

# Research and Development of Active Seismic Isolation for LIGO 2

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JILA - University of Colorado

PAC 9 Meeting

LIGO - Livingston, LA

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# Introduction

- Proposing to work on LIGO 2 seismic isolation R&D on the physics issues in design, fabrication and characterization.
- Science is well known by the PAC.
- SEI and SUS are critical parts of balanced upgrades.
- Smaller level of effort than in the past
- New model: Lab handles the procurements, LSC members propose for infrastructure (e.g., personnel, support equipment, miscellaneous expenses)

## LIGO 2 SEI Team

- Joe Giaime, lead scientist, LSU
- Gerry Stapfer, cognizant engineer, LIGO/LA
- MIT: David Shoemaker, Jonathon How, Jamie Rollins, Ken Mason (engineer), Rana Adhikari (grad student), Shourov Chatterji
- Stanford: Brian Lantz, Dan DeBra, Graham Allen, Corwin Hardham, Wensheng Hua, Jamie Nichol
- Colorado: Robin Stebbins, Giles Hammond, Christopher Erickson, Nathan Koral, Jim Faller, and Pete Bender

## Past Work - JILA System

- Goal: technology demonstrator
- Achievements:
  - A factor of 100 isolation down to 1 Hz for one stage
  - Equal isolation in all six degrees of freedom (DOFs)
  - Multi-stage active isolation with total isolation factor of 3,000 at 1 Hz (exceeds LIGO 2 isolation spec by order of magnitude)
  - Low noise seismometers
  - The importance of position sensors to control very low frequencies
  - The utility of sophisticated dynamical models to predict and diagnose the behavior of actively controlled mechanical systems with many degrees of freedom.
- Status
  - High sensitivity seismometers not fully functional
  - Further work stopped
  - Final report in preparation

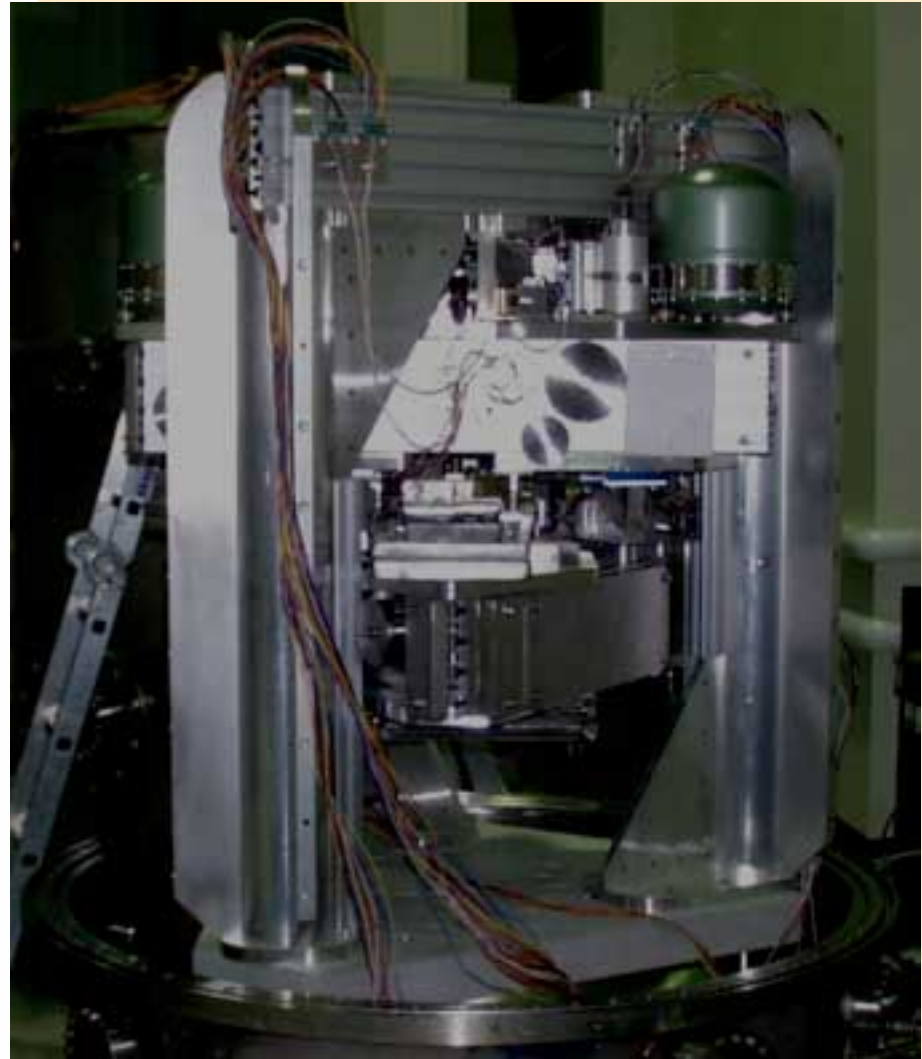
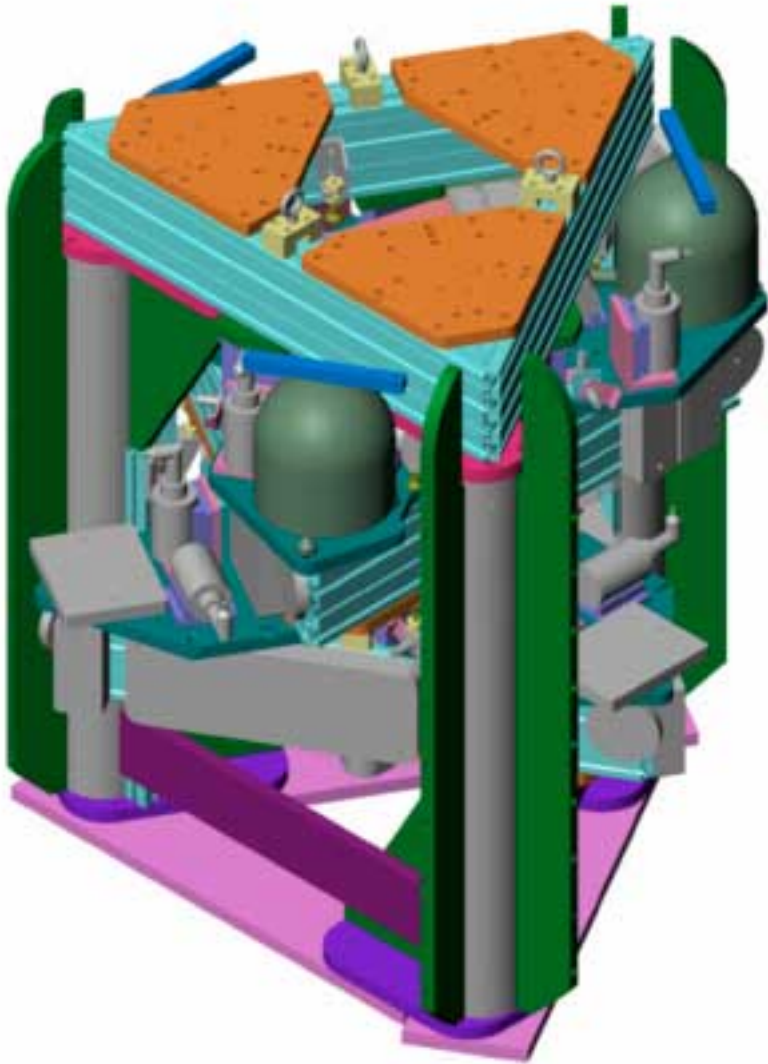
## Two Stage Prototype at MIT

- One of a suite of prototyping activities undertaken by the Stiff Team
- Goals:
  - Demonstrate isolation factors and rms reduction
  - Demonstrate robustness
  - Parametrically “similar” design to HAM and BSC reference designs
  - Transfer JILA technology to Stiff Team
- Responsibilities
  - Conceptual design - Stiff Team
  - Detailed mechanical design and fabrication - Colorado
  - Control system design and fabrication - MIT
  - Modeling - LSU, Stanford and MIT
  - Vacuum system/support - MIT

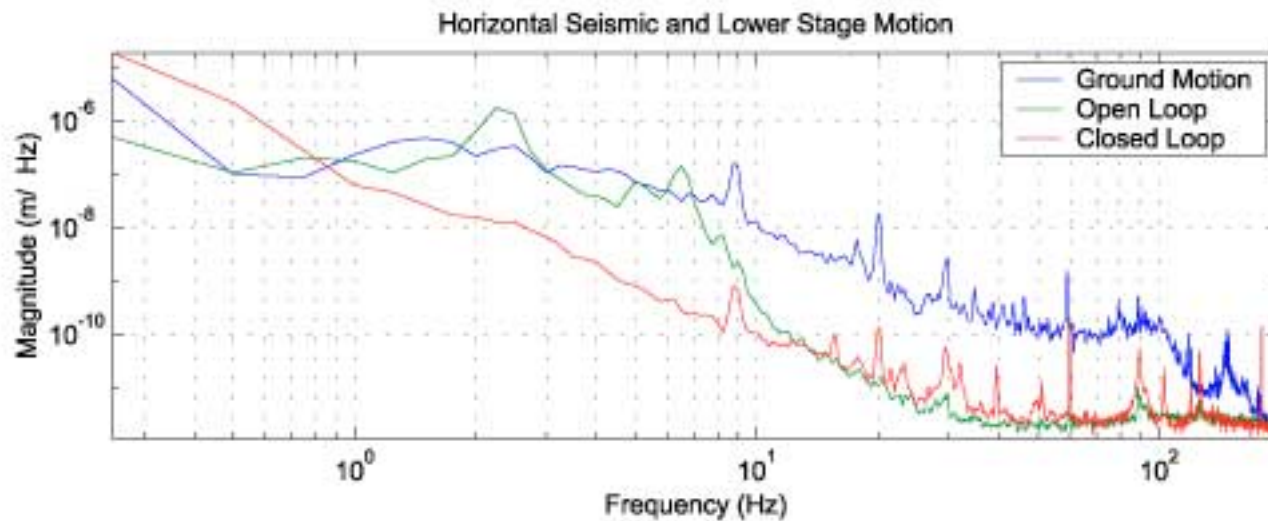
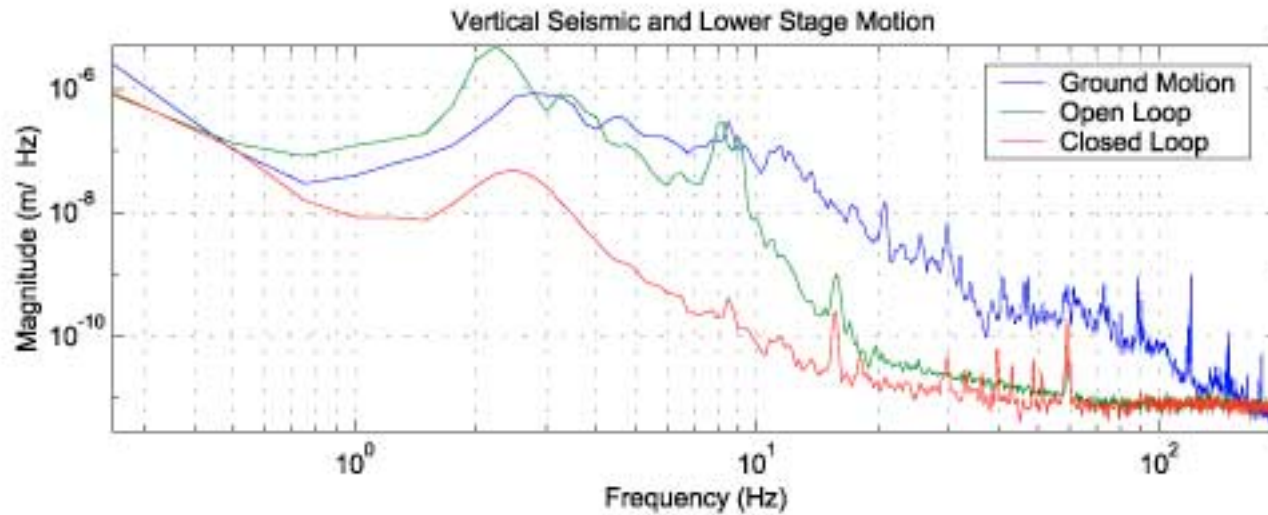
## Two-Stage Prototype Design

- Stiff suspension from blade springs and short pendulum links, body modes between 1 and 8 Hz
- Commercial long- and short-period seismometers and proximity sensors for high reliability
- Blended sensors: long- and short-period seismometers and proximity sensors on upper stage, short-period seismometers and proximity sensors on lower stage
- Commercial digital controller, reconfigurable sensor blending, SISO or MIMO topologies
- Stiff structure, no internal resonances between 10 and 100 Hz
- Pre-assembly, simple alignment, unit installation
- Stable and robust
- Rapid design, construction and installation

## Two-Stage Prototype

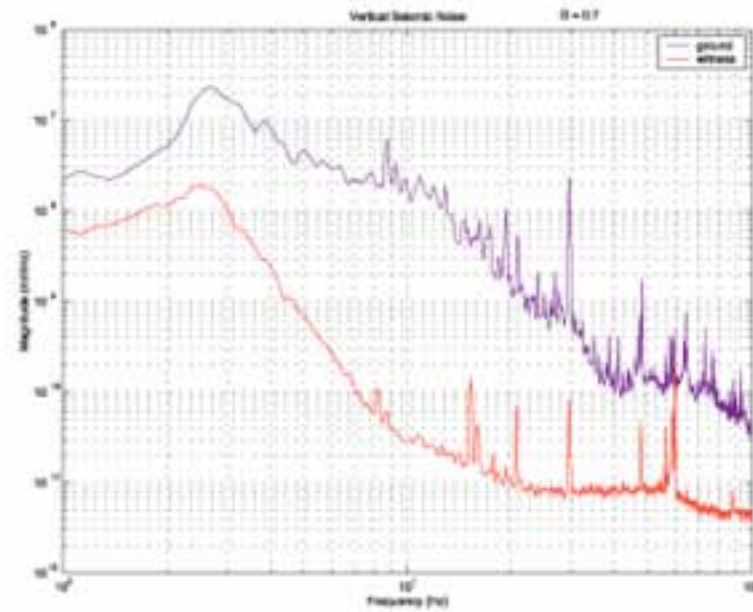
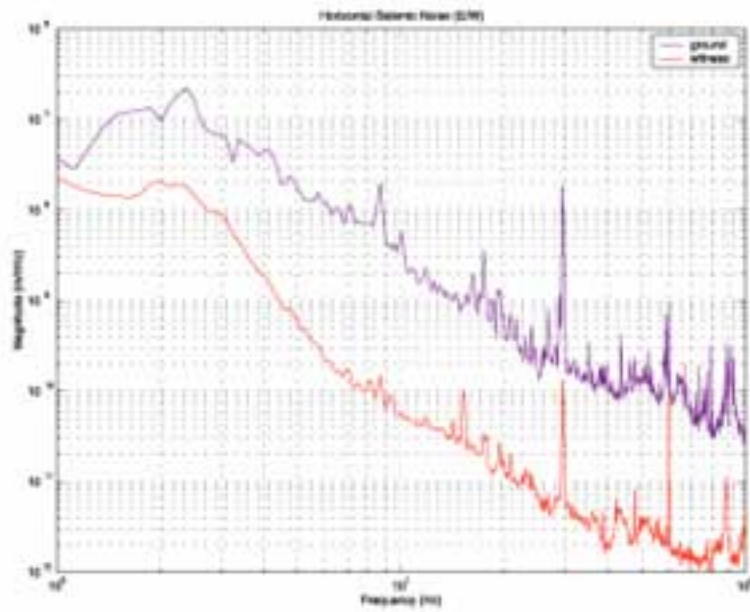


# Two-Stage Prototype Performance





# Two-Stage Prototype Performance



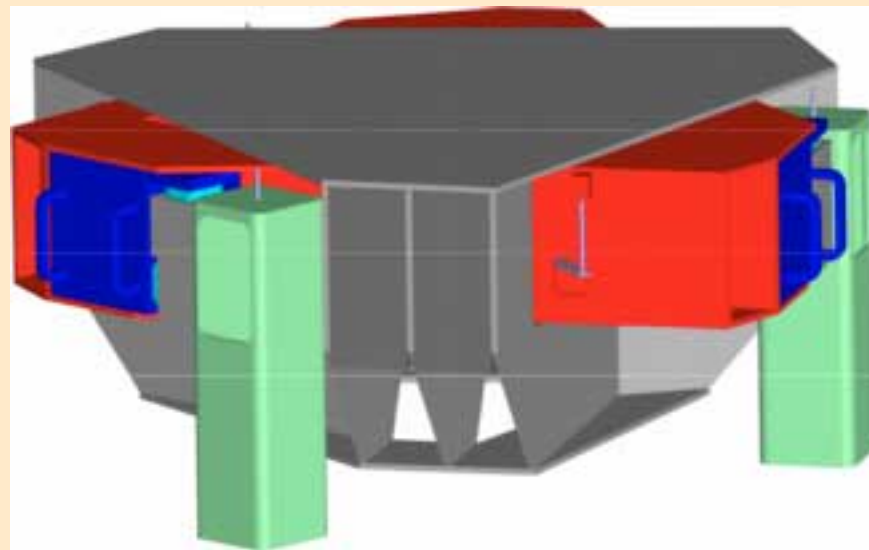
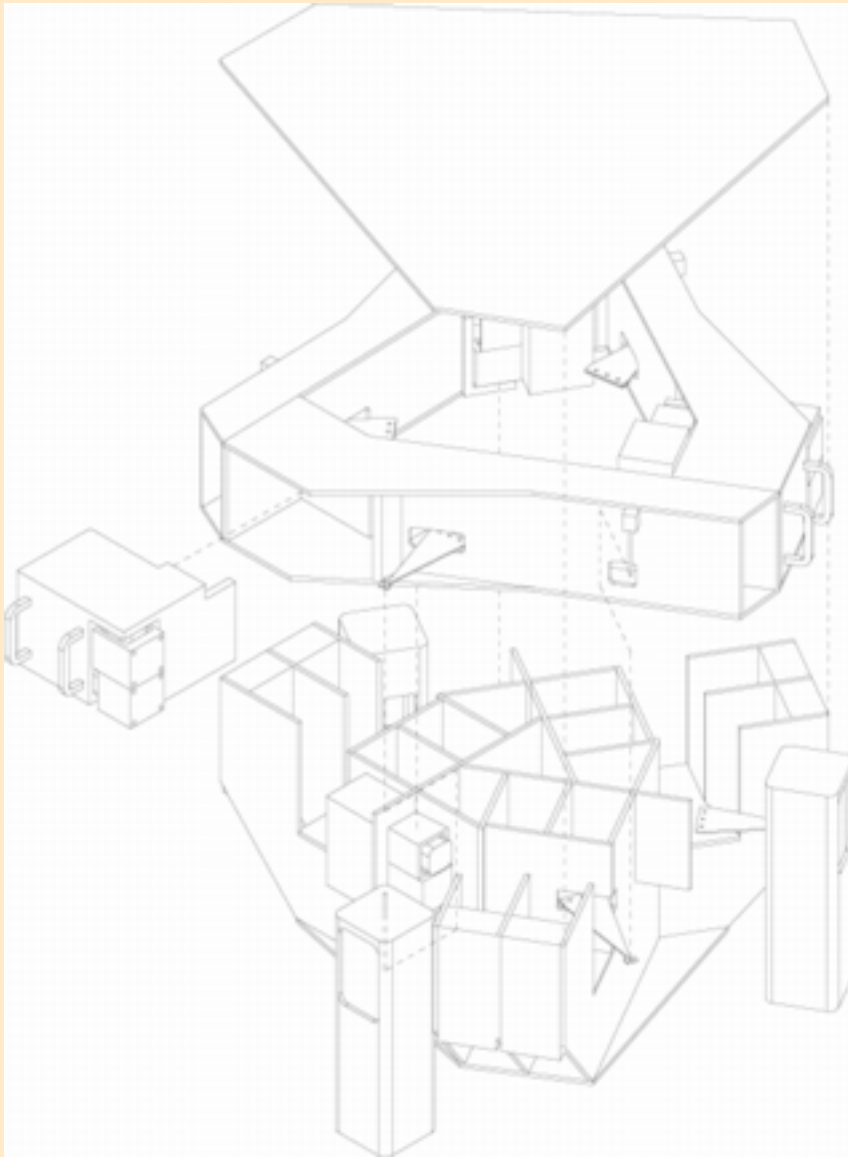
# Two-Stage Prototype Status

- Control system
  - Sensors blended
  - Low-frequency isolation
  - Dealing with MIMO issues: tilt-horizontal coupling, sensor-forcer separation
- Mechanical
  - Stable, satisfactory...
  - Spring assembly may need retrofit

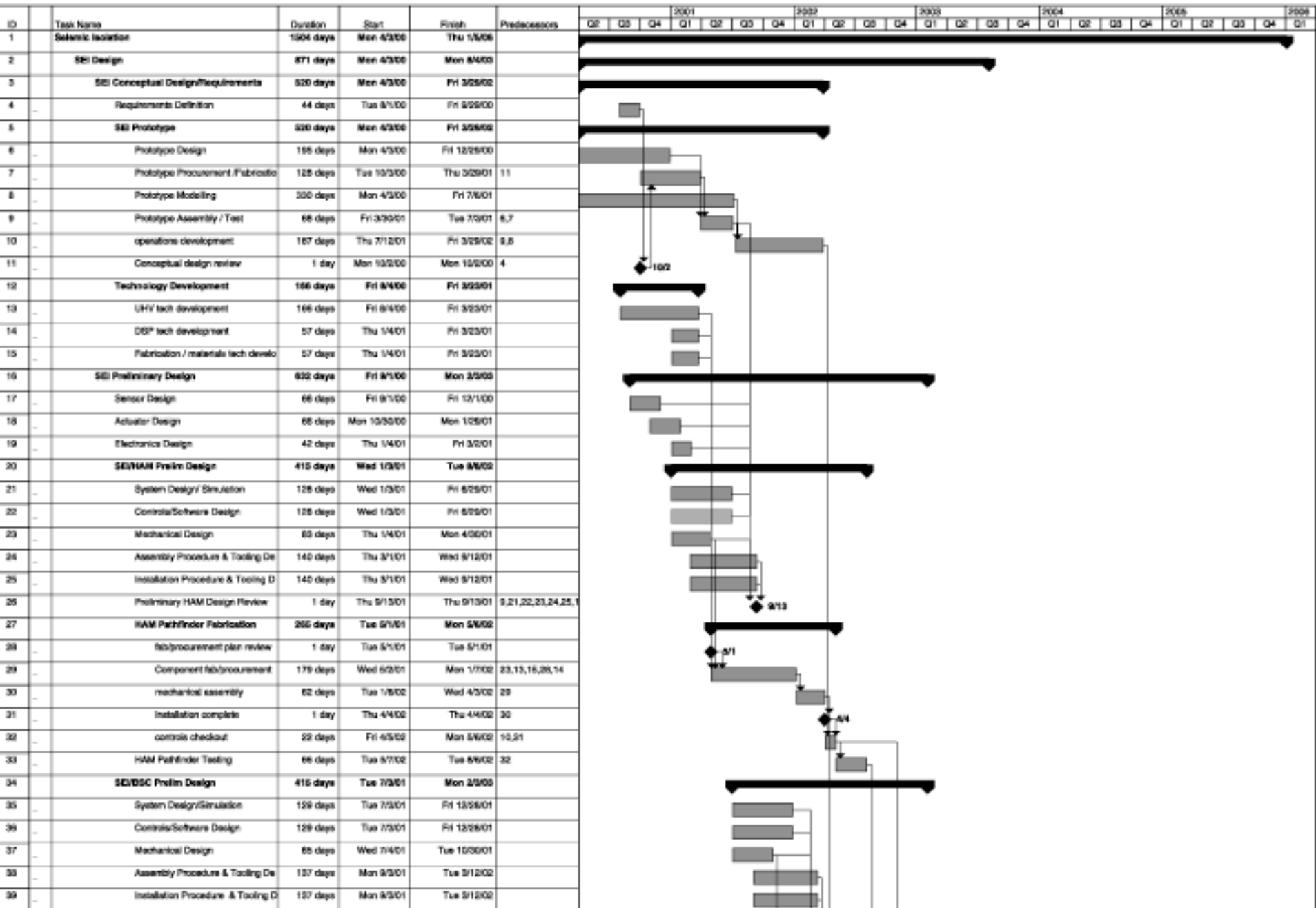
## Other Activities

- Magnetic coupling
- Forcer cross-coupling
- Forcer design
- SEI Prototype design

# SEI Prototype Design



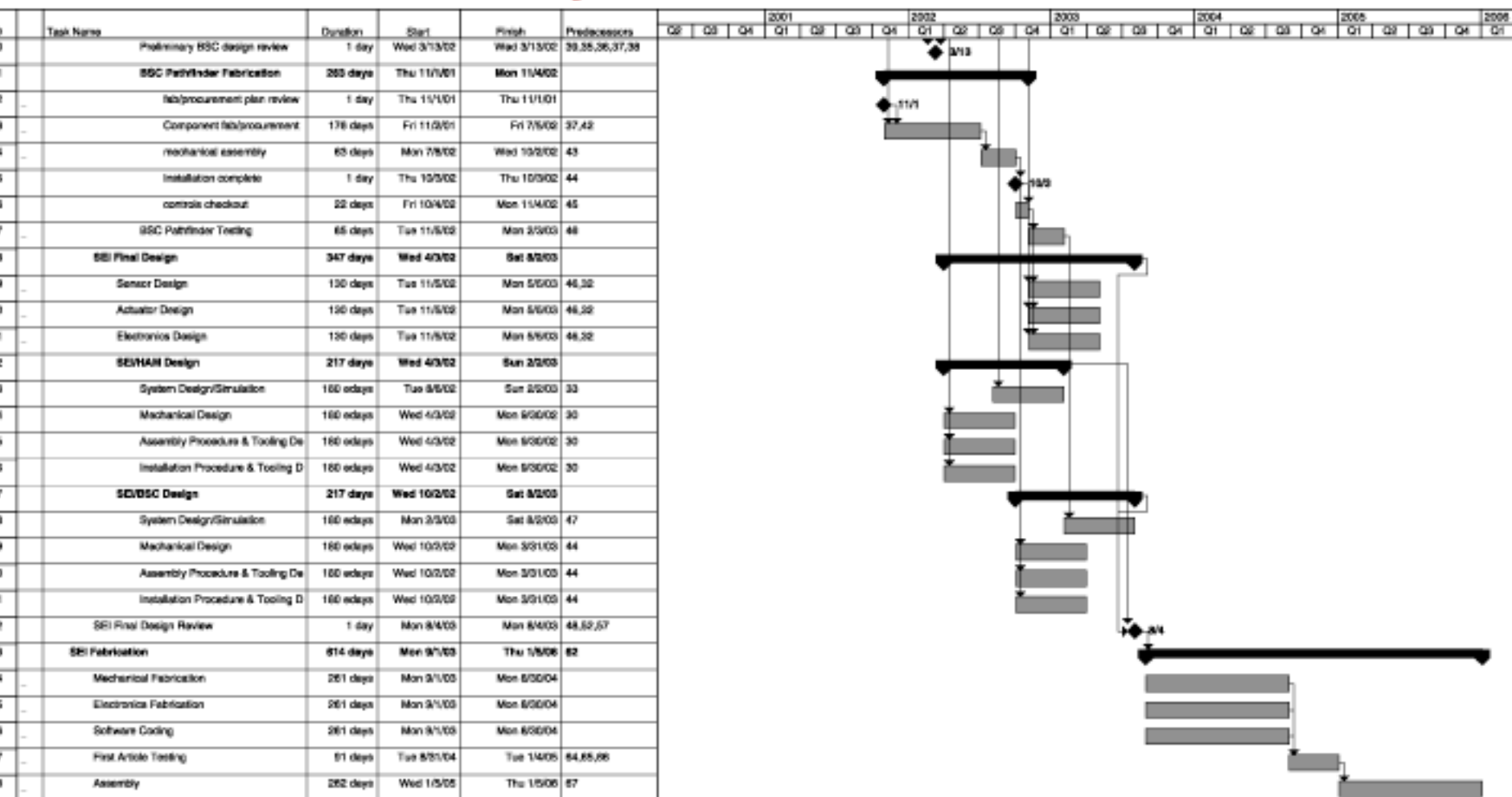
# Preliminary Draft, Advanced LIGO SEI



Project: SEI project  
Date: Fri 8/25/00



# Preliminary Draft, Advanced LIGO SEI



# Physics Issues

- Design
  - Fundamentals: geometry, stiffness
  - Details: sensor interaction, pods, spring assemblies, ...
  - Assembly, alignment, access
  - Learning curve: prototypes, HAM pathfinder, BSC pathfinder
- Operational considerations
  - Vacuum preparation
  - Assembly, alignment, installation, maintenance
  - Multiple operating modes
- Characterization
  - Performance measures
  - Robustness
  - Range of payloads
  - Range of environmental conditions

# Specific Tasks

- SEI Prototype
  - Operations development at ETF
- HAM Pathfinder
  - Fabrication
  - Characterization at LASTI
  - Operational development at LASTI
- BSC Pathfinder
- SEI Sensor and Actuator Design
- Final HAM and BSC Design



## Summary

- Extensive past experience in active isolation technology
- Recent work with the stiff, now SEI, team
- Addressing physics issues in design, operations, and characterization of prototype, pathfinders and final designs for LIGO 2 SEI systems