



State of the LIGO Project

Gary Sanders
LIGO Laboratory
LSC Meeting, March 2001
Baton Rouge

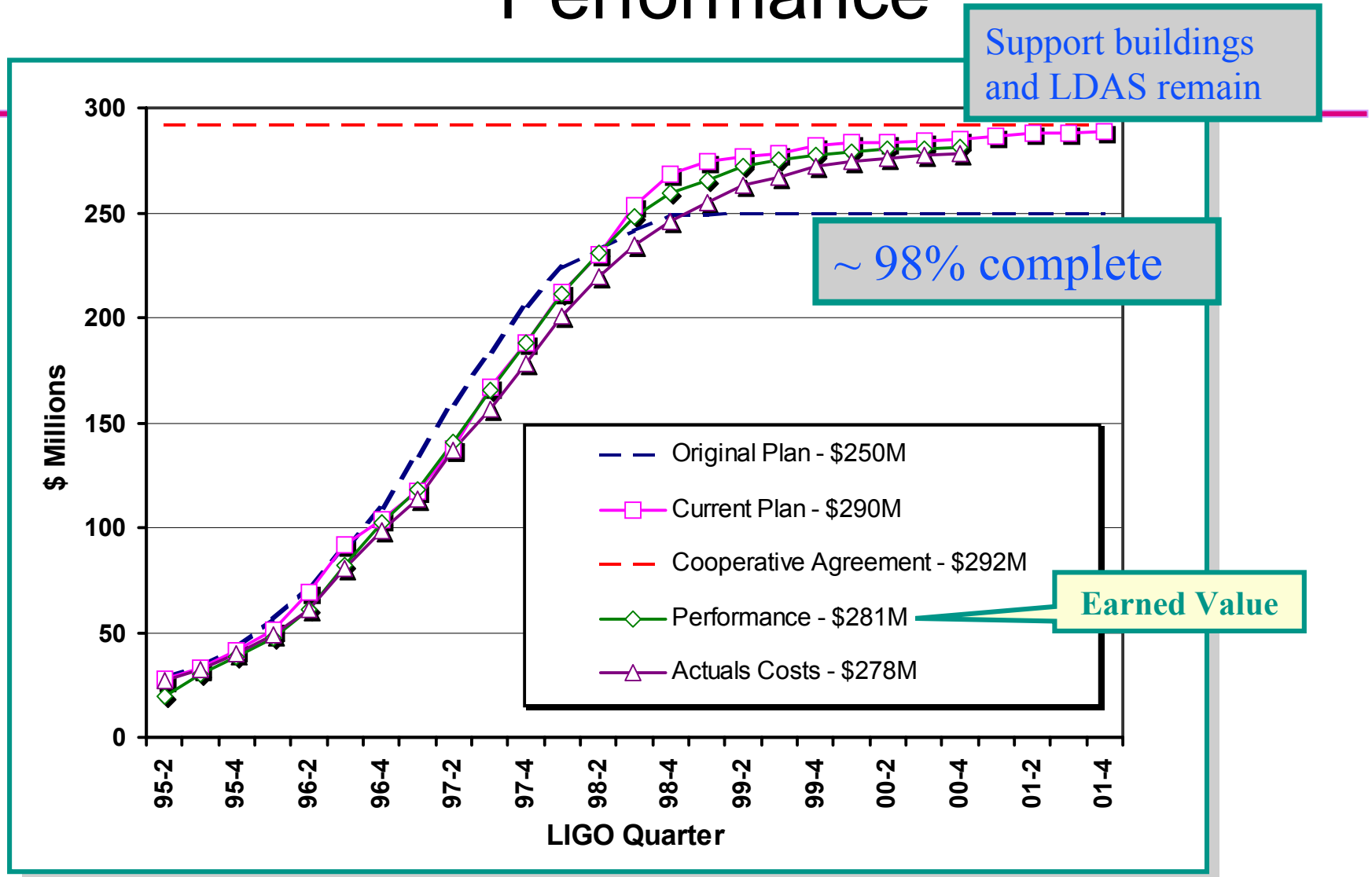


LIGO Plans *schedule*

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

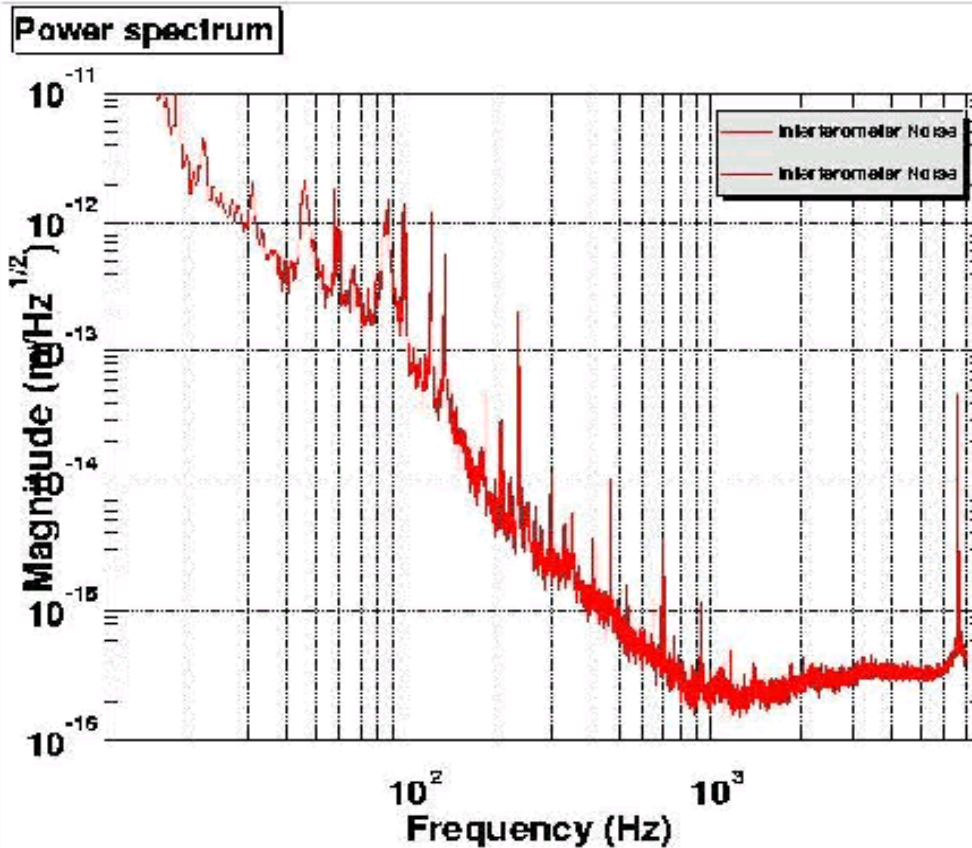


Construction Cost/Schedule Performance





Current Noise Spectrum



Since November

Factor of 20 improvement:

- Recycling
- Reduction of electronics noise
- Partial implementation of alignment control

Two Weeks AGO

LIGO-G010035-00-D

NSF Operations Review

25



X-Sender: stan@127.0.0.1

X-Mailer: QUALCOMM Windows Eudora Version 4.3.2

Date: Thu, 22 Feb 2001 09:14:29 -0800

To: Mark Coles <coles@ligo-la.caltech.edu>, David Shoemaker <dhs@ligo.mit.edu>, Barry Barish <barish@ligo.caltech.edu> barish@ligo.caltech.edu, "Kip S. Thorne" <kip@tapir.caltech.edu>, coyne@ligo.caltech.edu, whitcomb_s@ligo.caltech.edu, Rainer Weiss <weiss@ligo.mit.edu>, David Shoemaker <dhs@ligo.mit.edu>, Gary Sanders <sanders@ligo.caltech.edu>, Mark Coles <coles@ligo.caltech.edu>, raab_f@ligo.caltech.edu, phil@ligo.caltech.edu, gerry@ligo.caltech.edu, otto@ligo.caltech.edu

From: Stan Whitcomb <stan@ligo.caltech.edu>

Subject: Absolutely final version of NSF talk

Cc: ewood@ligo.caltech.edu, berry_j@ligo.caltech.edu

The final version of my NSF talk is available at

<http://ligo-wa.caltech.edu/~stan/G010035-00.pdf> and .ppt The .ppt version will need to have access to the .mpg file in the same directory.

Now I intend to devote my efforts toward making the current noise spectrum obsolete.

stan



...and then...



Installation Status

- All installation complete for LHO 2km and LLO 4km interferometers
 - » Commissioning underway
- LHO 4km interferometer
 - » Seismic isolation complete
 - » Prestabilized laser installation underway
 - » In-vacuum optics installation currently underway
- Data Acquisition/Control Network infrastructure complete at both sites
 - » Basic functionality all in place; still working on reliability, enhancements

Some reinstallation
underway



Commissioning Status

- LHO 2 km interferometer

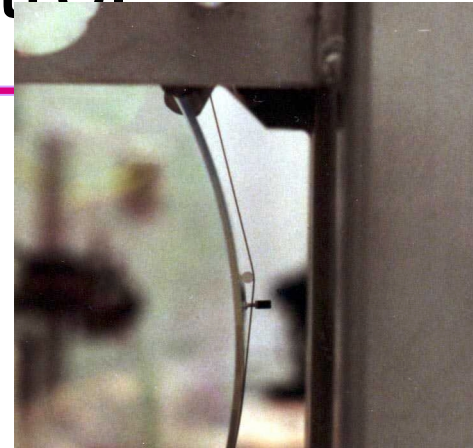
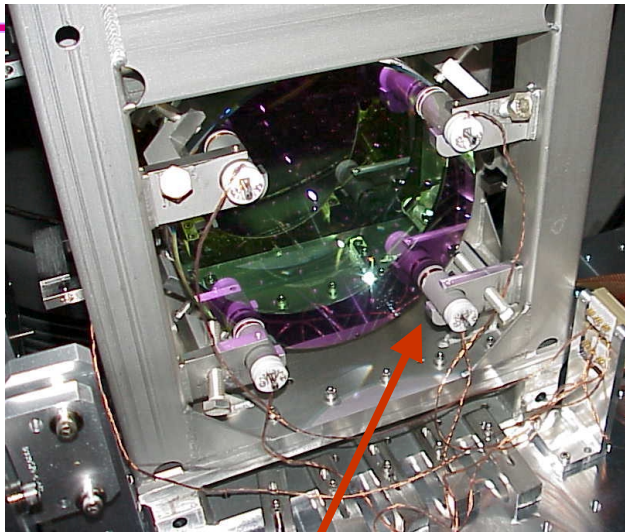
- » Identified problem with scattered light in suspension sensors during mode cleaner testing – moved to lower power and continued on
- » Full interferometer locked at low input power (100 mW)
 - All longitudinal degrees of freedom controlled
 - Partial implementation of wavefront-sensing alignment control
- » Still tuning servo loops to get design performance

- LLO 4 km interferometer

- » Careful characterization of laser-mode cleaner subsystems
- » Single arm testing underway – full lock soon
- » Repetition of 2 km integrations taking much less time than (I) expected (20 times shorter to date, but probably can't continue)
- » Seismic background is an issue



Core Optics Suspension and Control



- Optics suspended as simple pendulums
- Local sensors/actuators for damping and control
- Problem with local sensor sensitivity to laser light

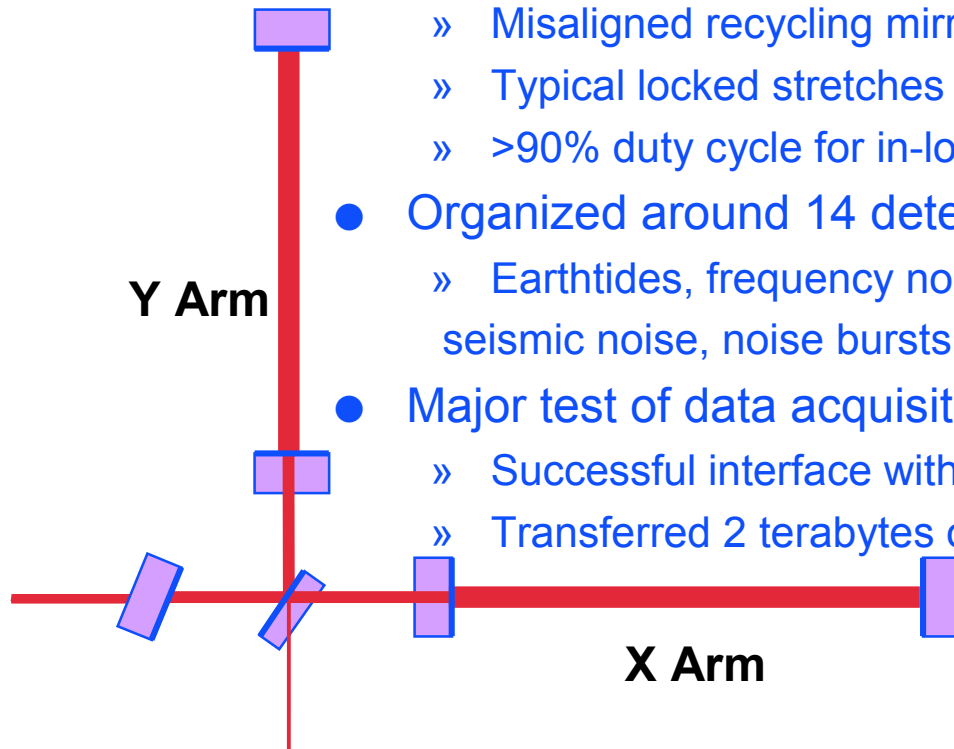


Engineering Runs

- Involve the broader LSC in detector commissioning
- Engineering Runs are a key part of our commissioning plan
 - » Test interferometer stability, reliability
 - » Well-defined dataset for off-site analysis
 - » Develop procedures for later operations
- First Engineering Run (E1) in April 2000
 - » Single arm operation of 2 km interferometer with wavefront sensing alignment on all angular degrees of freedom
 - » 24 hour duration
 - » Lots of interest, seven LSC groups made arrangements for data access

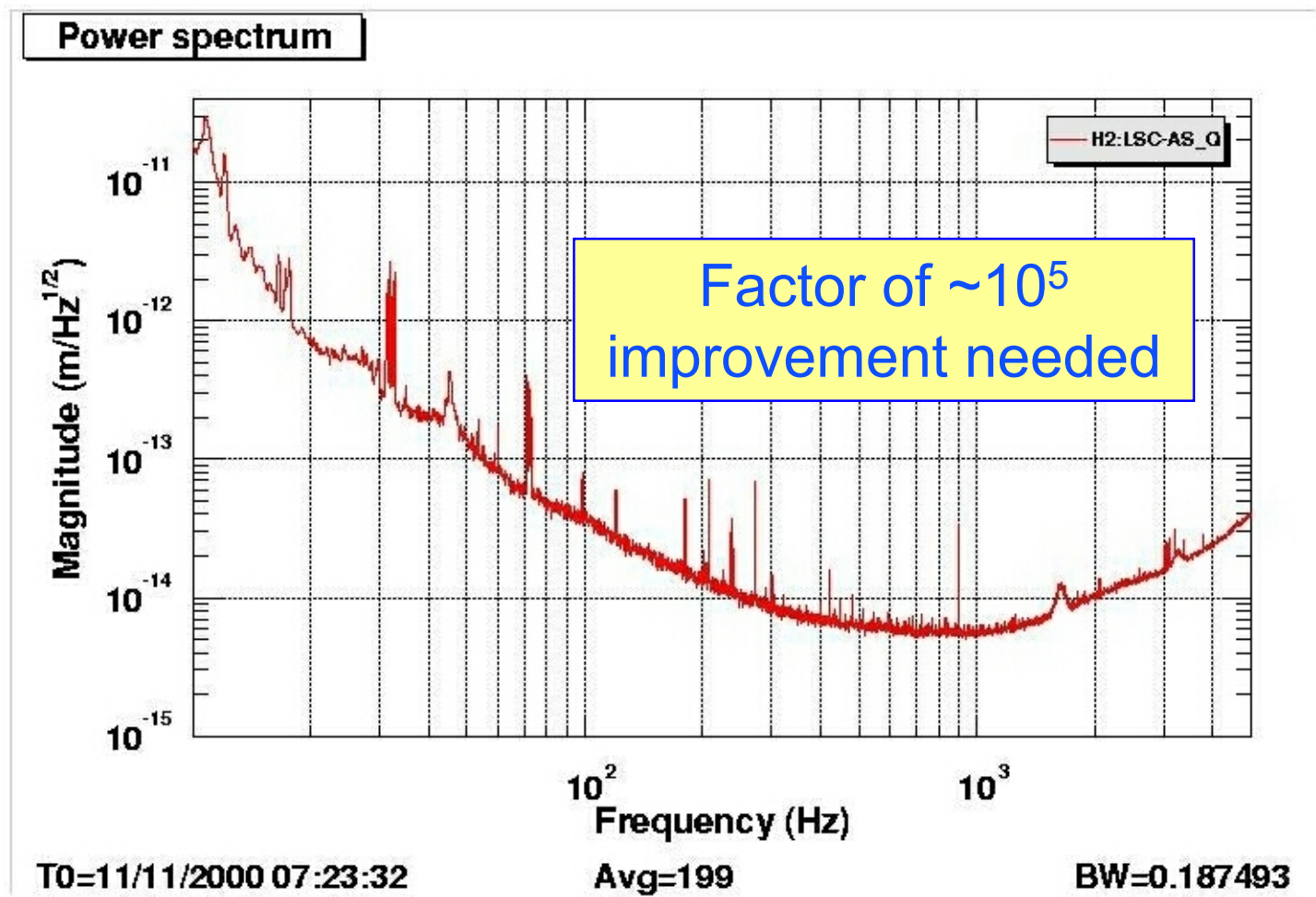
Second Engineering Run (E2)

- November 2000
 - » One week of 24/7 operation of 2 km interferometer
 - » Approximately 35 scientists participated on site
- Recombined Michelson with Fabry-Perot arms
 - » Misaligned recycling mirror to make for more robust locking
 - » Typical locked stretches 30 – 90 minutes (longest ~ 3 hours)
 - » >90% duty cycle for in-lock operation
- Organized around 14 detector investigations
 - » Earthtides, frequency noise, calibration, noise stationarity, seismic noise, noise bursts, line tracking, ...
- Major test of data acquisition system
 - » Successful interface with LDAS front-end
 - » Transferred 2 terabytes of data to Caltech archive



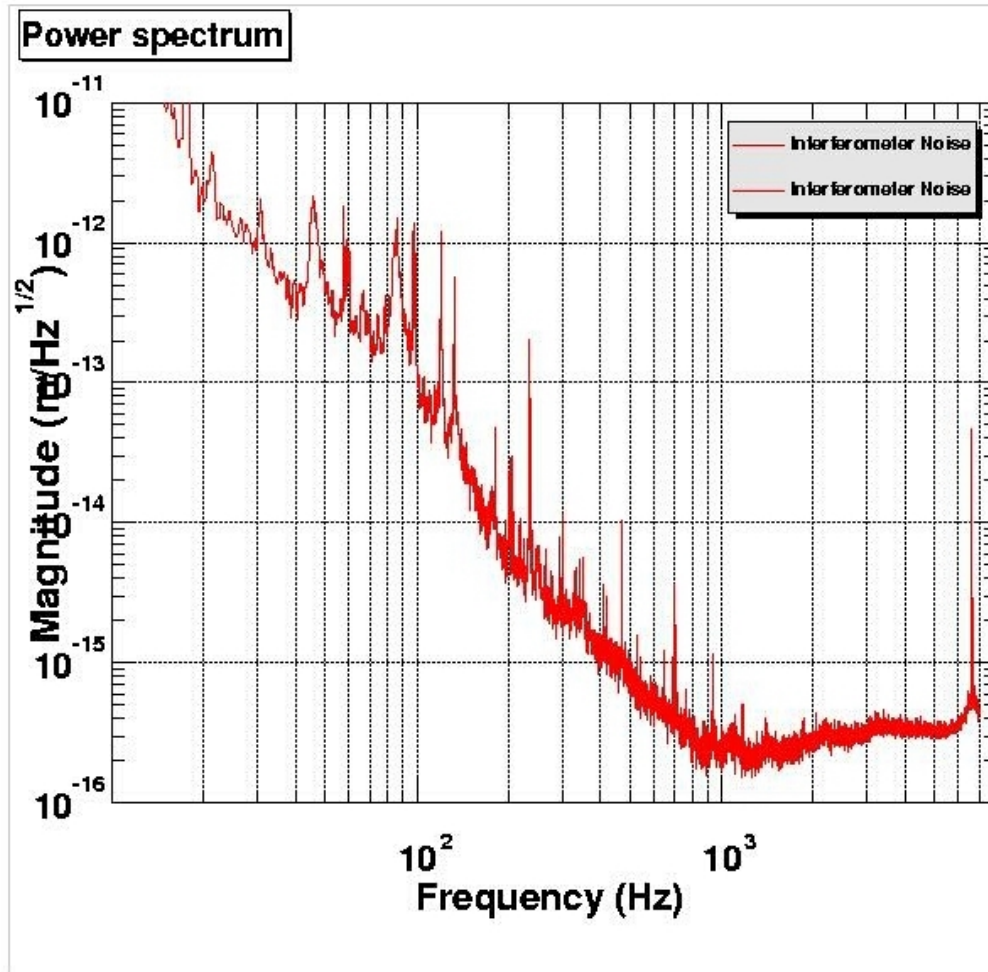


E2: Recombined Spectrum



First differential arm spectrum, Nov. 2000

Current Noise Spectrum

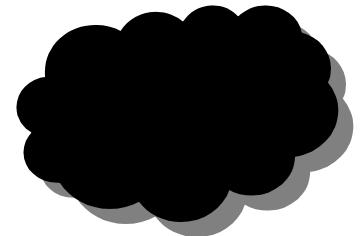


- Factor of 20 improvement:
- Recycling
 - Reduction of electronics noise
 - Partial implementation of alignment control



E3 Engineering Run

- Last week
- **First coincidence run** between LHO 2 km interferometer (PEM only) and LLO 4 km interferometer (single arm)
- Again organized around investigations
- Specific goals
 - » Correlations between environmental signals
 - » Integration of data streams from two sites
 - » First operation of full recycled F-P Michelson interferometer





Engineering run 3. (E3) 9-12(13) LLO-LHO

- **First joint engineering run between LIGO sites**
 - » X-arm locked for LLO
 - » PEM for LHO
- **Principal goals:**
 - » High up time
 - » High overlap time
 - » Record excellent data for investigations
 - » Help off site members to get hands on experience with the detector
 - » Hone our skills, identify bottle necks

From Szabi Marka





E3 run summary: **E3 run is a success!**

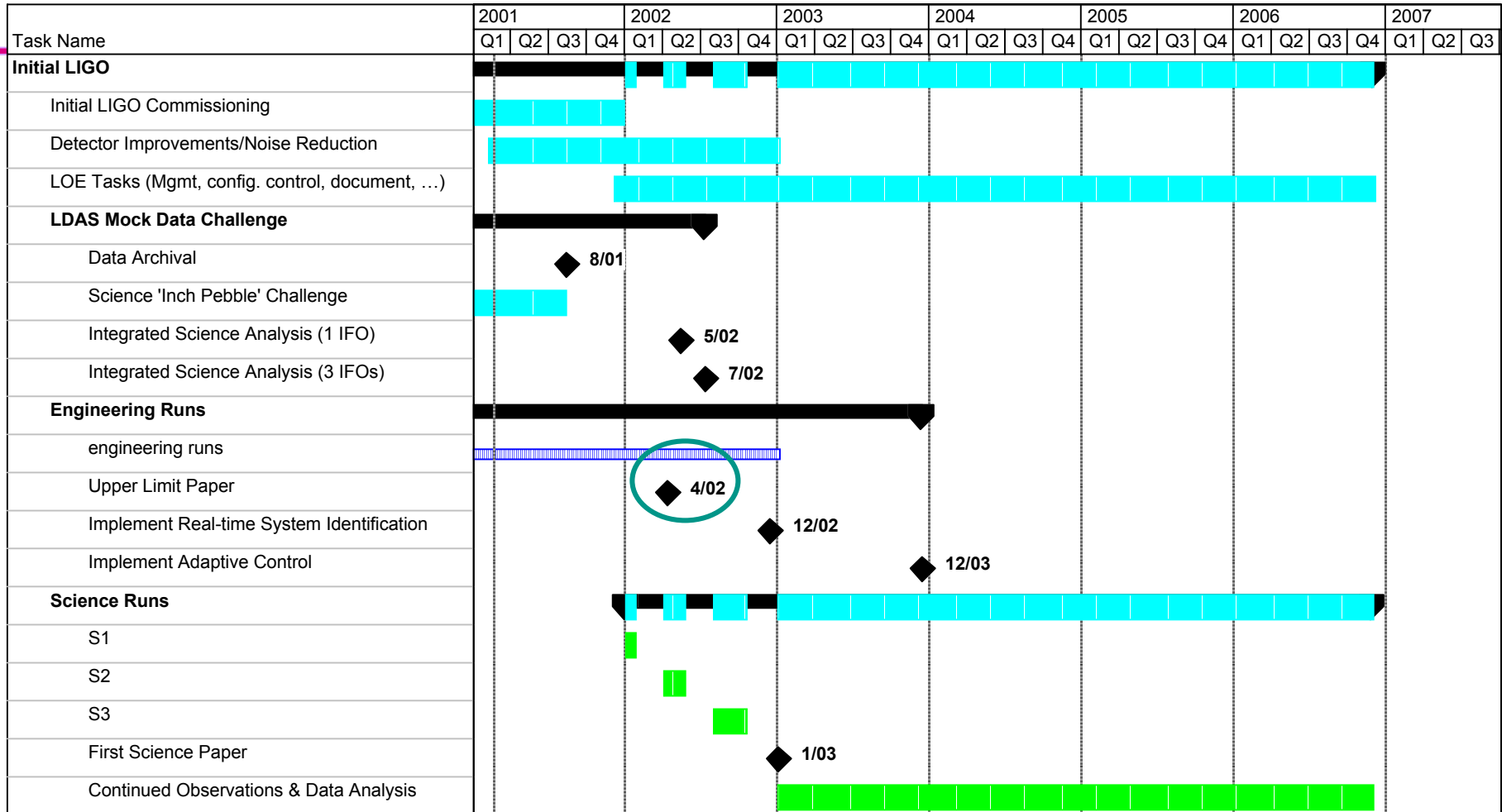
- **Smooth operation and great learning experience!**
 - » ~**0.9Tb** of continuous data is on tape by LDAS
 - » ~**450Gb** of RDS data was recorded during the 3+1 days
 - » We estimate that the X-arm was locked **80-90%** of the time during 72 hour run and close to **95+%** for the extra day
 - » Minor problems fixed quickly and effectively by experts

- **Strong LSC interest!**
 - » **13+** scientific investigations
 - » **10+** monitors running on the Data Monitoring Tool
 - » Close to **20** off site scientists and 8 operators gave shifts
 - » Large number of very interested scientists were working in the control room and computer users room nearly around the clock

From Szabi Marka

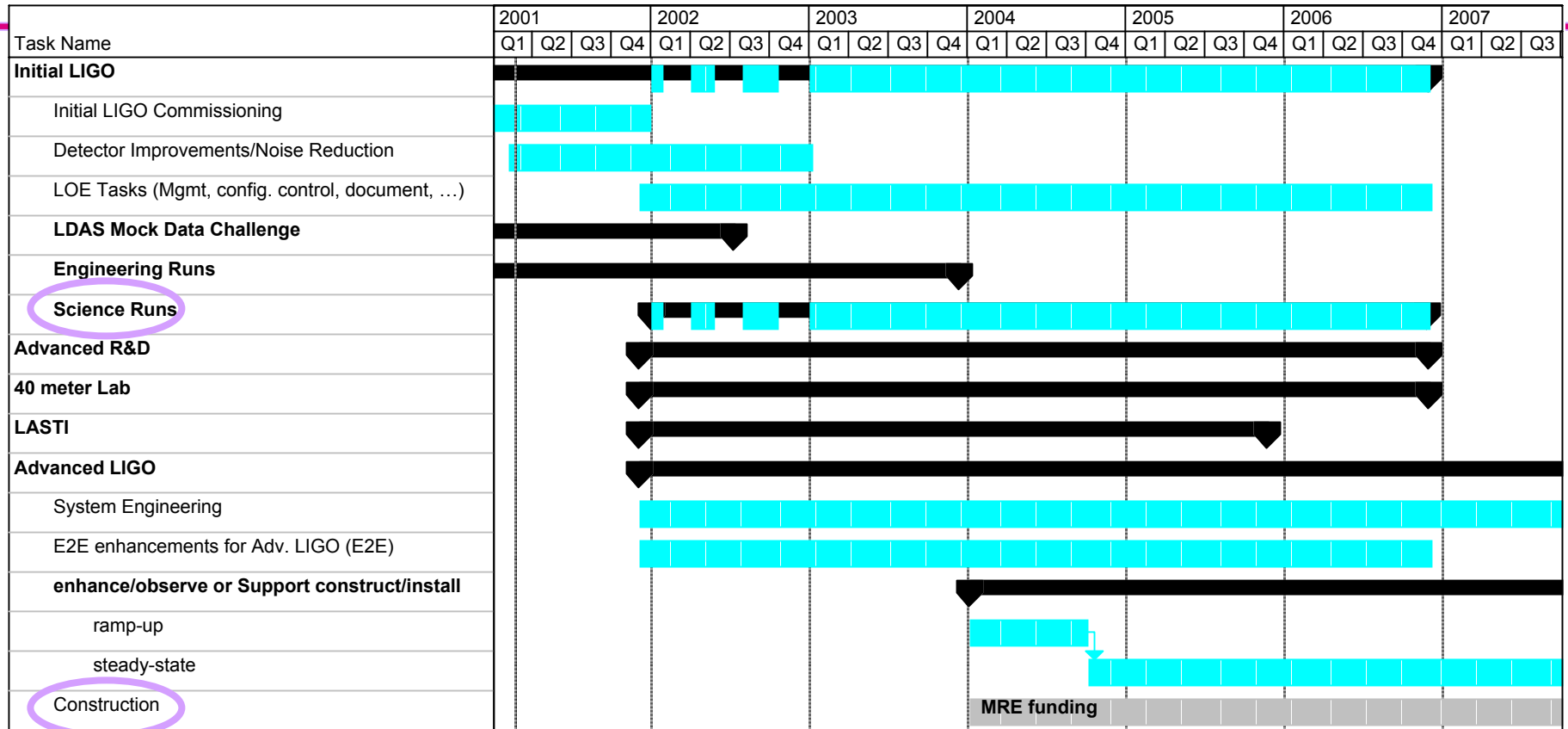


Initial Detector Milestones





Overall Proposed Schedule





LIGO

Program and Mission of the LIGO Laboratory

LIGO Renewal

Proposal 2002 - 2006

- *observe gravitational wave sources;*
- develop advanced detectors that approach and exploit the facility limits on interferometer performance;
- operate the LIGO facilities to support the national and international scientific community;
- and support scientific education and public outreach related to gravitational wave astronomy.



LIGO Proposes To:

- Complete commissioning of the initial LIGO interferometers;
- operate the LIGO interferometers for the initial LIGO Science Run;
- process and analyze the Science Run data and publish the results of the first scientific searches for gravitational wave sources;
- characterize and improve the sensitivity and availability of the operating interferometers;
- define interferometer upgrades and carry out a research and development program to underpin future upgrade proposals;
- support the development and research of the LIGO Scientific Collaboration;
- support the development of the international network of gravitational wave detectors;
- interpret the LIGO program to the public;
- leverage LIGO in educational settings;
- and address new industrial technologies and applications stimulated by the requirements of gravitational wave observation.



Funding History

**MRE
Funds**

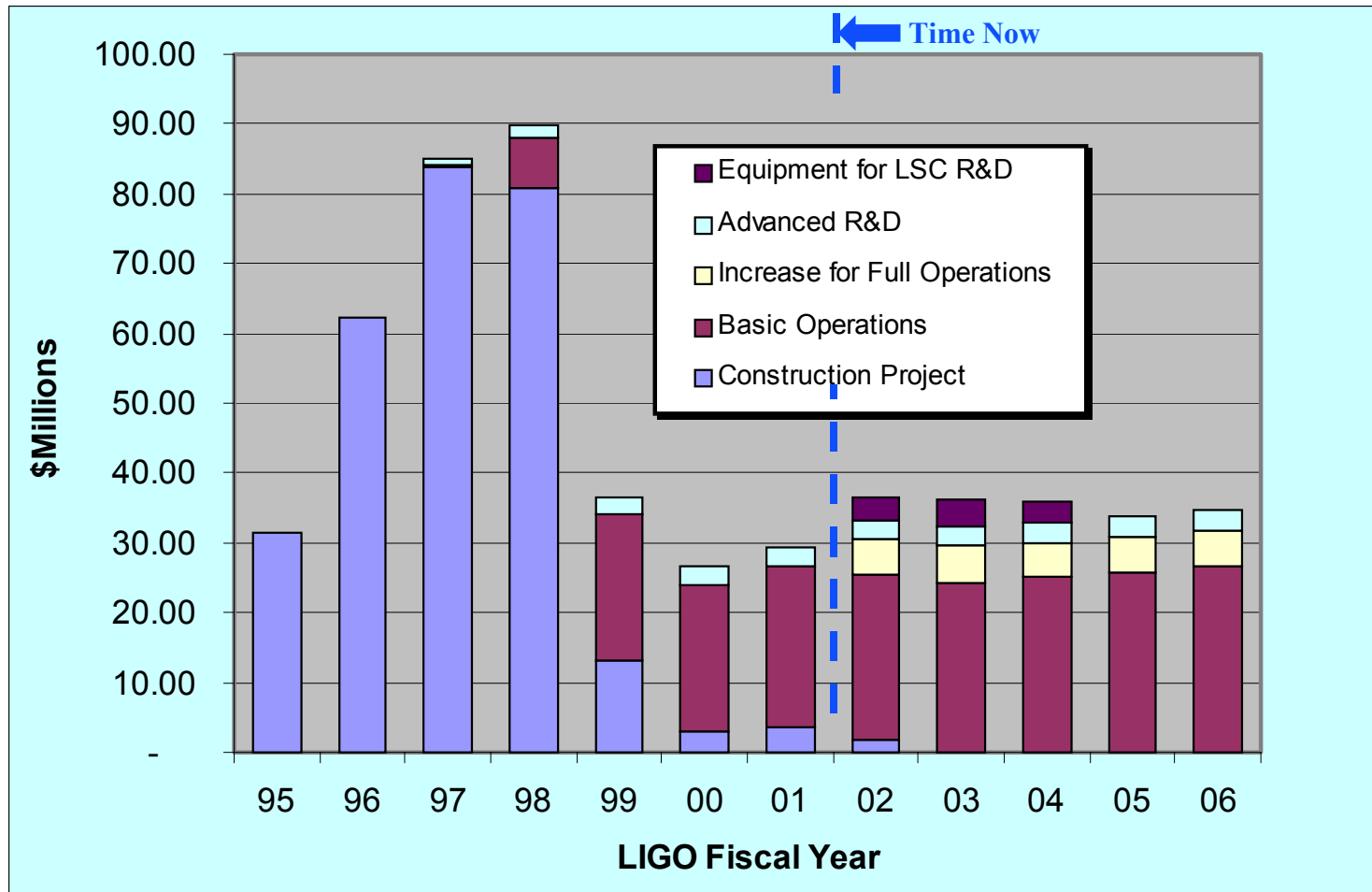
Fiscal Year	Construction (\$M)	R&D (\$M)	Operations (\$M)	Advanced R&D (\$M)	Total (\$M)
1992-94	35.90	11.19	-	-	47.09
1995	85.00	3.95	-	-	88.95
1996	70.00	2.38	-	-	72.38
1997	55.00	1.62	0.30	0.80	57.72
1998	26.00	0.86	7.30	1.82	35.98
1999	0.20	-	20.78	2.28	23.26
2000	-	-	21.10	2.60	23.70
2001 (10 mo.)	-	-	19.10 (10 mo.)	2.70	21.80 (10 mo.)
2001 (12 mo.)			22.92 (12 mo.)	2.70	25.62 (12 mo.)
Total (10 mo.)	272.10	20.00	68.58	10.20	370.88

Construction Project

Operations



Budget History and Request





Future Operations Proposal Budget

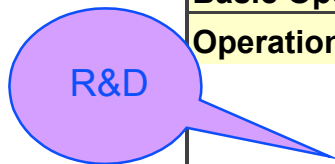
	FY 2001 (\$M)	FY 2002 (\$M)	FY 2003 (\$M)	FY 2004 (\$M)	FY 2005 (\$M)	FY 2006 (\$M)	Total 2002-6 (\$M)
Currently funded Operations	22.92	23.63	24.32	25.05	25.87	26.65	125.52
Increase for Full Operations		5.21	5.20	4.79	4.86	4.95	25.01
Advanced R&D	2.70	2.77	2.86	2.95	3.04	3.13	14.76
R&D Equipment for 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.

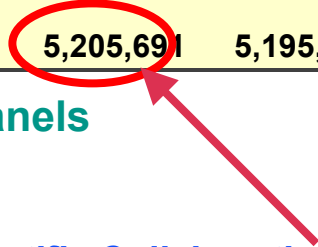


Increase for Full Operations

Budget Category	Increase	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
Basic Operations						
	* CDS Hardware Maintenance	513,800	502,434	517,507	533,032	549,023
	* LDAS Maintenance	1,378,728	1,378,728	1,322,235	1,303,163	1,303,163
	Outreach	249,848	257,343	265,063	273,015	281,206
	Site Operations	558,485	575,240	592,497	610,272	628,580
	* Telecommunications / Networking	540,500	542,200	542,200	539,500	539,500
	Staff for Site LSC Support	254,678	262,318	270,187	278,293	286,642
Basic Operations Totals		3,496,039	3,518,263	3,509,689	3,537,275	3,588,114
Operations Support of Advanced R&D						
	Seismic Development	506,300	434,574			
	Engineering Staff	920,868	948,494	976,949	1,006,257	1,036,445
	* Simulation & Modeling Staff	282,485	293,949	305,614	317,772	330,617
R&D Total		1,709,652	1,677,017	1,282,562	1,324,029	1,367,062
Grand Total		5,205,691	5,195,280	4,792,252	4,861,304	4,955,176



* Need recognized by NSF review panels





Internal Review by LIGO Program Advisory Committee...

- Reviewers:

- » Abe Seiden (SCIPP)
- » John Domingo (Jefferson Lab)
- » Tom Nash (FNAL)
- » P. Saulson (Syracuse)

- PAC commented that operating budgets were tight

- » “Judging from the detailed presentation of the operating budget for the Livingston and Hanford sites, this budget appears extremely tight. In particular the staffing level for these sites is so lean...”
- » “The maintenance and replacement costs for the control room data acquisition and control hardware are based on a very modest replacement rate...”
- » “A continuous [computing] replacement cycle is, therefore, not an option or a luxury, but mandatory during this period of dynamic change...”



Quotations From the Draft NSF Review February 2001

- “The Review Panel was extremely impressed with all aspects of the LIGO Program and feels that it should receive the highest possible rating.”
- “The scientific goals ... are of revolutionary importance.”
- **“The Review Panel recommends that the NSF, even in the eventuality of overall fiscal pressures, support the LIGO program at the requested level.”**
- **“NSF should continue to fund the LSC member institutions and gravitational wave research at a level that makes it possible to exploit the full scientific potential of the LIGO facility.”**
- “The panel finds that the organization of the LIGO Laboratory and the LSC is remarkably healthy and flexible...One panel member called the level of cooperation in the program "breathtaking".”
- “The Review Panel felt that both of these goals are of paramount importance, and that the balance between the resources planned by LIGO on these two efforts is about right.”





...but...



Quotations From the February OMB Budget Book...



A BLUEPRINT FOR NEW BEGINNINGS

A RESPONSIBLE BUDGET
FOR AMERICA'S PRIORITIES

- “Provides \$4.5 billion for the National Science Foundation (NSF), a \$56 million increase from 2001. This level is more than \$1 billion greater than 1998.”
- “The 2002 Budget does not renew funding for these projects, saving \$45 million...The budget also better focuses facility project resources by maintaining commitments for the Large Hadron Collider, the Network for Earthquake Engineering Simulation, and Terascale Computing Systems. Facility project spending will be reduced by \$13 million, reflecting no new starts of major facility projects in 2002.”



...Quotations From the February OMB Budget Book...

- “Provides approximately \$1.5 billion for new research and education awards in 2002, to fund nearly 10,000 new competitively reviewed awards.”

NSF budget = ~ \$4.5 billion/year

about 30,000 awards

average award length 3 years



...Quotations From the February OMB Budget Book...

- *“Reorganize Research in Astronomy and Astrophysics: NSF and NASA provide more than 90 percent of Federal funds for academic astronomy research and facilities. Historically, NASA has funded space-based astronomy and NSF has funded ground-based astronomy, as well as astronomy research proposals. Several changes have evolved which suggest that now is the time to assess the Federal Government’s management and organization of astronomical research. NSF and NASA will establish a Blue Ribbon Panel to assess the organizational effectiveness of Federal support of astronomical sciences and, specifically, the pros and cons of transferring NSF’s astronomy responsibilities to NASA. The panel may also develop alternative options. This assessment will be completed by September 1, 2001.”*



...Quotations From the February OMB Budget Book

- *“Increase NSF’s Ability to Manage Large Facility Projects:* NSF is managing several multi-year, large facility projects. NSF’s capability to manage proposed projects needs to be enhanced given the magnitude and costs of these projects. NSF will develop a plan to enhance its capability to estimate costs and provide oversight of project development and construction. This plan should help ensure that NSF is able to meet and stick to cost and schedule commitments for major facility projects.”
- For more information, view <http://www.whitehouse.gov/news/usbudget/blueprint/blueprint.pdf>

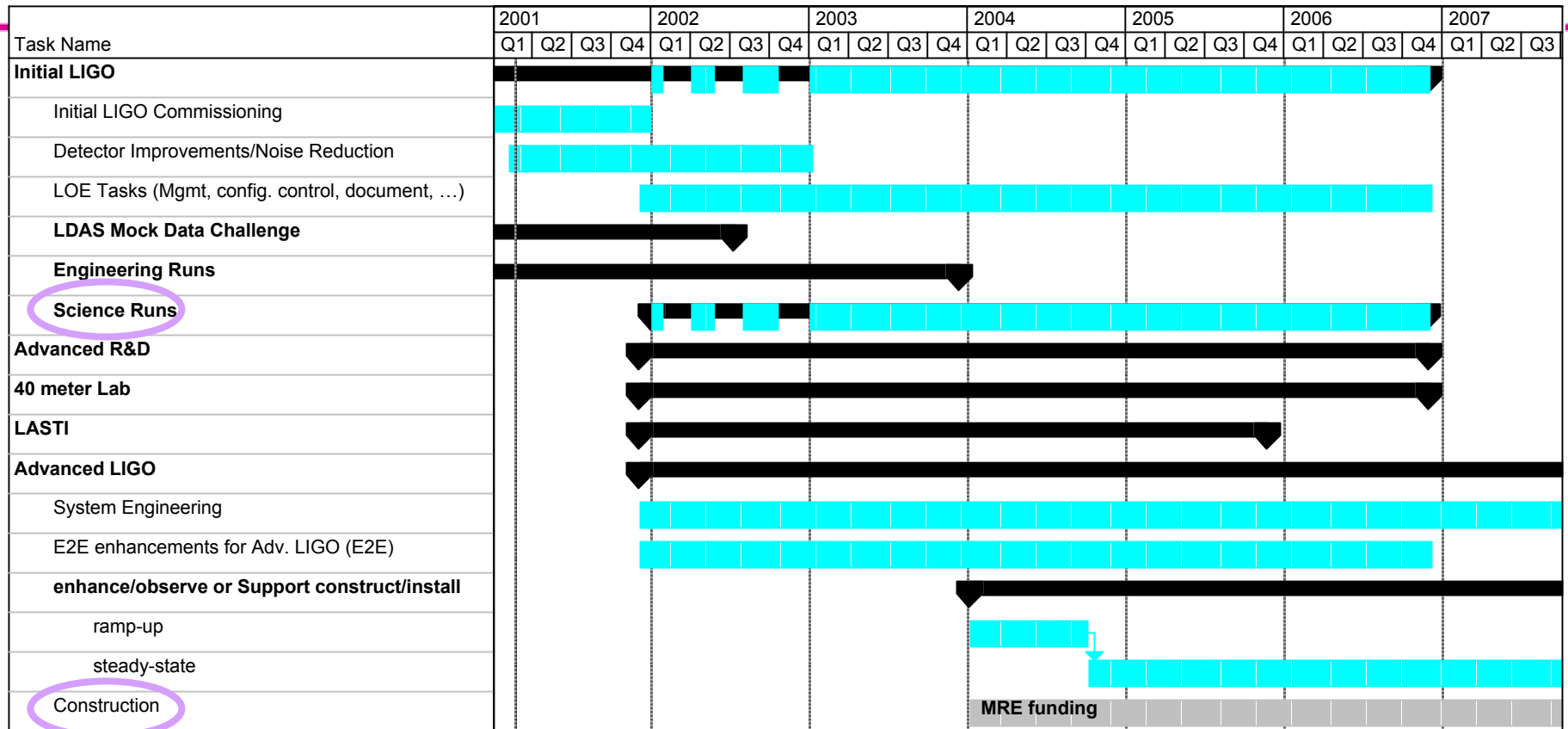


Plan

- Continue forward in all aspects of the plan with initial LIGO
 - » Upper limits papers Spring 2002
 - » Science Run to start next year
- Continue R&D program with no delays
- Submit MRE proposal for Advanced LIGO construction by end of this year for 2004 fund start



Overall Proposed Schedule





This Meeting

- Getting to astrophysics on LIGO I
 - » Mock Data Challenges
 - » Engineering Runs
 - » Upper Limits Groups → physics publications !!
- Getting to astrophysics on Advanced LIGO
 - » R&D Program