LIGO Overview & Background

Jay Marx

Advanced LIGO PAP Meeting
November 30, 2006
G060578-00-A

Role of the PAP

- We will be open with you--tell you about what is not going as well as we'd like. Not try to just impress you
- We want to consider you part of the extended Advanced LIGO family and we will be frank with you.
- We've told NSF that they can't attend these meets so we can be open with you
- In return, we want frank, helpful advice.
- And we want you to be discrete about information presented to you. You must regard what you hear at this meeting as confidential and treat it as such.

Overview topics

- What is LIGO, its mission, current status
- Advanced LIGO from 40,000 feet
- How Advanced LIGO fits into LIGO Laboratory
- The Project Advisory Panel-
  - » Role of PAP
  - » Charter of PAP
  - » Charge for this meeting

LIGO--what is it?

- LIGO = LIGO Laboratory and the LIGO Scientific Collaboration
- LIGO Laboratory
  - » ~180 people, headquartered at Caltech with observatories in Livingston Louisiana and Hanford Washington and a very significant group at MIT
  - » Managed by Caltech under a cooperative agreement with NSF
  - » Annual operating budget is ~33M$
- The LIGO Scientific Collaboration (LSC)
  - » LSC has ~ 500 members (including LIGO Lab), 411 names on author list from 44 institutions
  - » LSC does R&D, analyses data and publishes science
  - » LSC has been integrated into the LIGO Lab management structure
    - – LSC maintains independent governance

LIGO's mission

World-leading capability for Gravitational Wave science

- Discovery the gravitational waves predicted by General Relativity
- Use gravitational waves as tool to do astrophysics and astronomy
- Advance the science of precision interferometry
- High quality education and outreach with significant public impact
- Train the next generation of GW scientists and provide trained scientific and technical manpower for the nation
- Work towards an international network of coordinated GW observatories

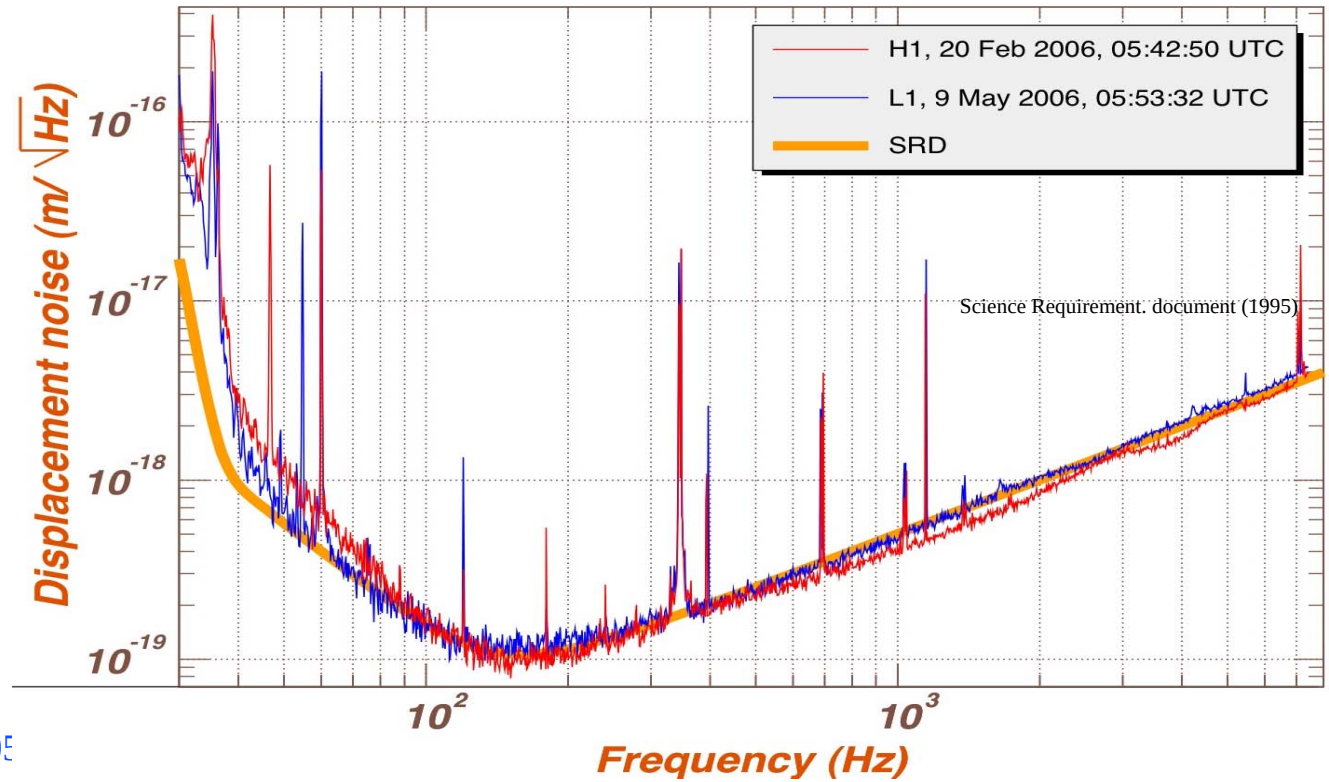
LIGO

Current Status of LIGO

(including Advanced LIGO from 40,000 feet)

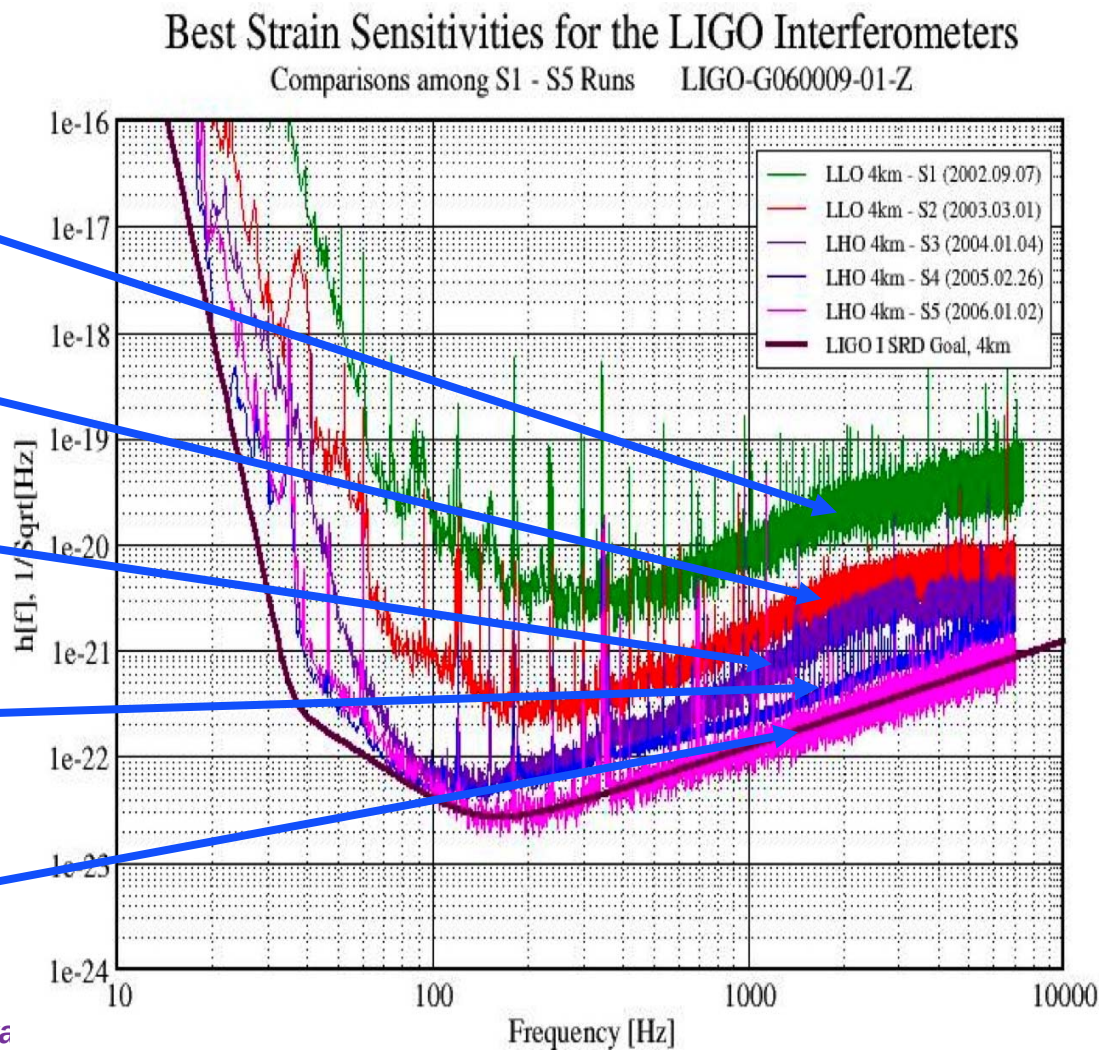
LIGO is at design sensitivity

- After 5 years of intense effort to reduce noise by ~ 3 orders of magnitude, in 2005 the design sensitivity predicted in 1995 was reached



Science runs and sensitivity--the history

Run	# days
S1 Sept '02	17
S2 Feb 02-Apr 03	59
S3 Nov 03-Jan 04	70
S4 Feb- March 05	30
S5 Nov 05------	> 1 year



The current search for gravitational waves

- A science run (S5) at design sensitivity began in November 2005 and is ongoing
- Searching for signals in audio band (~50 Hz to few kHz) from inspiraling neutron star and black hole pairs, collapsing supernovae, pulsars, for stochastic sources including the big bang, and from the unknown.

Hanford, Washington

4 km and 2 km interferometers

Livingston Louisiana

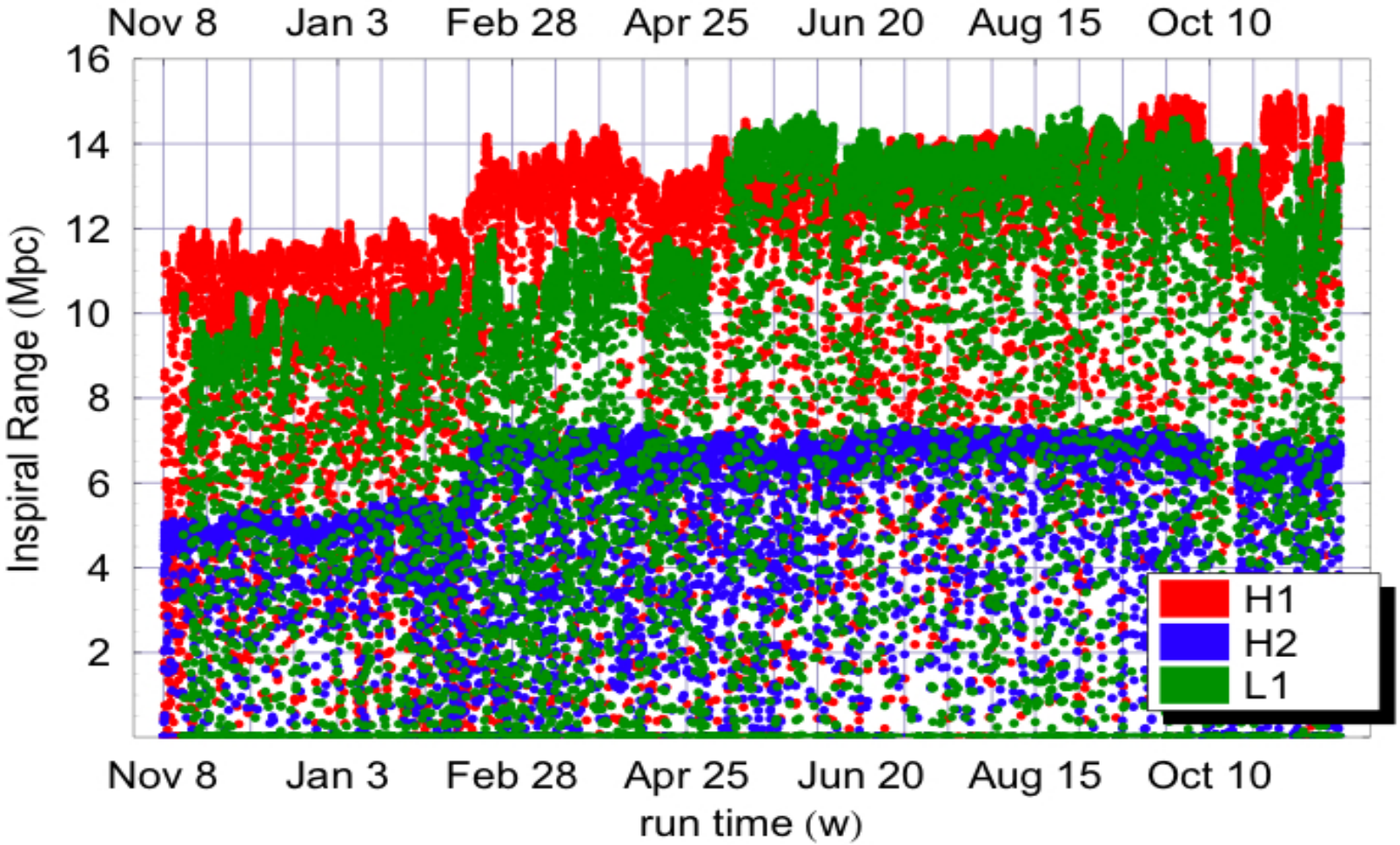
4 km interferometer

Some LIGO Hardware

Current status of S5 science run

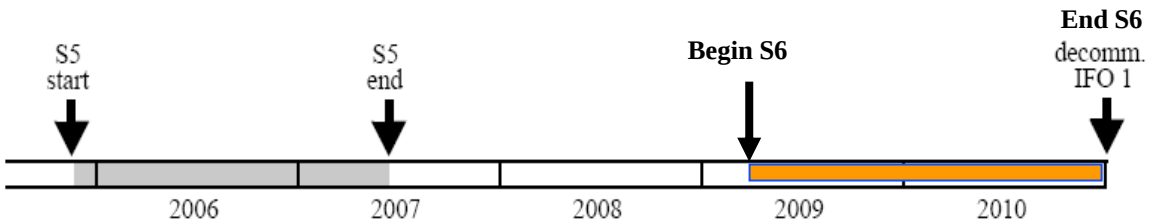
- Goal for this science run--
  - One year's data with coincident operation of both observatories at the our science performance goal --for H1, L1: range over 10 Mpc inspiral range, H2: over 5 Mpc (for 1.4 M_o neutron star pairs)
- Run going extremely well--began run at sensitivity goal
  - Sensitivity is now 40% greater than beginning of run
- Reliability and duty factor improving and approaching our target of 85% for each IFO 70% coincidence between sites
- Run now >55% complete
  - Expect run to end summer 2007

Figure of merit
1.4 M_O NS-NS inspiral range, since beginning of S5



Next step-Enhancements to initial LIGO

- After current run, make modest changes to LIGO to enhance sensitivity by ~2
  - To both 4 km interferometers, not the 2 km
  - Readout enhancement--Reduce noise and junk light at dark port sensing-- add mode filter cavity, DC readout of GW channel, move into vacuum, seismically isolate
  - Increase laser power by ~3.5-- modify things like thermal compensation to handle power
- Increase number of sources in range by factor ~8
- Goal- next science run with enhanced sensitivity in 2009



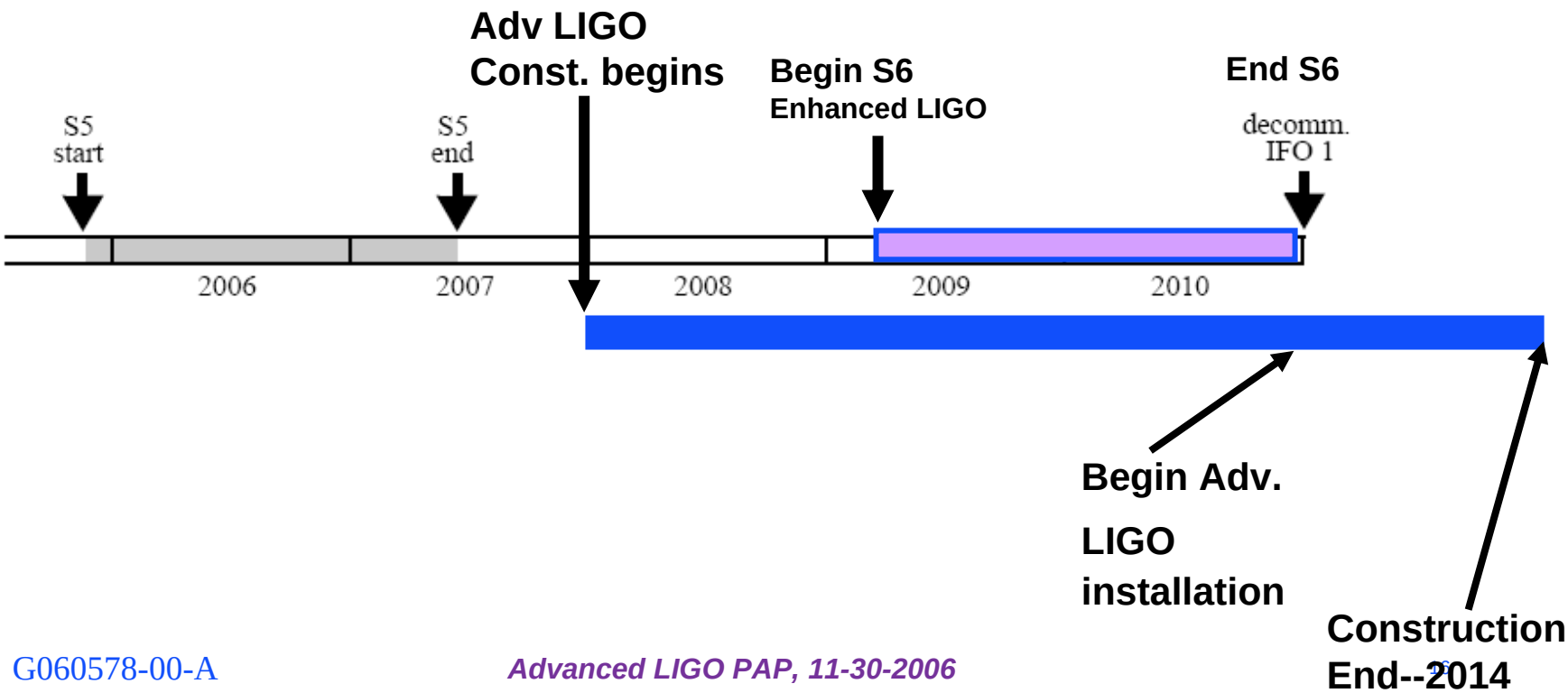
LIGO *Advanced LIGO- ready for construction start in FY08*

- A proposed NSF MREFC project to increase the sensitivity of LIGO by a factor of 10 and so increase the number of sources in range by ~1000
  - » Build on initial LIGO infrastructure and experience
  - » Higher power laser, improved seismic suspension and isolation, signal recycling & improved readout (like enhancements), larger mirrors (to handle increased thermal load), etc.
- Approved by the National Science Board
- Successful NSF Baseline Review of Advanced LIGO-
  - » May 31-June 2, 2006; ~20 outside experts; chair- Don Hartill
  - » *"The Panel looked carefully at the Advanced LIGO project and was impressed."*
  - » *"The Panel recommends that the Advanced LIGO project go forward and agrees that the project can be constructed for (*the estimated cost) *a total cost of 172.2 M$ (FY 2006 $) on the proposed schedule and is ready for a construction start in FY 08."*
- We expect Advanced LIGO to receive construction start and initial funding in the President's FY08 Budget Request.

Advanced LIGO--the project

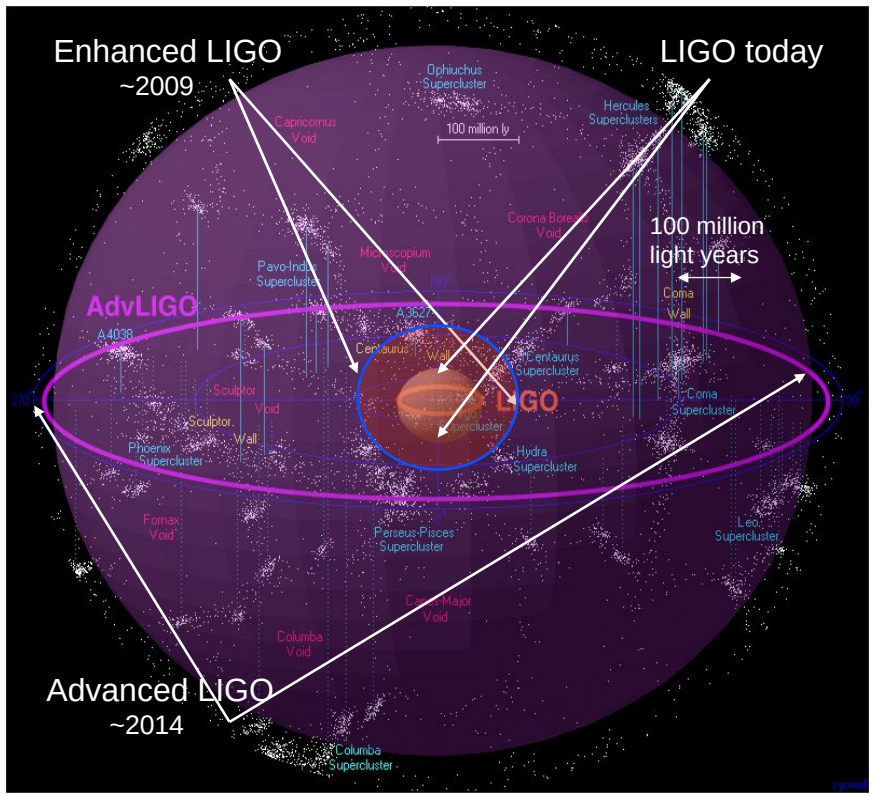
- Schedule-
  - » October 2007--August 2014 including 11 months schedule contingency
- Total NSF cost (then-year $)--
  - » $205M including ~4.2% inflation and 27% contingency
  - » $24M equivalent contributions by UK and Germany: each worth equivalent of ~$6M for development and $6M for fabrication of hardware
    - – This hardware is now being tested; delivery ahead of US schedule
- In FY07---
  - » Completing needed development and design in preparation for letting contacts in 2008
  - » Staffing up from within and outside LIGO Lab, LSC and new hires
  - » Strengthening our management processes, etc. for the project

Simplified timeline for LIGO



The scientific vision for LIGO

- 1st full science run of LIGO at design sensitivity in progress
  - » Began November 2005; >50% complete
  - » Hundreds of galaxies now in range
  - » Discovery possible but not probable during coming year
- Enhancement program
  - » In 2009 ~8 times more galaxies in range; discovery probability moderate
- Advanced LIGO project
  - » Construction start expected in FY08
  - » 1000 times more galaxies in range
  - » Expect ~1 signal/day- 1/week in ~2014
  - » Will usher in era of gravitational wave astrophysics



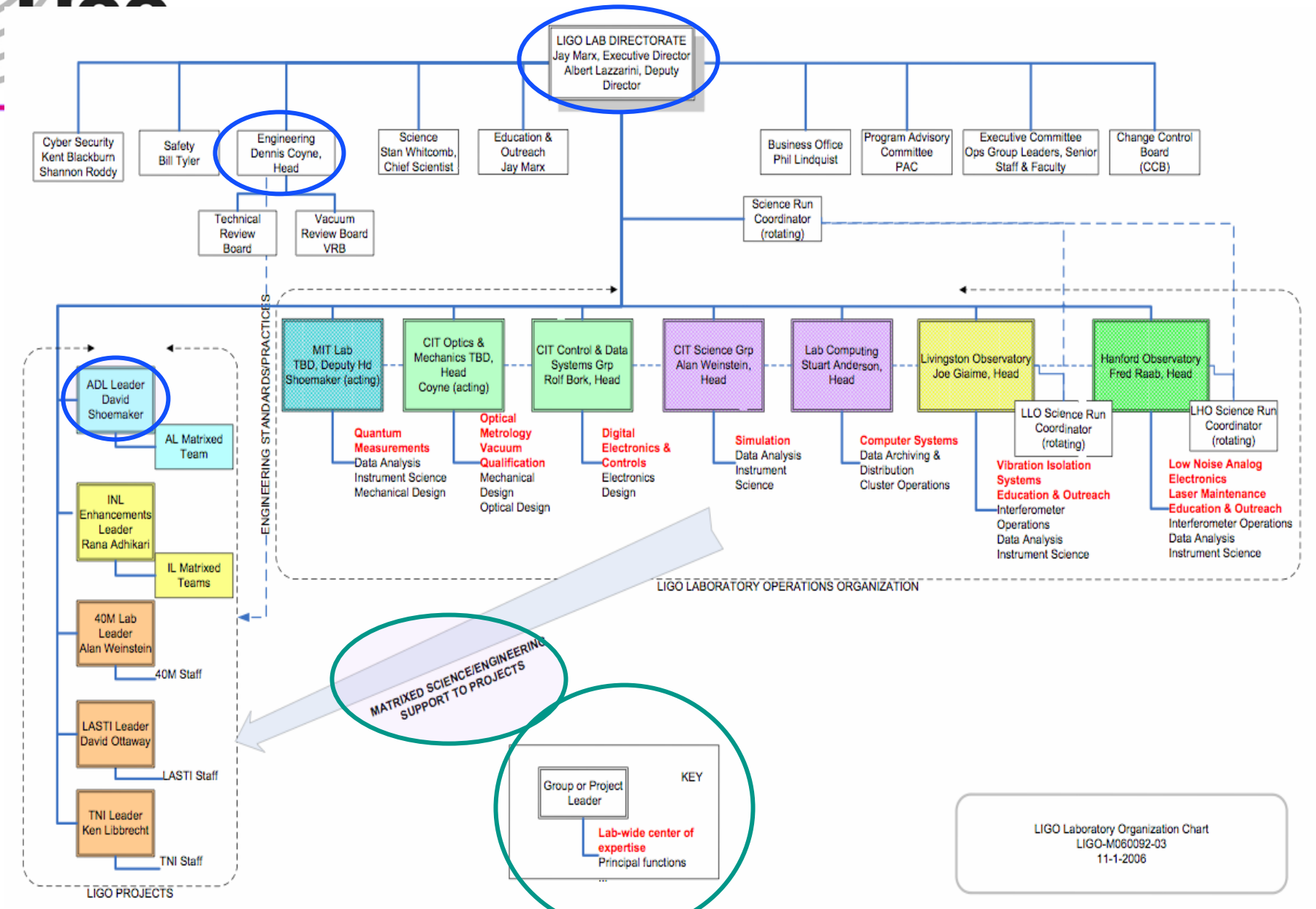
Advanced LIGO PAP,

How Advanced LIGO fits into LIGO Lab

- LIGO Laboratory organization
- Operations activities during and after Advanced LIGO
- Special challenge--
  - » firewall between operations and Advanced LIGO

LIGO Lab Organization- relevant to Advanced LIGO

- Implemented standard matrix system
  - » With Advanced LIGO coming the Lab needs flexibility to staff the project and carry out its other responsibilities
  - » Operations groups (horizontal) and “projects” (vertical)
    - – “Projects” include Adv LIGO, enhancements and R&D facilities
- Implemented formal “Project” groups in laboratory
  - – Advanced LIGO
  - – Initial LIGO Enhancements
  - – R&D facilities (40m, LASTI, TNI)


LIGO LAB DIRECTORATE
Jay Marx, Executive Director
Albert Lazzarini, Deputy Director
Cyber Security
Kent Blackburn
Shannon Roddy
Safety
Bill Tyler
Engineering
Dennis Coyne, Head
Science
Stan Whitcomb, Chief Scientist
Education & Outreach
Jay Marx
Business Office
Phil Lindquist
Program Advisory Committee
PAC
Executive Committee
Ops Group Leaders, Senior Staff & Faculty
Change Control Board
(CCB)
Technical Review Board
Vacuum Review Board
VRB
Science Run Coordinator (rotating)
ENGINEERING STANDARDS/PRACTICES
MIT Lab
TBD, Deputy Hd
Shoemaker (acting)
CIT Optics & Mechanics
TBD, Head
Coyne (acting)
CIT Control & Data Systems Grp
Rolf Bork, Head
CIT Science Grp
Alan Weinstein, Head
Lab Computing
Stuart Anderson, Head
Livingston Observatory
Joe Giaime, Head
Hanford Observatory
Fred Raab, Head
Quantum Measurements
Data Analysis
Instrument Science
Mechanical Design
Optical Metrology
Vacuum
Qualification
Mechanical Design
Optical Design
Digital Electronics & Controls
Electronics Design
Simulation
Data Analysis
Instrument Science
Computer Systems
Data Archiving & Distribution
Cluster Operations
LLO Science Run Coordinator (rotating)
Vibration Isolation Systems
Education & Outreach
Interferometer Operations
Data Analysis
Instrument Science
LHO Science Run Coordinator (rotating)
Low Noise Analog Electronics
Laser Maintenance
Education & Outreach
Interferometer Operations
Data Analysis
Instrument Science
LIGO LABORATORY OPERATIONS ORGANIZATION
ADL Leader
David Shoemaker
AL Matrixed Team
INL Enhancements Leader
Rana Adhikari
IL Matrixed Teams
40M Lab Leader
Alan Weinstein
40M Staff
LASTI Leader
David Ottaway
LASTI Staff
TNI Leader
Ken Libbrecht
TNI Staff
LIGO PROJECTS
MATRIXED SCIENCE/ENGINEERING SUPPORT TO PROJECTS
Group or Project Leader
KEY
Lab-wide center of expertise
Principal functions
LIGO Laboratory Organization Chart
LIGO-M060092-03
11-1-2006

LIGO Lab. R&D facilities and Advanced LIGO

- 40m Interferometer at Caltech
  - Test Advanced LIGO interferometer sensing and controls
  - Test interferometer locking strategies
  - Beyond-Baseline-Advanced-LIGO- interferometry R&D in use of squeezed light, etc.

- LASTI at MIT-- full scale vacuum chambers
  - Test in-vacuum prototypes-- e.g. mirror suspensions, seismic isolation, etc.
  - Test Advanced LIGO digital controls systems, multi-input multi-output servocontrols
  - Perform partial integration of seismic, suspension, input optics, and pre-stabilized laser subsystems
  - Beyond-Baseline-Advanced-LIGO interferometry R&D in use of pondermotive squeezing

- Thermal Noise Interferometer (at Caltech)
  - Perform further direct measurements of optical coating thermal noise
  - Beyond-Baseline-Advanced-LIGO R&D on non-gaussian beams to reduce thermal noise

Planning for operations during and after Advanced LIGO

- Current LIGO Operations continue
  - Observatory operations (personnel, travel, infrastructure)
  - Data management and analysis
  - Incremental detector improvements
  - Management and administration
  - Education and Outreach
- Advanced LIGO construction begins in FY2008 funded by MREFC (separate from operations)
- R&D will remain an important part of Lab's mission
  - Important experience from initial LIGO:
    - R&D must go on in parallel with Advanced LIGO construction and commissioning to develop techniques for risk reduction, solving problems and future improvements
  - Some R&D aimed to longer term future for good of field and to keep quality instrument scientist engaged
- Additional computing needs must be met for Advanced LIGO era
- Resources for ongoing refreshment of computational capabilities and maintenance of Advanced LIGO are needed

LIGO LAB Manpower planning

- Manpower planning takes account of all Lab activities including base Lab staff on Advanced LIGO
  - » Developed staffing model for 2015 when in Advanced LIGO operations
    - – For observatories, LIGO Lab. At Caltech and MIT
    - – Take account of increased complexity of IFOs, additional computational needs
    - – Modest additional staffing (interferometer scientists, EEs and realtime programmers) to reflect increased complexity of operating Advanced LIGO and a few additional data management staff reflecting increased computing and data analysis load with Advanced LIGO, and a few more post-docs
  - » Projected backward to look at when additional staff compared to 2015 model is needed
- Will decrease in Laboratory operations funding during MREFC equivalent to cost of current staff moving to Advanced LIGO project
- Plan does not include term hires and contractors for Advanced LIGO construction

Anticipated LIGO Lab staffing FY09 and beyond

- Transition to 2015 asymptopia:

Year	On Ops budget	Current staff to Adv LIGO	Total staff
FY2007	167	--	167
FY2008	135	29	164
FY2009	117	44	161
FY2010	114	49	163
FY2011	113	50	163
FY2012	122	45	167
FY2013	144	25	169
FY2014	158	15	173
FY2015	172	2	174

Cooperative Agreement

Note-- These staffing levels are for LIGO Lab staff shifted to and eventually from Advanced LIGO Project. Does not include additional staff hired just for construction project

Special challenge-- the firewall

- Goal: To comply with the need to fence-off project costs from LIGO Lab operations in a manner that would be auditable and practical.
- Challenge-- how to avoid having to keep track of every man-microsecond and allocate the cost of every light bulb between operations and the project
- Approach:
  - » All labor that is full time on Advanced LIGO will be charged to the project. For personnel working on both the project and other activities, an estimate will be made and verified by supervisors on a 2 week or monthly basis of the time e\ach person spent on the project and construction accounts will be charged accordingly.
  - » All LIGO Laboratory expenses that would be incurred even without the Advanced LIGO project (e.g. administrative people in LIGO Laboratory, infrastructure costs such as maintenance, electricity, heating, of buildings, etc.) would be considered outside the project.
  - » Any clearly identified incremental costs related to Advanced LIGO will be charged to the project.
  - » We want NSF to provide LIGO Laboratory with written guidance based on this approach. It will be part of the PEP which will be approved and signed off on by NSF

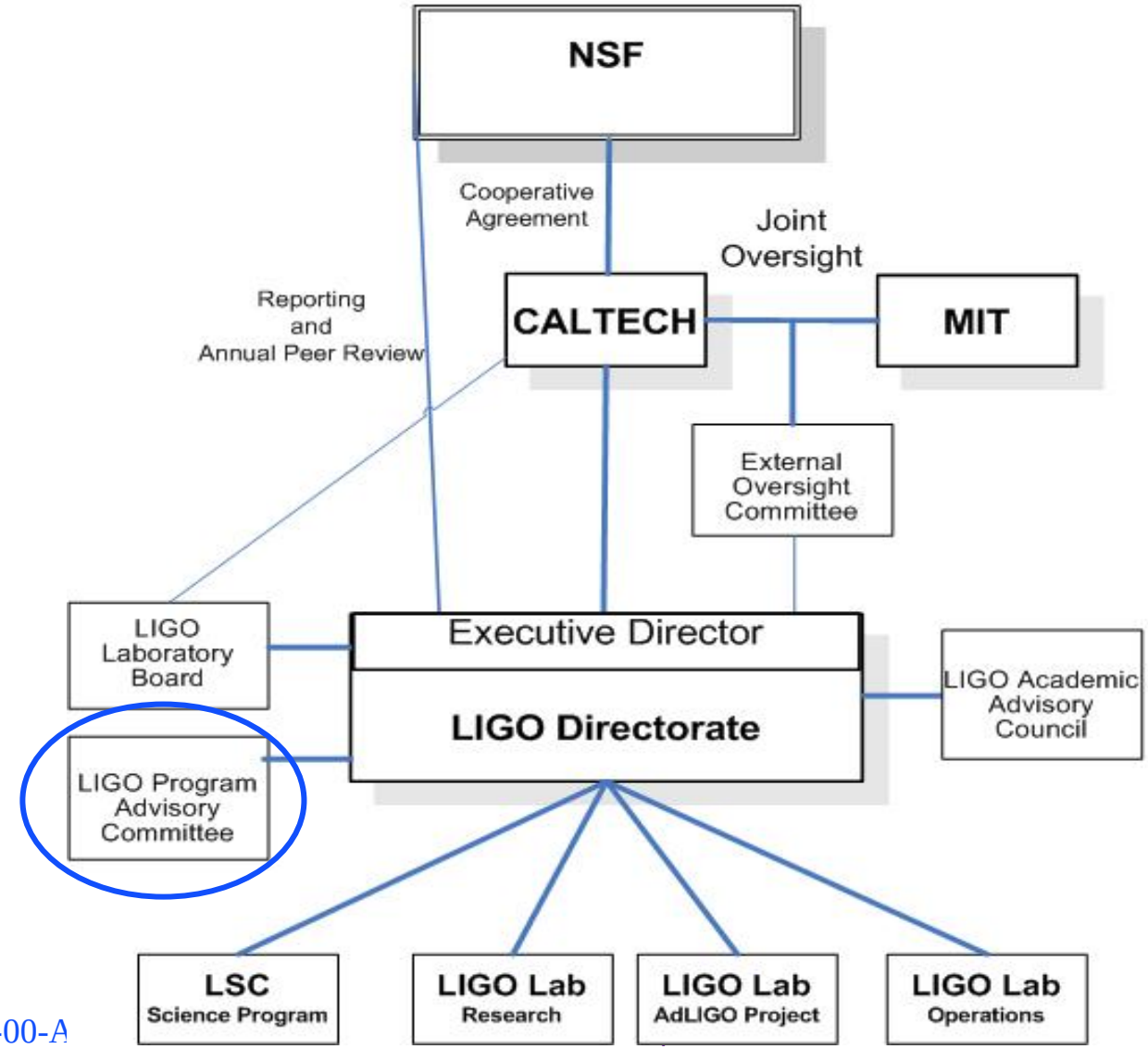
LIGO

The Project Advisory Panel

- Role of the PAP
- How the PAP fits into LIGO
- The Charter
- The Charge for this meeting

LIGO Organization

And the PAP



LIGO Program Advisory Committee

- The LIGO Program Advisory Committee (PAC) is a principal source of ***external*** advice to LIGO on scientific policy, technical choices, support of the scientific community and organizational matters.

- Reports to the LIGO Directorate

- A subcommittee of the PAC serves as the Project Advisory Panel (PAP) for the Advanced LIGO Project.

PAP Charter

- The Advanced LIGO Project Advisory Panel (PAP) reports to the LIGO Executive Director.
- The PAP will conduct periodic reviews and assessments of the status, planning and other aspects of the Advanced LIGO project as defined in the charge for each meeting, and provide appropriate advice to the Executive Director and the Advanced LIGO Project Head.
- The PAP will meet at least once each year and more frequently if necessary. PAP meetings will be called by the LIGO Executive Director and a charge for each meeting will be provided to the PAP.
- A written report from the PAP should be provided to the Executive Director during the 2 week period following each meeting.

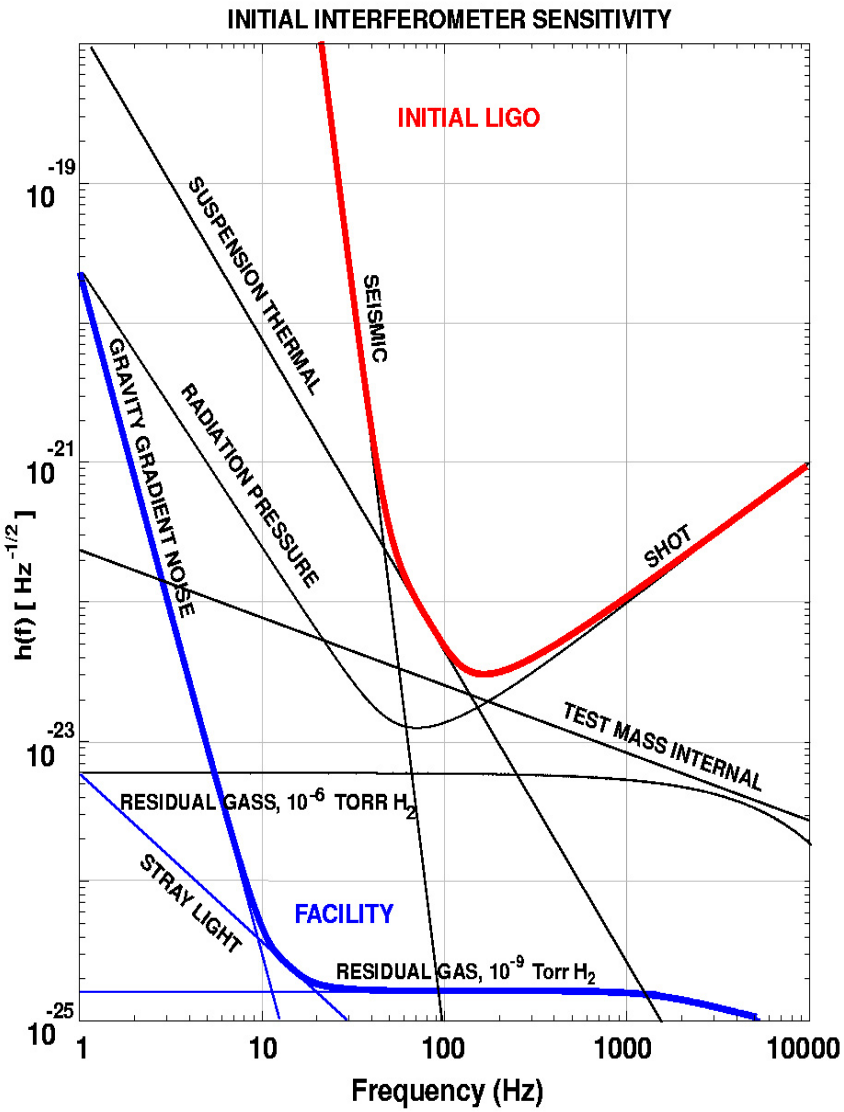
Charge for this meeting

1) Examine the state of development and advise on any ‘triage’ or prioritization to ensure readiness
2) Examine the approach to managing and distributing ‘float’ in the schedule; address the recommendation from the review committee to manage to a ‘fragile’ schedule
3) Examine the approach to the start of the installation currently planned; is there an approach to increase flexibility for an early, or distributed, start?
4) Advise on handling the barrier between Operations and Project funding, from a practical and an audit perspective
5) Advise on approaches to minimizing the duration of the post-project effort to reach design sensitivity; are there autopsies from initial LIGO, design, or simulation efforts now which we could use to our advantage?
6) How can we ensure quality control and quality assurance with a minimum of bureaucracy or unproductive paperwork?
7) Is our planned methodology for risk management effective; is there a better way?

Conclusions

Learn about LIGO and give us wise advice

Major noise sources for LIGO



- Displacement Noise
  - » Seismic motion (limit at low frequencies)
    - – Ground motion from natural and anthropogenic sources
  - » Thermal Noise (limit at mid-frequencies)
    - – vibrations due to finite temperature
  - » Radiation Pressure
- Sensing Noise (limit at high frequency)
  - » Photon Shot Noise
    - – quantum fluctuations in the number of photons detected
- Facilities limits
  - » Residual Gas (scattering)
- Inherent limit on ground
  - » Gravity gradient noise