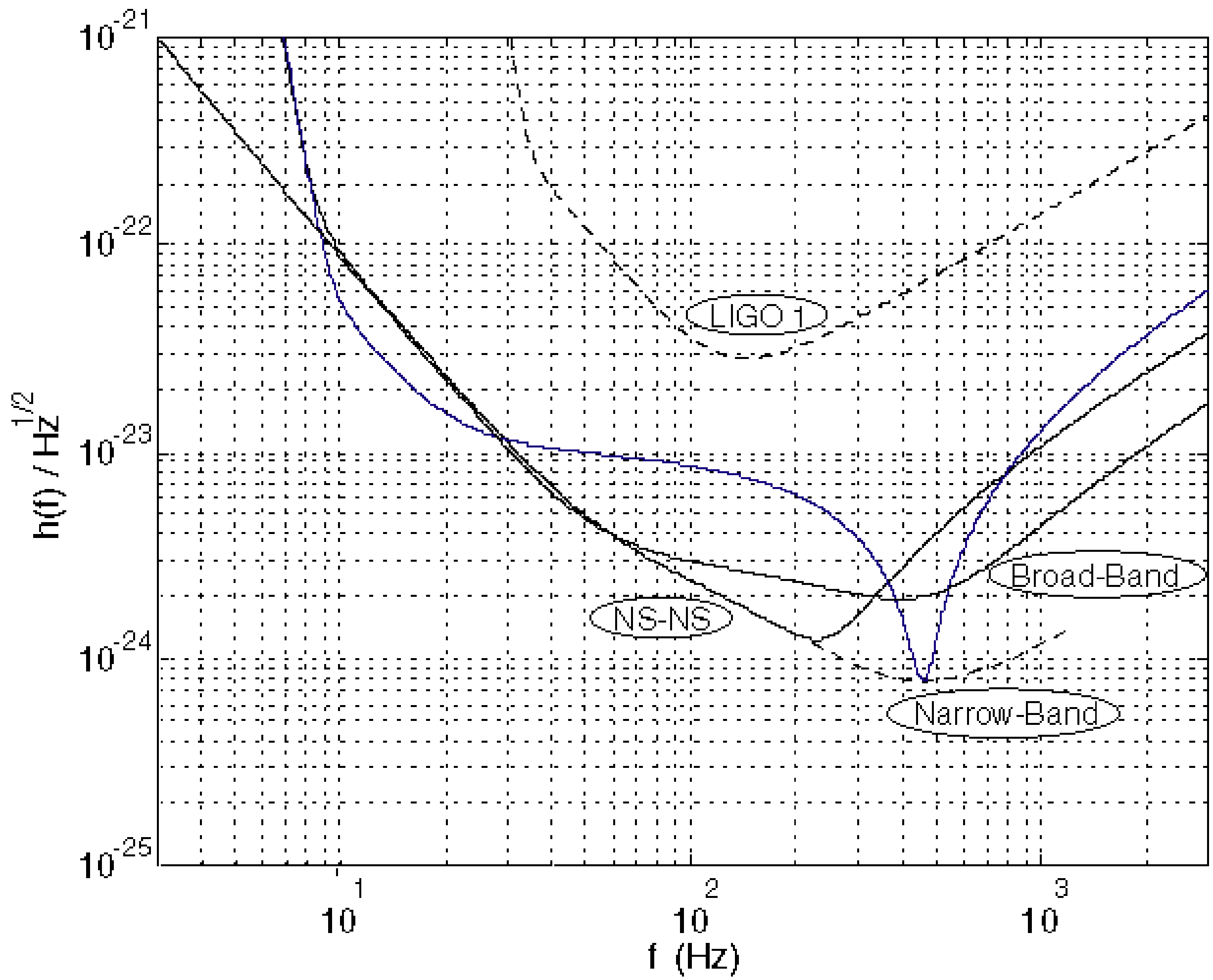
LIGO II Reference Design Parameters / LIGO I Comparison

Subsystem and Parameters	**LIGO II Reference Design**	**LIGO I Implementation**
Comparison With LIGO I Top Level Parameters		
Strain Sensitivity [rms, 100 Hz band]	2×10^{-23}	*10^{-21}*
Displacement Sensitivity [rms, 100 Hz band]	8×10^{-20} m	*4×10^{-18} m*
Fabry-Perot Arm Length	4000 m	*4000 m*
Vacuum Level in Beam Tube, (Vacuum Chambers)	$< 10^{-6}$, ($< 10^{-7}$) torr	*$< 10^{-6}$ torr*
Laser Wavelength	1064 nm	*1064 nm*
Optical Power at Laser Output	180 W	*10 W*
Optical Power at Interferometer Input	125 W	*5 W*
Power Recycling Factor	80 x	*30 x*
Input Mirror Transmission	3%	*3%*
End Mirror Transmission	15 ppm	*15 ppm*
Arm Cavity Power Loss on Reflection	1%	*3 %*
Light Storage Time in Arms	0.84 ms	*0.84 ms*
Test Masses	Sapphire, 30 kg	*Fused Silica, 11 kg*
Mirror Diameter	28 cm	*25 cm*
Test Mass Pendulum Period	1 sec	*1 sec*
Seismic Isolation System	Active/Passive, 6 stage	*Passive, 4 stage*
Seismic Isolation System Horizontal Attenuation	10^{-8} (10 Hz)	*^{3} 10^{-5} (100 Hz)*
Maximum Background Pulse Rate	1 per 10 years, triple interferometer coincidence	*1 per 10 years, triple interferometer coincidence*

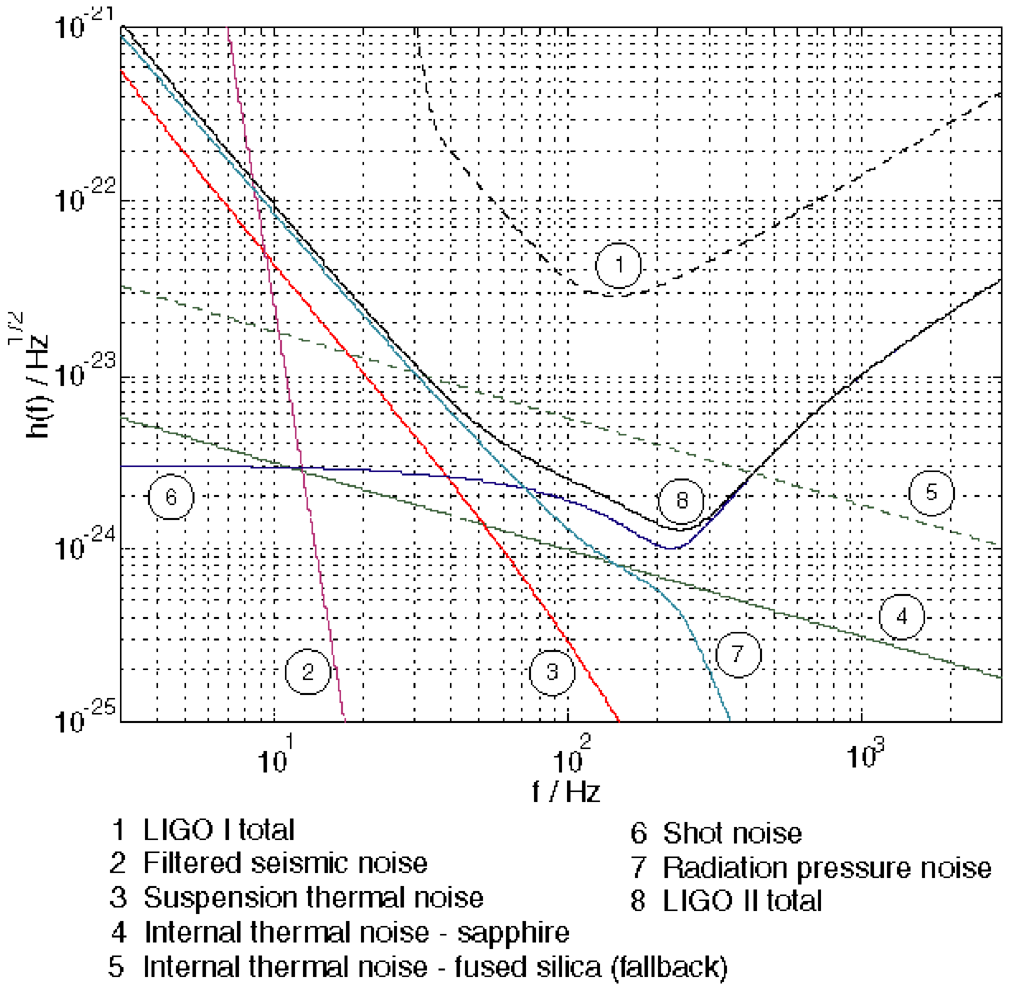
The Real Goals

- Physics - "would be surprising if don't see many sources" - Thorne yesterday
- Instrumental - quantum limited interferometer across entire sensitive band

LIGO II and LIGO I Sensitivity



Noise Anatomy of LIGO II



The Scenario

YEAR	LIGO I	LIGO II
2000	Installation and commissioning	R&D
2001	Installation and commissioning	R&D
2002	Science run starts	MRE/R&D funds start, R&D, design, long lead items
2003	Science run	R&D, design, fabrication
2004	Science run	Fabrication, on-site assembly
2005	LIGO I interferometers removed	Fabrication, on-site assembly, installation into vacuum system
2006		Installation and commissioning

LIGO Laboratory and LSC Role

- LIGO Laboratory will organize and manage the LIGO II project
- LSC participation in the construction of LIGO II will be governed by Memoranda of Understanding (MOU) and specific, periodic Attachments describing tasks, funding, milestones and personnel, with subcontracts
  - » this model used successfully with Univ. of Florida during LIGO I
  - » this model used with LSC for R&D activities, without subcontracts

LSC is driving the LIGO II scientific goal and concept

- GEO is proposing a collaborating role and a capital contribution role
- ACIGA role developing (recent)

LSC and Lab Submitted Conceptual Documents

- September White Paper on Advanced Detector R&D
  - » Working Group chairs and spokesperson represented you well
    - – this exercise is a success of the LSC structure and governance
- Conceptual Project Book prepared by Lab staff working with the LSC leadership
  - » Assumed all 3 interferometers replaced in 2005-2006 !
  - » Therefore all of LIGO I is turned off
  - » Assumed maximum possible choices of all options
    - – intended to get cost envelope bracketed
  - » Cost estimate is MRE request $94 million + GEO proposed contribution + contribution from LIGO Lab Operations budget!
    - – Larger cost than expected due to active isolation, number of control loops and data acquisition/analysis complexity

Major Project Options

- How many interferometers to upgrade?
  - » Assume all 3 interferometers upgraded
- Convert the Hanford 2 kilometer to a 4 kilometer?
  - » Assume length is increased
- Upgrade done in one phase?
  - » Assume all 3 interferometers upgraded in one parallel installation
  - » **Decision on this may interact with other gravitational wave detectors to insure that observational coverage is considered**
  - » **Phasing of upgrade is a major scientific decision**

My Summary of NSF Review Recommendations

- LIGO Lab should proceed with full construction proposal for LIGO II to be submitted late in 2000
- NSF should establish a framework for evaluating R&D proposals related to LIGO II in order to assure coordination and monitoring
- LIGO Lab should submit an integrated R&D plan for Lab and LSC research in 2000 and 2001
- Construction proposal should identify Preconstruction R&D to begin in 2002
- Meaningful LIGO I data analysis results should be in hand prior to turning LIGO I off

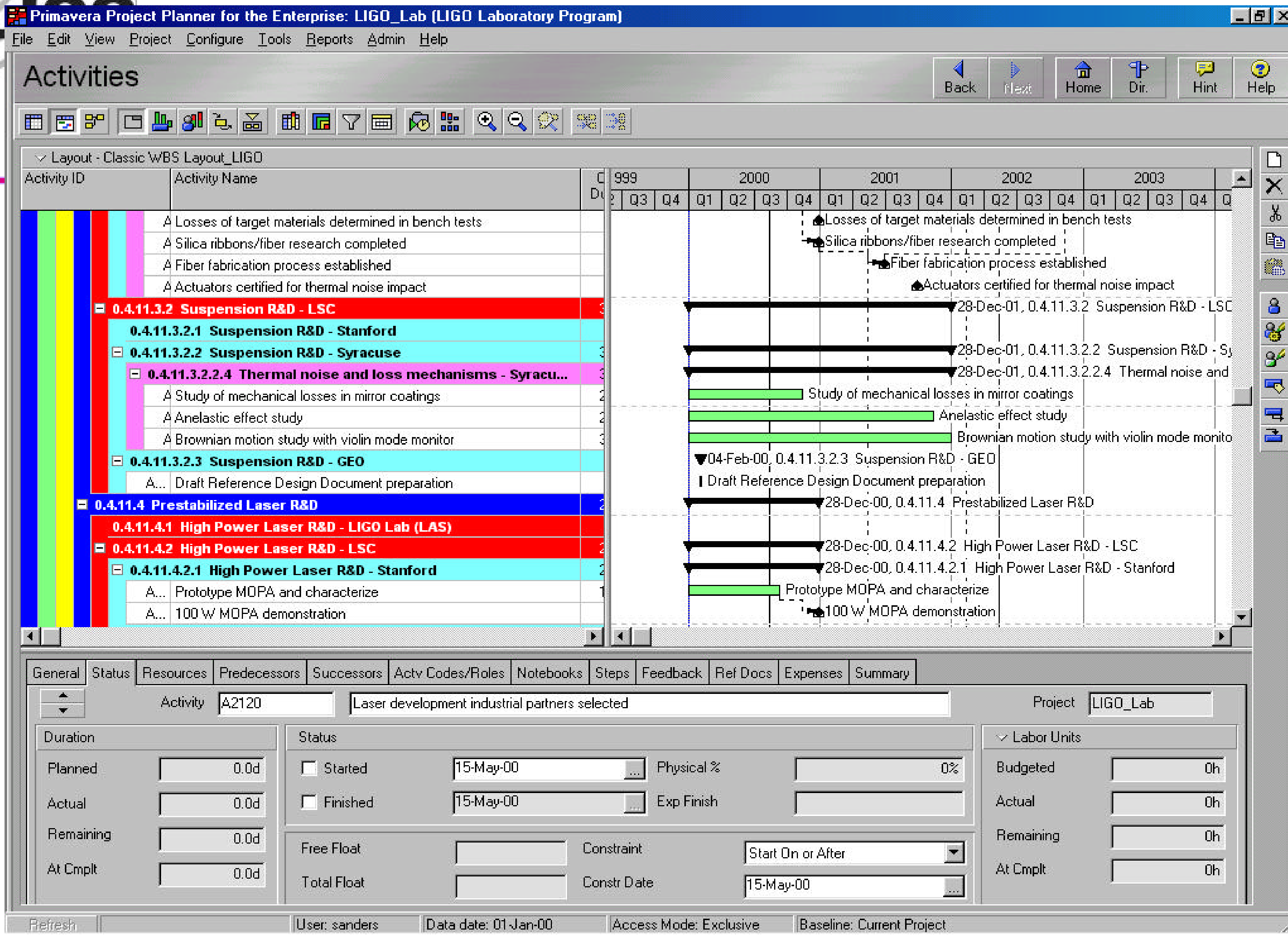
LIGO Lab's Plan

- Integrated R&D Plan for 2000 and 2001 submitted in March
- Briefing document for NSF MRE selection submitted last month and is under review at NSF
- Full LIGO II Proposal to be submitted near end of 2000, with LSC and GEO participating
- Request R&D $ increment for 2002
- Request construction $ for 2003
- Plan first installation in vacuum system in 2005

Phased Funding/Decision Scenario for NSF

FY	2002	2003	2004	2005	2006	TOTAL
Design/Development	$9M	$11M	$4M	$3M		$27M
Construction		$9M	$21M	$22M	$15M	$67M
Project Total	$9M	$20M	$25M	$25M	$15M	$94M

- Assumption is MRE Design & Development start in FY2002
- Construction start in FY2003
- NSF debating whether MRE budget line should be used for development of projects or only for projects fully ready to construct


Primavera Project Planner for the Enterprise: LIGO_Lab (LIGO Laboratory Program)
File Edit View Project Configure Tools Reports Admin Help
Activities
Back Next Home Dir. Hint Help
Layout - Classic WBS Layout_LIGO
Activity ID
Activity Name
1999 2000 2001 2002 2003
Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Losses of target materials determined in bench tests
Silica ribbons/fiber research completed
Fiber fabrication process established
Actuators certified for thermal noise impact
0.4.11.3.2 Suspension R&D - LSC
0.4.11.3.2.1 Suspension R&D - Stanford
0.4.11.3.2.2 Suspension R&D - Syracuse
0.4.11.3.2.2.4 Thermal noise and loss mechanisms - Syracu...
Study of mechanical losses in mirror coatings
Anelastic effect study
Brownian motion study with violin mode monitor
0.4.11.3.2.3 Suspension R&D - GEO
Draft Reference Design Document preparation
0.4.11.4 Prestabilized Laser R&D
0.4.11.4.1 High Power Laser R&D - LIGO Lab (LAS)
0.4.11.4.2 High Power Laser R&D - LSC
0.4.11.4.2.1 High Power Laser R&D - Stanford
Prototype MOPA and characterize
100 W MOPA demonstration
28-Dec-01, 0.4.11.3.2 Suspension R&D - LSC
28-Dec-01, 0.4.11.3.2.2 Suspension R&D - Sy
28-Dec-01, 0.4.11.3.2.2.4 Thermal noise and
04-Feb-00, 0.4.11.3.2.3 Suspension R&D - GEO
28-Dec-00, 0.4.11.4 Prestabilized Laser R&D
28-Dec-00, 0.4.11.4.2 High Power Laser R&D - LSC
28-Dec-00, 0.4.11.4.2.1 High Power Laser R&D - Stanford
General Status Resources Predecessors Successors Actv Codes/Roles Notebooks Steps Feedback Ref Docs Expenses Summary
Activity A2120 Laser development industrial partners selected
Project LIGO_Lab
Duration
Planned 0.0d
Actual 0.0d
Remaining 0.0d
At Cmplt 0.0d
Status
Started 15-May-00
Finished 15-May-00
Physical % 0%
Exp Finish
Free Float
Total Float
Constraint Start On or After
Constr Date 15-May-00
Labor Units
Budgeted 0h
Actual 0h
Remaining 0h
At Cmplt 0h
Refresh
User: sanders
Data date: 01-Jan-00
Access Mode: Exclusive
Baseline: Current Project

Management of the R&D

- LIGO Lab is working with LSC Working Group Chairs to define and monitor R&D program
- Fully integrated schedule of Lab and LSC activities is in preparation
- MOU's/Attachments B, C, D updated to agree with this plan
- LSC is hosting monthly progress telecons with LIGO Lab participating to assess progress and to identify issues
  - » this is working quite well

Since September, 1999 White Paper

- R&D White Paper failed to fully consider thermal noise sources
- Braginsky et al and Thorne et al papers on thermoelastic damping change sapphire perspective
  - goal is to work this result into R&D and into LIGO II design choices
  - increased emphasis on measuring thermal noise limits with suspended sapphire optics
- Some R&D is being curtailed or accelerated to focus on the LIGO II goals
  - sapphire optical and mechanical properties
  - thermal compensation
  - use of test interferometers
- R&D program is undergoing greater discussion and coordination
  - Aspen workshop was intense……!
  - LSC meeting was intense
  - System design summit scheduled later this month

R&D Questions

- How much risk can we tolerate from limits of our knowledge of the LIGO II thermal noise floor?
  - » How well can we measure thermoelastic noise?
    - – Direct measurement in suspended mass interferometers with fine displacement sensitivity (TNI,…)
    - – Tabletop measures of damping (anelastic tests,…)
  - » Other contributions to thermal noise
    - – Brownian motion noise
    - – Young’s modulus response to thermal fluctuations (G. Cagnoli)
    - – Index of refraction response to thermal fluctuations (B. Kells)
    - – intensity noise from thermal compensation via laser
    - – others…
- This is not a zero risk endeavor

R&D Questions

- Signal tuned configuration research
  - » 10 m Glasgow system
    - – to prove the principle
  - » 40 Meter system
    - – to shakeout an engineering implementation
- How come we measured phase sensitivity for LIGO I and no plan to do this for LIGO II is in our White Paper?
  - » Did not consider path length fluctuations induced by thermal fluctuations driving refractive index
  - » ACIGA role?
- How to integrate opportunities from all the test interferometers in the community?

This Year:
Towards Full LIGO II Proposal

- Team forming in LIGO Lab
- Integrated plan being assembled
- Schedule for proposal preparation forming
- Seismic isolation decision MUST be made in April!
- Monthly R&D telecons started for 3 working groups
- Schedule/cost estimating this summer
- Document complete in October
- LSC full participation is crucial
- Lot's of competition pounding the NSF door !
  - » Our field will be held to its own high standards

May

Issues

- Pressure on key Lab staff is intense
  - » LIGO I vs. LIGO II deadlines
- No funding for LIGO II proposal generation and engineering before 2002
  - » using reserve funds for the moment
- Staffing down at end of construction and staffing up for LIGO II
- Early science results from LIGO I engineering runs very important to establish confidence that we will move from instrument builders to investigators of the gravitational wave universe