QUARTERLY REPORT
NSF COOPERATIVE AGREEMENT NO. PHY-9210038
THE CONSTRUCTION, OPERATION, AND SUPPORTING RESEARCH AND DEVELOPMENT OF A LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY

R. E. Vogt, Principal Investigator and Project Director
S. E. Whitcomb, Deputy Director
W. E. Althouse, Chief Engineer

June 1, 1993

I. INTRODUCTION

This report summarizes the Laser Interferometer Gravitational-Wave Observatory (LIGO) Project activities from March through May 1993.

This summary includes work of the Caltech and MIT science groups and the engineering team located at Caltech. The principal areas of activity are:

- LIGO development, including sites, facility design and development of the initial interferometers.
- Prototype laboratory activities aimed at improved understanding of interferometer noise sources or at development of key interferometer techniques.

II. LIGO DEVELOPMENT

A. Sites

Livingston Parish, Louisiana. Louisiana State University (LSU) obtained two appraisals of land value for the site, but subsequently appeared to be making little progress toward purchasing the land. After several phone calls to LSU, including one from the NSF LIGO Program Manager, additional high level attention at LSU was provided, with a commitment to complete the purchase by July.

All site investigation contracts have been placed. Some site investigation work, such as wetlands constraints analysis, has progressed, but the majority must await clearing of the forested area. Land clearing had been initiated by the owner of most of the land, but was suspended when the land acquisition delay became evident. We are now assuming that the land clearing operation will not proceed until the land purchase has been completed.

Hanford, Washington. The latest draft DOE/NSF land use permit and MOU reflects the majority of comments we offered for the earlier draft. The principal differences have been discussed verbally and we are confident that the agreement can be formalized during the coming quarter.

A biological field survey of the site was conducted in late April, and found no threatened or endangered species at the most sensitive time of the year. This is the last activity required for completion of the environmental assessment (EA) documentation. The complete draft EA report will be forwarded to NSF for review upon completion of our internal review.

All site investigation work has been completed. An engineering firm was selected to produce plans, specifications and a cost estimate for the rough grading of the site. This work, expected to be completed by September, will allow construction to proceed at the Hanford site if the land use permit and environmental assessment are approved.

B. Industrial Design Subcontracts

One of the four proposers for the beam tube module effort, Chicago Bridge and Iron, Inc. (CBI), was selected for contract negotiations, which were initiated. The work is divided into a design and demonstration phase and an option for the construction of the beam tubes at both LIGO sites. The design and demonstration phase will culminate in a full test of a prototype section of the beam tube using the techniques to be employed in the final construction. Upon completion of negotiations, the proposed contract will be forwarded to NSF for review and approval.

Other pressing demands on management have continued to delay the preparation of specifications and RFPs for the rest of the LIGO vacuum system and remote facilities.

C. LIGO Beam Tube Investigations

After consideration of the results of the beam tube development work (including outgassing measurements, weld tests, microanalysis, scattering measurements and calculations, and the relevant programmatic issues), the process specification for the stainless steel to be used in the LIGO beam tubes was finalized.

A program at JPL's welding laboratory was initiated to investigate various welding parameters and their relationships for the low hydrogen stainless steel material. Although the beam tube module contractor is responsible for establishing and controlling weld procedures, we concluded that it is prudent to develop our own independent expertise in order to be able to more quickly react to unforeseen problems.

D. LIGO Interferometer Conceptual Design

Research leading to the specification for the large aperture optics of the initial LIGO interferometer has progressed. The wavefront perturbation specifications expressed in terms of spatial power spectra or Zernike functions have been drafted for polishing and coating vendors. Metrology of the wavefronts from coated and uncoated substrates in reflection and transmission has been carried out on the 10-cm diameter test masses for the 40-m interferometer. The transmission wavefronts of the 10-cm test masses meet the LIGO specification but with little or no margin. Sample large aperture mirrors, including the 10-cm test masses, have shown wavefront distortions in reflection that are substantially better than the LIGO specification.

III. PROTOTYPE ACTIVITIES

A. 40-Meter Interferometer

Mark II Interferometer. Assembly of the Mark II prototype in its new vacuum system continued. The vacuum envelope and pumping system have been completed and certified. The vibration isolation stacks, electrical feedthroughs, and associated cabling have been installed. Assembly of the input optics and auxiliary optics has begun.

B. Suspended-Mirror Mode Cleaner

Construction of all parts has been completed but integration has been delayed as effort and equipment have been dedicated to Mark II construction.

C. Stationary Interferometers

The goal of stationary interferometer research is to model the two candidate modulation and optical topology schemes that may be used in the initial LIGO interferometer.

The stationary interferometer to test the external modulation/subcarrier concept has been modified to use a single polarization of input light. This is of importance for the LIGO application where a single polarization may be required if a triangular mode filter cavity is used. The interferometer performs as expected with this modification. The measurement of the frequency response of the interferometer is in process.

The stationary interferometer for testing the scheme using asymmetric Michelson arms in the power recycling cavity has been improved to provide more stable locking and to acquire lock more rapidly. A detailed comparison of predicted and observed responses to applied perturbations is underway.

D. Interferometer Alignment

The research is directed to providing a means for alignment of the LIGO initial interferometer.

The analytic and numerical techniques developed to study the misalignment of cavities have been applied to a power recycled Michelson interferometer. A useful means of describing the misalignment is in terms of the aligned recycling cavity modes and symmetric and antisymmetric misalignments of the Michelson mirrors. The analytic research has now firmly established that to obtain alignment discriminants in the coupled cavity configurations will require separate wavefront sensors for each cavity.

The demonstration of automatic alignment techniques in a suspended cavity has progressed. A suspended cavity in the central tank of the 5 meter facility has been locked to a frequency stabilized laser. The ambient vibrational noise and the suspension control transfer functions are currently being measured and analyzed.

E. Optics Testing and Development

Surface contamination by detergent residue was found to be the cause of recently observed degradation of mirrors after light exposure. The residue was positively identified by measuring X-rays emitted during electron bombardment of the surface. These characteristic X-rays were only emitted from the region of mirror surface that had been exposed to laser light, indicating that the light had "fixed" impurities to the exposed region. Changes to the mirror cleaning procedure are being implemented.

F. Suspension Development

Measurements of mechanical Q values of the internal vibrational modes of a monolithic test mass (9 cm diameter by 10 cm thick) and associated modeling have identified the anomalously low Q's associated with certain modes as due to the attachment of magnets to the mass. After the magnets were removed from the mass, the measured Q values were in the range $2\times10^5 \leq Q \leq 2\times10^6$, exceeding the goal for initial LIGO interferometers. Further investigations were started to understand how magnet attachment causes additional losses in these modes.

IV. OTHER ACTIVITIES

A paper ("Thermal Noise in the Test Mass Suspensions of a Laser Interferometer Gravitational-Wave Detector Prototype" by A. Gillespie and F. Raab) was submitted to *Physics Letters A*.

The LIGO and VIRGO projects have signed an MOU establishing a cooperative program with PMS to develop large aperture coatings of the requisite uniformity and loss for both the initial and advanced interferometers.

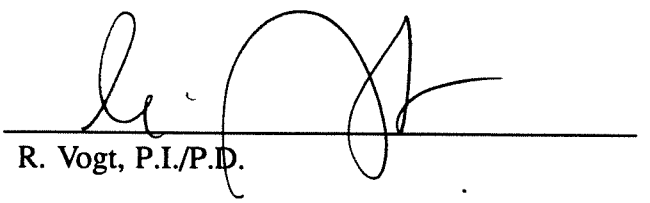
V. FINANCIAL STATUS

Cooperative Agreement No. PHY-9210038 Financial Status as of 4/1/93 ($M)	
Cumulative Funding to date	19.1
Cumulative Expenditures to date:	
Site Investigations	0.6
In-house	6.9
TOTAL	7.5

VI. ACTION ITEMS — CALTECH/NSF RESPONSIBILITIES

	Topic	Status
1.	Hanford land use permit	In process
2.	DOE/NSF Memorandum of Understanding	In process

Pasadena, June 29, 1993



R. Vogt, P.I./P.D.