



State of the LIGO Project

Gary Sanders
LIGO Laboratory / Caltech
LSC Meeting, LLO
March, 2003

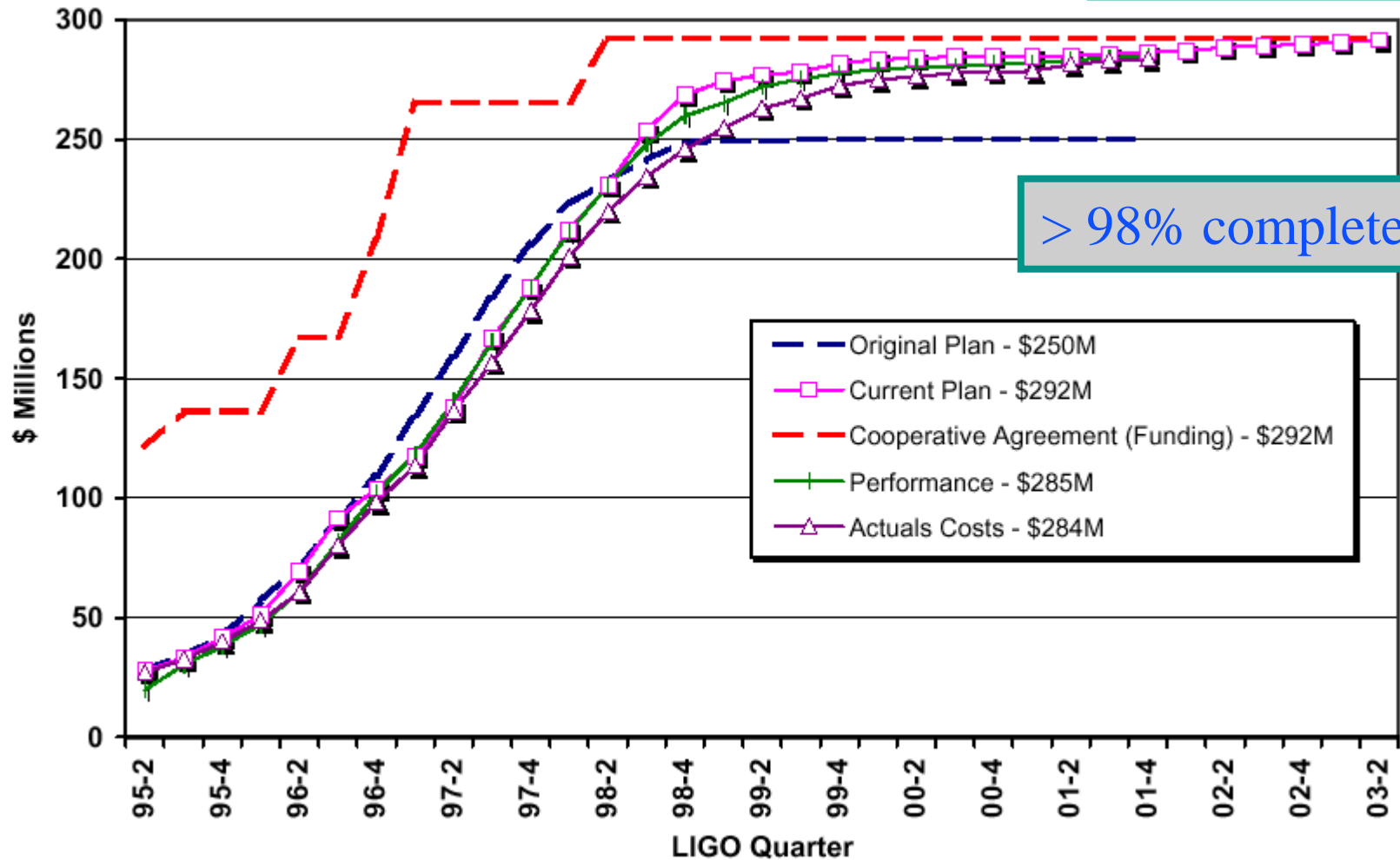


LIGO science has begun!



Construction Cost/Schedule Performance

Support buildings and LDAS remain





LIGO Plans *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
 2007	

This is still the working plan

LIGO-G010036-00-M

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LIGO-G030061-00-M

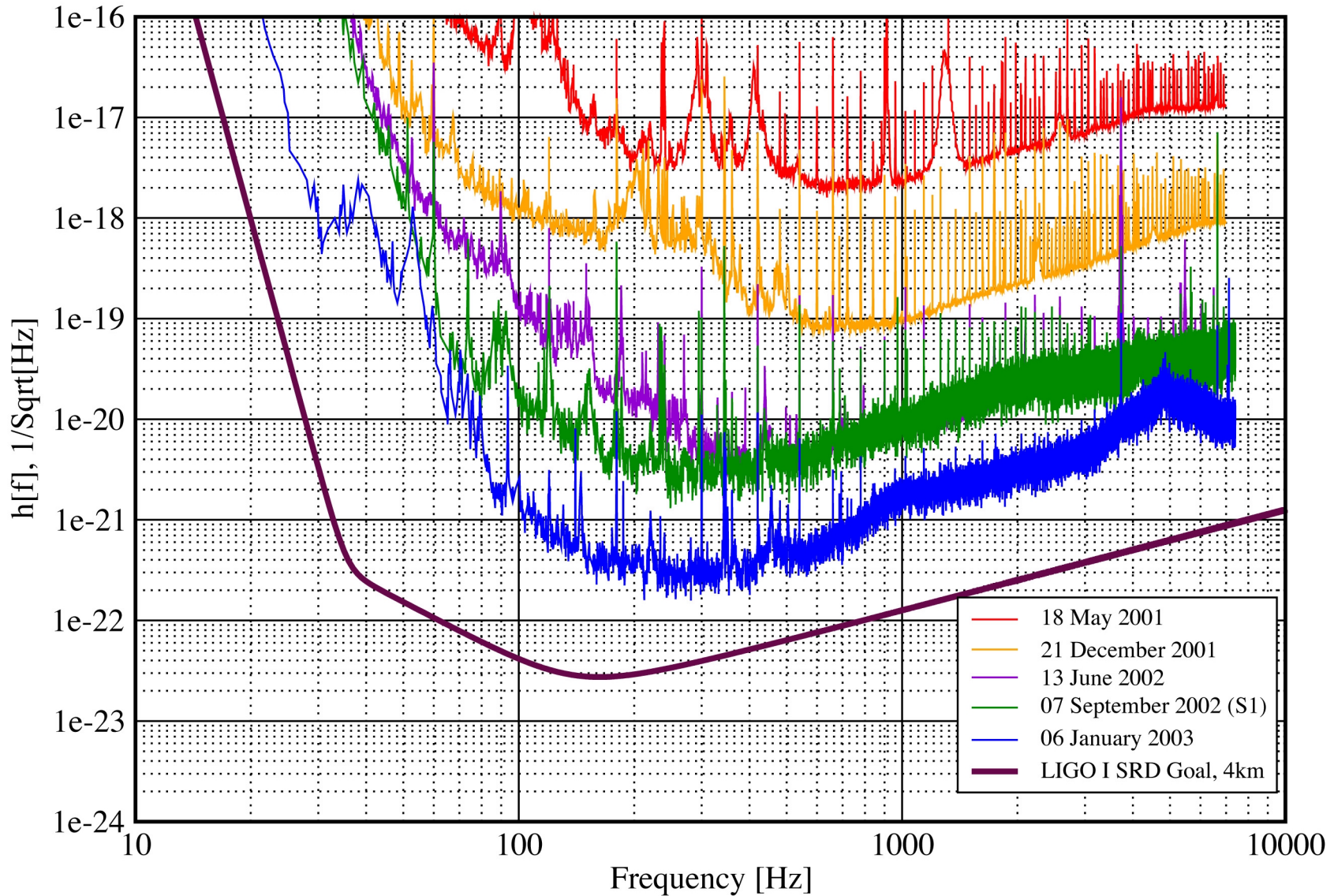
LIGO Laboratory

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Strain Sensitivity for the LLO 4km Interferometer

31 January 2003

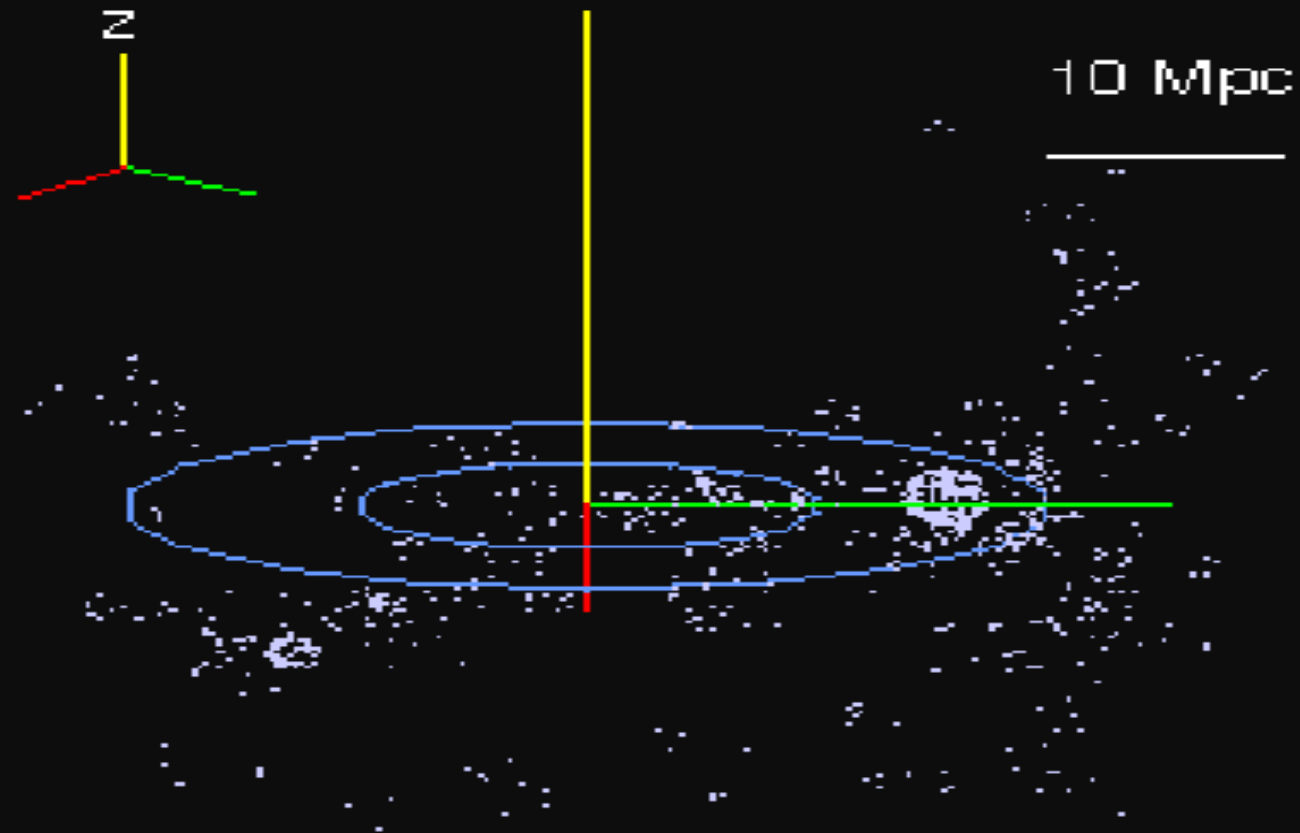
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Galactic Neighborhood within 31 Mpc



L



Albert



LIGO Goals and Priorities

- Interferometer Performance
 - » Significant progress from S1
- Physics from S1 and S2
 - » Draft papers from S1 discussed this week
 - » Lessons for the next round of data analysis
- Advanced LIGO Development
 - » R&D making significant progress
 - » A LIGO/GEO/ACIGA consortium has now proposed Advanced LIGO construction
 - PPARC – UK approval seems imminent
 - » David Shoemaker assuming role of LIGO Lab project leader
- Broader Impacts
 - » Education and outreach at the observatories now proposed for an expanded level of activity
 - » Advanced LIGO proposal calls for coordinated effort across the LSC

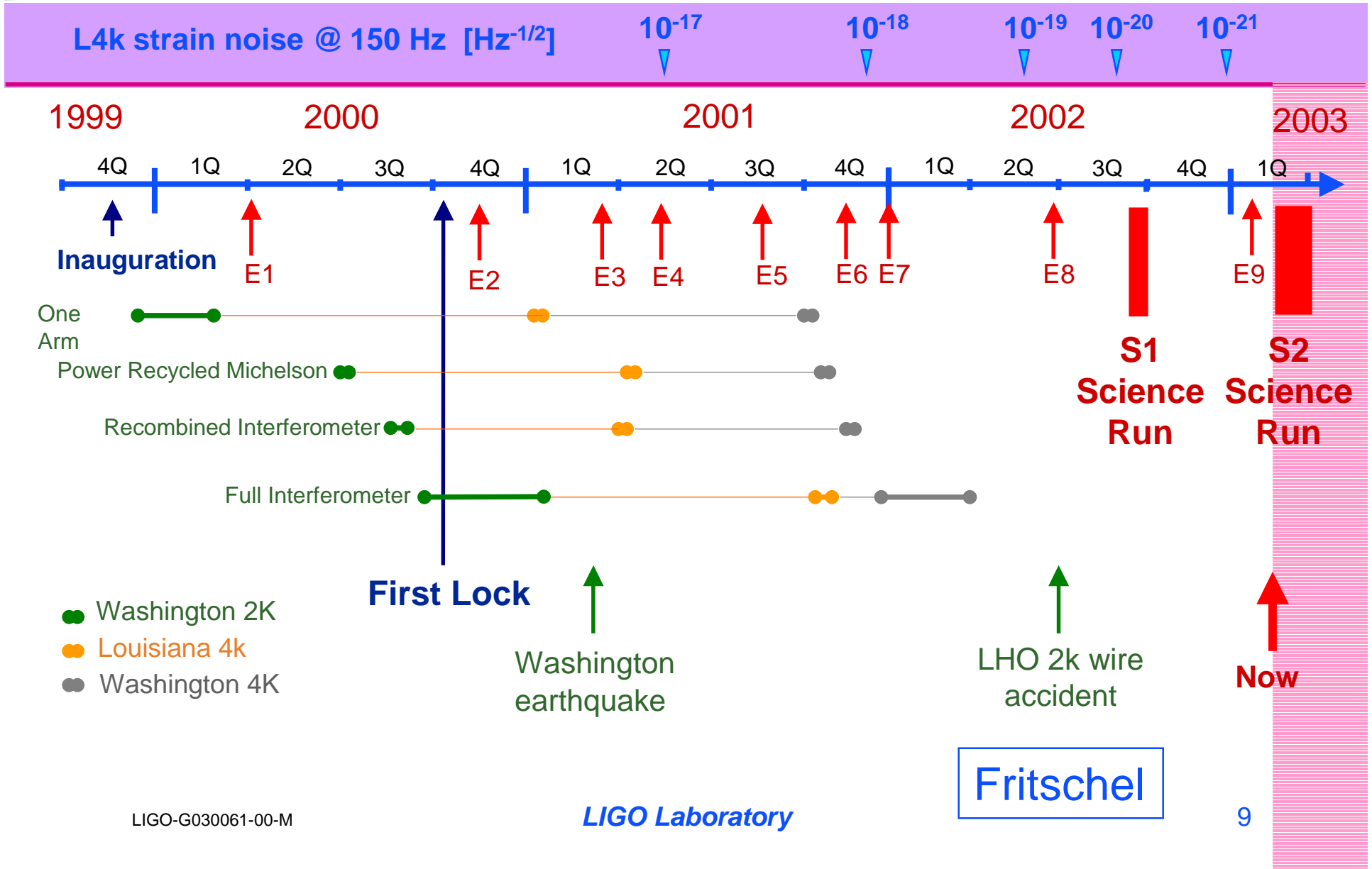


2003 Run Plan at Last LSC Meeting

- S1 essentially underway at that meeting
- Post-S1 commissioning planned until S2 freeze
- Upper Limits Groups to carry out analysis yielding papers as S2 is started
- S2 for 8 weeks starting 14 February
- Commissioning continues after S2
- Following S2, LLO preisolation installed and L1 recommissioned
- S3 begins late in 2003
- Preisolation installation now planned about October
- S3 (first long search run) will be later
- Should we schedule an intermediate S2-like run in early fall?



Commissioning History





Commissioning Steps Since S1

- Optical lever improvements and application to alignment
- Improved DAC “de-whitening”
- New coil drivers and controls
- Digital suspension controls (H2, L1)
- Improved realtime control code
- Wave front sensing (8 of 10 loops closed on H1)
- Higher laser power (higher photocurrent)
- PZT actuators used as fine adjustors (LLO)
 - ≈ μ Seismic feedforward using fine actuators
 - » PEPI – Piezo Electric Pre Isolation controlling from geophones
- Linear power supplies and other EMI/RFI measures



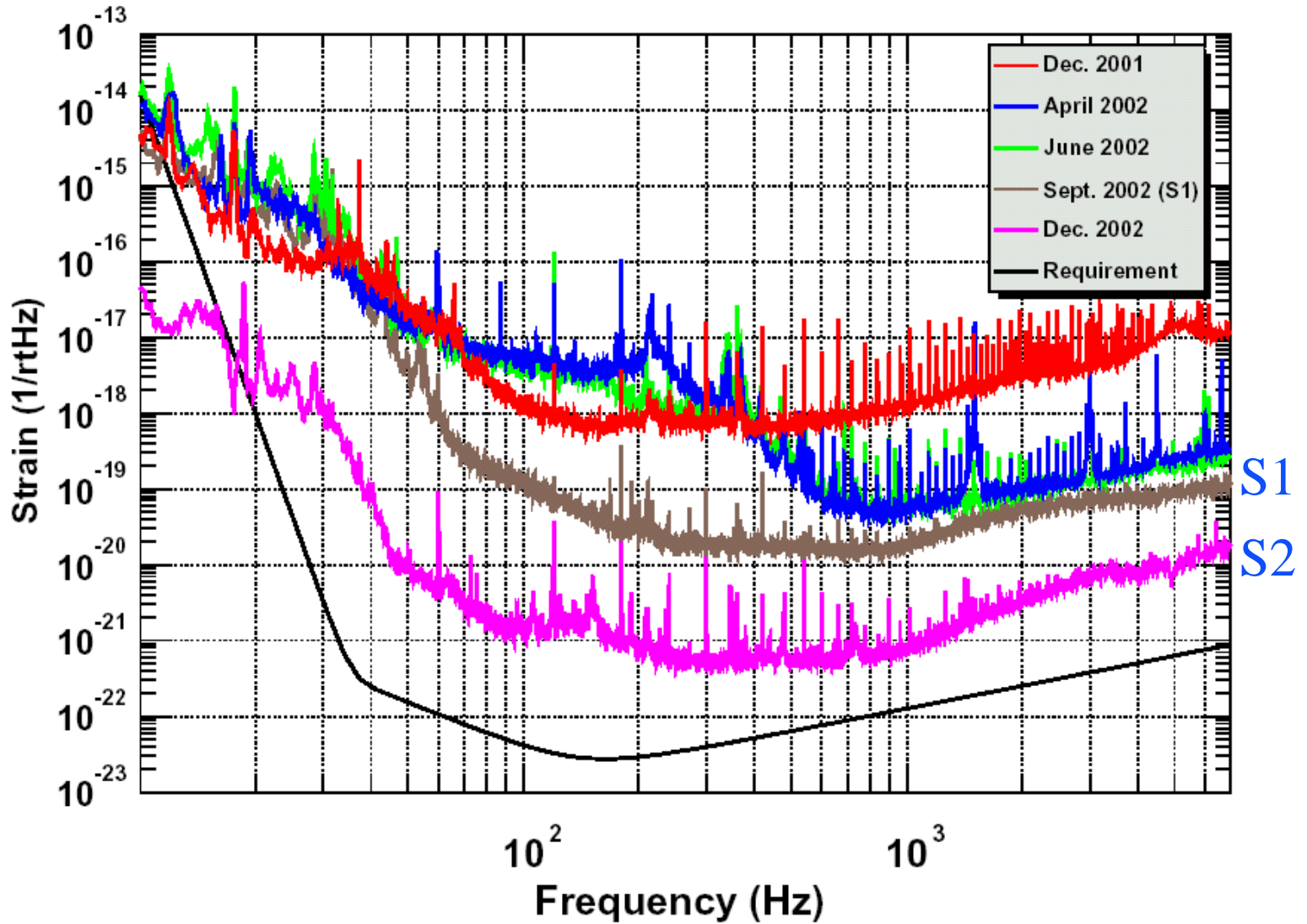
LIGO Hanford Observatory

- Moved scientists to new building
- Completed S1
- H1 commissioning restarted
 - » Improved sensitivity by factors of 10 – 100 across frequency band
 - » Improved stability – implemented wavefront sensing on 8 of 10 degrees of freedom
- H2 commissioning restarted
 - » Switched to digital suspension controllers
 - » Sensitivity improved to near H1 level in final sprint to the freeze
- S2 begun
- Formed Local Educators Network

Fred



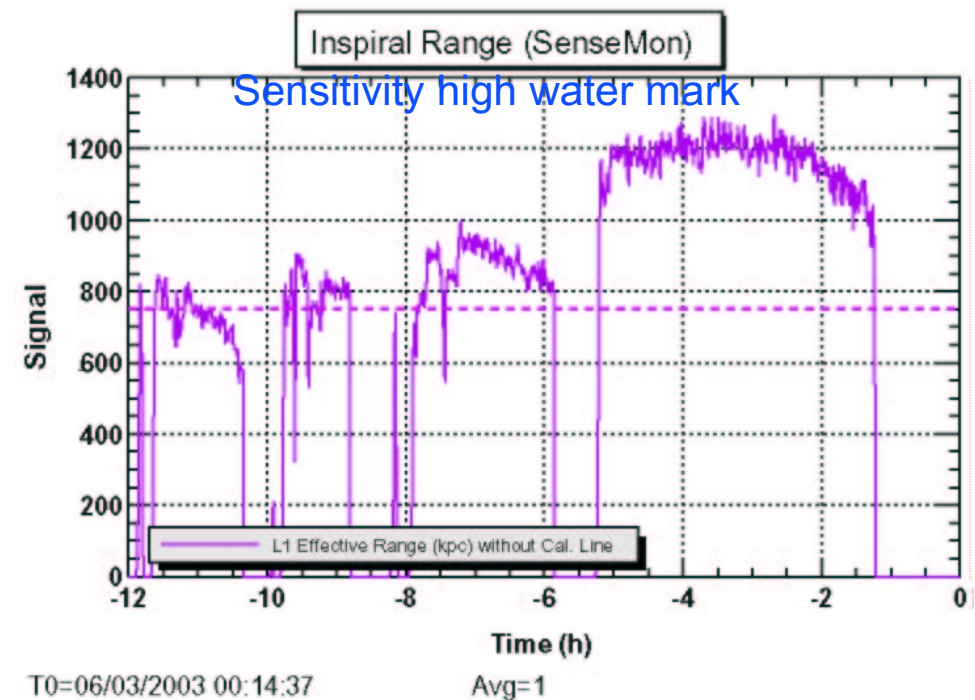
Hanford 4k Progress for 2002





S2 at LLO

- Generally smooth, high sensitivity running at night:
 - » Duty factor limited primarily by daytime man-made seismic noise
 - » Approximately 40% operation in science mode
- Sensitivity has varied between 0.8-1.2 Mpc for inspirals.
- Interferometer hardware has been generally reliable
 - » Most disruptive event - site-wide power interruption of electric utility service during severe electrical storm



Coles



Status of S2

- Duty cycles are comparable to S1
 - » 67% H1, 60 % H2, 40% L1
- Longest “science” segment is a record
 - » 66 hours (H1)
- Range for NS binary inspiral exceeds plan
 - » **1.2 Mpc L1** with 250-350kpc H1 and 150-300kpc H2
- 8 of 10 alignment DOFs under WFS control on H1
 - » gives improved calibration stability
- Control room tools and operational procedures really starting to gel! - Stan

Stan



Commissioning After S2

- DAC upgrade
 - » Current commercial DAC's have excess noise, timing problems, EMI
 - » Custom DAC being developed by commercial partner to LIGO specs
- Intensity stabilizer outer loop (post-MC sensing)
 - » Should improve RIN from $\sim 10^{-7}/\text{Hz}^{1/2}$ to $< 10^{-8}/\text{Hz}^{1/2}$
- RFI cleanup, linear power supplies everywhere
 - » Guided by experts at NRAO, Los Alamos, Birmingham
 - » LLO power supply retrofit has already dramatically reduced line interference
- Operate at full 6W power
- Wave Front Sensor (WFS) completion
 - » Spatial beam profile, sensing matrix proved more subtle than planned
 - » Currently have 8 of 10 angular degrees of freedom under WFS control
- **Seismic retrofit at LLO: External Pre-Isolators**
 - » Most radical change, but needed to achieve 24/7 operation at Livingston
 - » Crash development program underway in MIT LASTI laboratory
 - » Expect to deliver turnkey system to LLO this fall for rapid integration

Zucker



SEI Preisolation Upgrade

- Ground motion @LLO
 - » Anthropogenic noise high; steady-state as well as transients particularly from logging
 - » Difficult to hold the interferometers locked reliably during the day
- Ground motion @LHO
 - » Wind induced seismic noise at LHO exceeds locking threshold at ~25 mph, or 10% of the time
 - » Expect that up-conversion is a problem at significantly lower wind speeds & a large fraction of the time



SEI Preisolation Upgrade

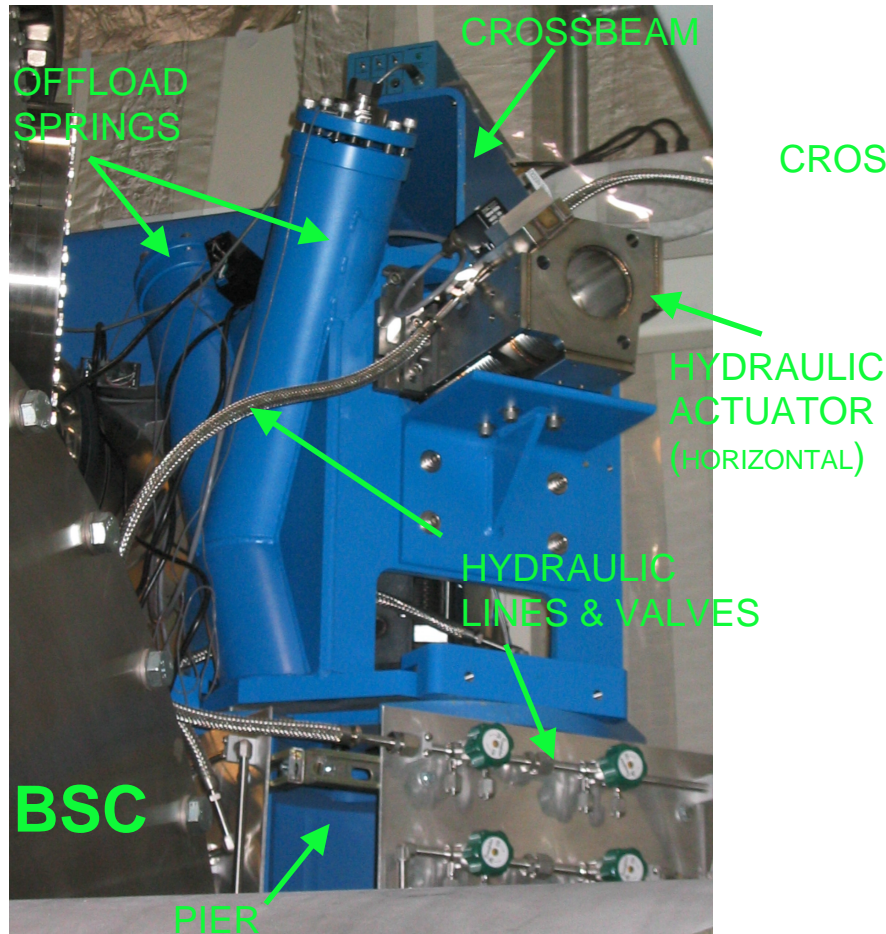
- External Pre-Isolation (EPI) is required to allow both reliable locking and to allow better noise performance while locked
 - » Design review scheduled for ~4/18
 - » Prototype testing at LASTI facility has demonstrated 10x reduction in 0.5 to ~2.5 Hz band (compared to 15x reduction requirement in the 1-3 Hz band); testing and optimization continues
 - » Earliest installation start is Oct with completion ~Jan
 - » To date have focused on LLO (more acute) problem; Plan to install PEPI systems at LHO for wind noise needs more evaluation

Dennis



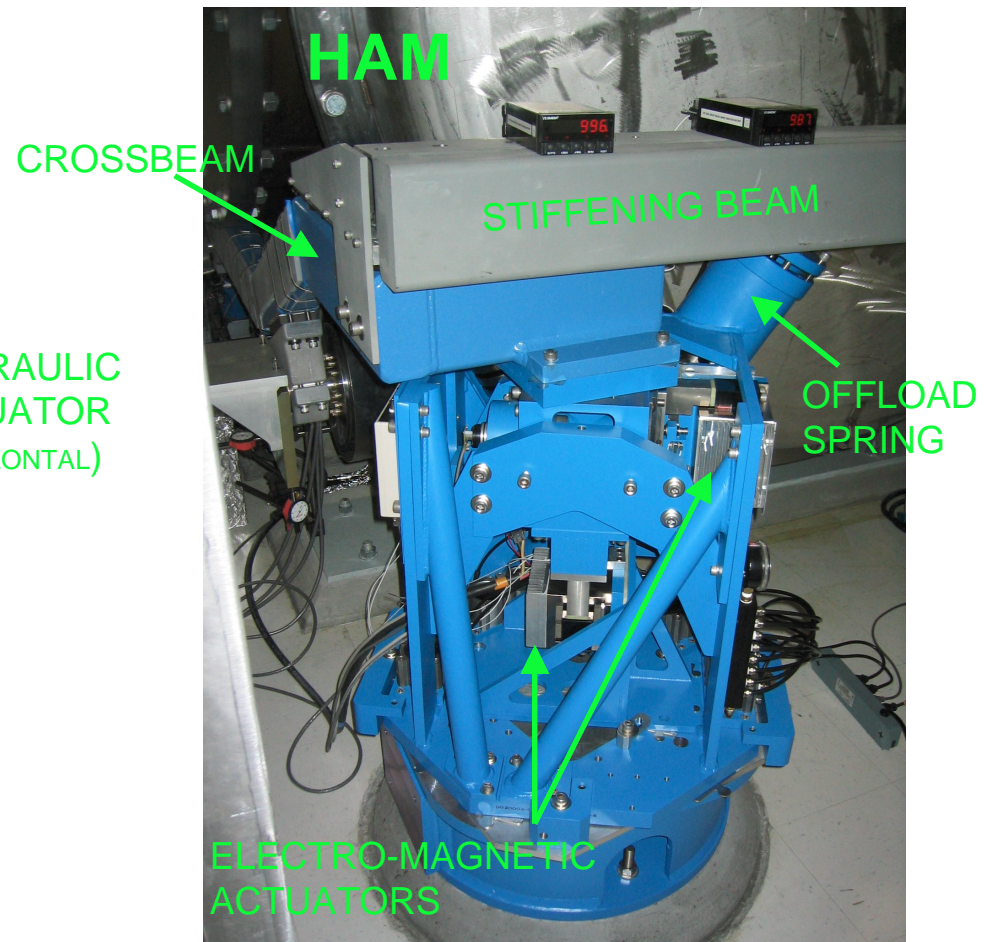
Commissioning: SEI Upgrade

Hydraulic External Pre-Isolator (HEPI)



LIGO-G030061-00-M

Electro-Magnetic External Pre-Isolator (MEPI)



LIGO Laboratory



Status of GEO600



- All main optics suspended **monolithically** as triple pendulums.
- Fundamental and 2nd harmonics violin modes dampened to a few 1E6 by painting sections of fibres with amorphous Teflon.
- All DOF for PR (not SR) Michelson under autoalignment control
→ longest lock 121h in S1.
- Automated operation of detector gives high duty cycles and complete remote control.
- Dual Recycling implemented. Lock lengths only 10 secs in detuned mode so far.
- Implemented ring heater behind far east mirror to compensate for wrong ROCs (666m and 687m instead of 640 due to stress in coating?). Permits PR operation and SR commissioning.
- S2 running during last two weeks of S2

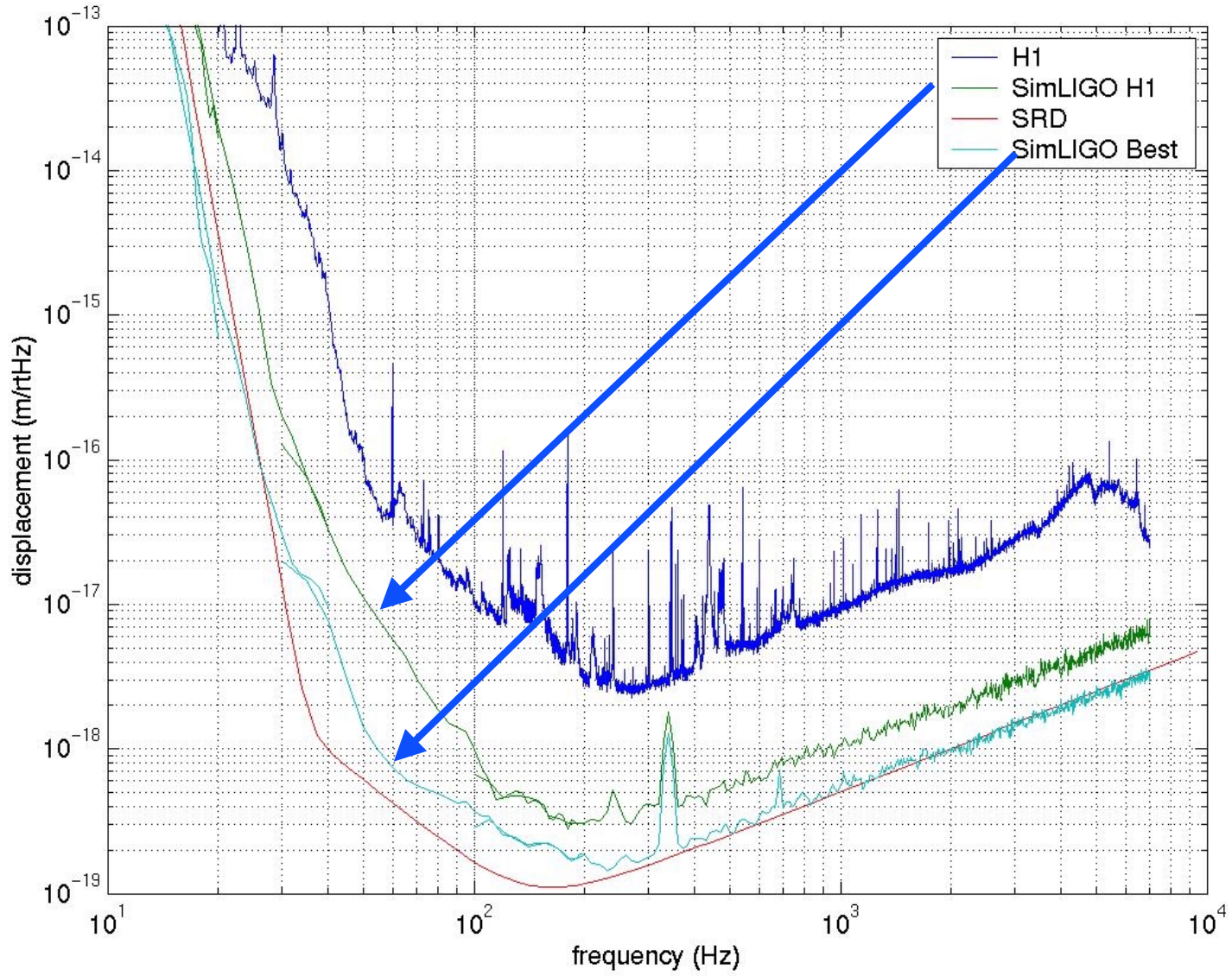
Harald Lück



Simulation & Modeling

- LIGO I simulation package improved (SimLIGO)
 - » Realistic simulation with as built parameters and digital and analog ISC
 - Wavefront sensing and optical levers for alignment control
 - » Thermal lensing and mode mismatch effects studied
 - Lock acquisition code improved for LIGO with mode mismatching
 - » LHO 4k sensitivity curve calculated (preliminary)
 - **SRD sensitivity reproduced - almost**
 - » Full discussion to be presented later this week by Matt Evans
- Ongoing studies with model:
 - » Effects of various imperfections on the limiting sensitivity curve
 - » Effects of seismic motion on the lock acquisition and lock loss
 - » Improvement of optics model for better simulation:
 - Radiation pressure effects on alignment
 - » FFT model vs e2e -- model validation
 - Study difference of FFT locked steady-state vs dynamic (e2e) locking

Hiro





Data Analysis Software

- Release for S2: 0.6.0
 - » 0.6.20 has been pushed to the sites since start of S2
 - More stable GCC compiler, resolved some issues with mpiAPI, frameAPI still buggy
 - » 0.6.25 at MIT appears to have fixed most of frameAPI bugs
- Version of FrameCPP (C++ frame I/O library) for 0.6.0 meets frame specification at about the 95% level or better
 - » Working on issues with Virgo between C and C++ libraries
- Plan for release 0.7.0 in May 2003
 - » Completed frameCPP (subject to resolution of issues with Virgo)
 - » Better performance and improved memory management where possible
 - faster interaction with SAM/QFS tape archive
 - » Multiple IFO support for creation of Reduced Data Sets
 - » Upgrade C++ XML library for lightWeightAPI
 - » Possible migration to 64-bit code support on Sun/Solaris 9

Albert



Data Analysis Computing & Archiving

- Tier 1 Archive at Caltech

- » After positive experience during S1, LIGO committed to SAM-QFS rather than HPSS for its frame archive -- started with E9 data.
- » Favorable licensing structure, administrative simplicity, and technical benefits will permit SAM-QFS to run at the Observatories
 - Local 1+ year look back of full frames -- provides redundant archive of LIGO data
- » Current central archive contents:
 - HPSS: 1.7M files / 58TB (S1 and before)
 - SAM-QFS: 0.5M files / 34TB (S1, E9, S2)

- Computation for LIGO Lab (all sites) - final build-out

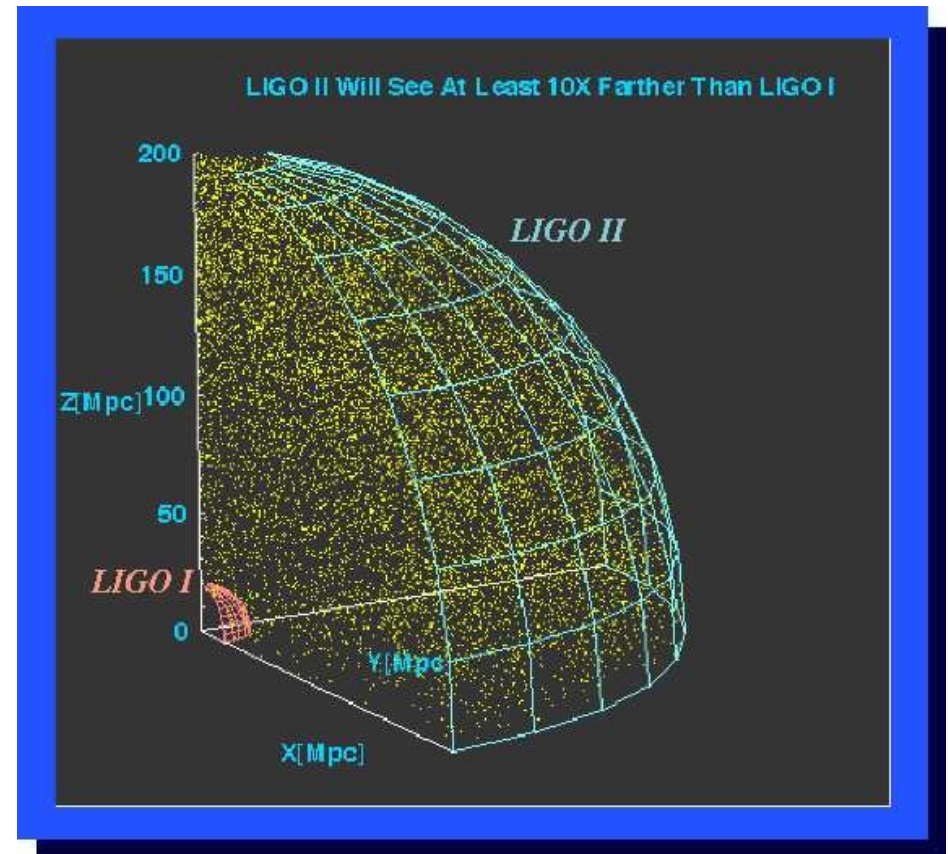
- » LDAS will use Gigabit Ethernet for the final build-out of large Beowulf clusters.
- » Install new 8-CPU Sun servers after S2 to support SAM-QFS and the larger Beowulf clusters.
- » A central (federated) LDAS database is planned to aggregate all of the database tables from the various LDAS systems.

Albert



Advanced LIGO Reach

- R&D since '97
- Construction proposal submitted end of February
- Follows our baseline
 - 3 interferometers, 4 km each
 - Signal recycled
 - ~180 W laser
 - Sapphire COC substrates
 - Quad monolithic suspensions
 - Active isolation system
- Schedule:
 - » Begin installation: 2007
 - » Begin observing: 2009



Science from the first 3 hours of Advanced LIGO observing should be comparable to 1 year of initial LIGO!



Advanced LIGO Proposal

- R&D through final design and first articles now underway
 - » supported by LIGO and partner funds already awarded
- Proposal requests funding for the construction
 - » \$122 million beginning in 2005
 - » Some early purchases in 2004
 - » International partners propose support of additional \$25.5 million
 - GEO (UK) - \$11.5 million (appears to be gaining approval this month)
 - GEO (Germany) - \$11.5 million
 - ACIGA - \$2.5 million
- Advanced LIGO now well exposed at NSF, OMB, OSTP
- Ready for NSF review soon



Buildup of Education and Outreach

- LIGO Lab outreach has been primarily observatory centered
- LIGO Lab renewal called for increased activity
- Supported new effort and formed a strategy and Local Educator's Networks at each observatory
- This process led to a new proposal with partners for a greatly expanded program
 - » Next slide has some details
- NSF is beginning an effort to produce a "half-hour" video on LIGO
- Advanced LIGO proposal calls for an LSC-wide education and outreach program



February 2003 Proposed Education & Outreach Program

- Proposal submitted to NSF Feb. 10 for major enhancement to outreach activity:
 - » Collaboration of Caltech, SUBR, La Board of Regents, Exploratorium of San Francisco
- Construct an educational outreach center on-site at LLO.
- Place hands-on exhibits from Exploratorium in center (with subset at LHO).
- Implement teacher pre-service and in-service training initiative to teach inquiry based science techniques at SUBR – extend to LHO communities
- Use LIGO staff to provide science leadership in selection of exhibits, development of science content in teacher training programs
- La Board of Regents, through La Systemic Initiative with leveraged resources from US Dept of Education LA GEAR UP program, will facilitate teacher training and student visits to outreach center from underserved communities.



Proposal Budget

LIGO Operations (2002 – 2006)

	FY 2001 (\$M)	FY 2002 (\$M)	FY 2003 (\$M)	FY 2004 (\$M)	FY 2005 (\$M)	FY 2006 (\$M)	Total 2002-6 (\$M)
Currently funded Operations	22.92	23.63	24.32	25.05	25.87	26.65	125.52
Increase for Full Operations		5.21	5.20	4.79	4.86	4.95	25.01
Advanced R&D	2.70	2.77	2.86	2.95	3.04	3.13	14.76
R&D Equipment for LSC Research		3.30	3.84	3.14			10.28
Total Budgets	25.62	34.91	36.21	35.93	33.77	34.74	175.57

FY 2001 currently funded Operations (\$19.1M for ten months) is normalized to 12 months and provided for comparison only and is not included in totals.

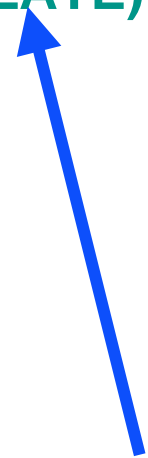


“Revised” Proposal Budget

LIGO Operations (2002-2006)

- \$28 million provided for FY 2002 Operations in February and May 2002
 - » Reduced or deferred hiring, Adv R&D, equipment, outreach, etc
- Our working assumption is that \$33M will be awarded in 2003
 - » Priority for commissioning and toward LIGO I 24x7 Operations
- **FULL \$33 MILLION AWARDED FOR FY2003 (6 MONTHS LATE)**

	FY 2002 (\$M)	FY 2003 (\$M)	FY 2004 (\$M)	FY 2005 (\$M)	FY 2006 (\$M)
Operations	\$24	\$29	\$30	\$30	\$30
Advanced R&D	\$4	\$4	\$3	\$3	\$3





For this meeting

- Bring S1 UL papers to endgame
 - » Next public results presented at April APS meeting
 - » Incorporate lessons learned from S1 analysis to broader S2 analysis
- Major commissioning steps ahead
 - » Preisolation plan addressed
- A data run before S3?
- Milestones approaching in Advanced LIGO program
 - » SEI bid about to go out
 - » Coating development plan for next phase
 - » Substrate selection
 - » Laser technology selection
 - » NSF review within 2 months



Thank You Rai!