

VIII. BUDGET

This is a three year proposal for continuation of activities currently supported by the National Science Foundation under two grants: PHY-8504136 to the California Institute of Technology (Drever, PI) and PHY-8504836 to the Massachusetts Institute of Technology (Weiss, PI). The proposed activities, combining the resources of both institutions under the management of the Director, will lead to a proposal for the construction of the LIGO, which we expect to submit in Fall 1989. When funded, the anticipated construction contract will replace the funding requested for the third year of the current proposal.

The Director will control the LIGO effort through technical and administrative direction, implemented by adjusting the allocation of manpower and financial resources as required to meet the needs and commitments of the LIGO Project. A baseline budget plan is given in the tables below, organized into three operating cost centers. A summary of the total budget request is shown in Table I. Table II gives a detailed breakdown for LIGO Science, Management and Engineering; this cost center includes the Director's Office, analytical science support, the engineering group, and supporting services from the Caltech's JPL, industrial and private consultants and the Preliminary Engineering Design contractor. Tables III and IV give detailed breakdowns for the Caltech and MIT science groups, respectively, including receiver research and science support for LIGO planning.

The Tables are followed by a presentation of budget details in the NSF standard format. For administrative and management reasons, the support for the MIT research group is shown as a subcontract to Caltech on line G5 of these forms. *The reader is cautioned, therefore, that an accurate impression of the level of effort proposed is to be found in Tables II, III, and IV; sections A and B of the standard NSF format, while contractually correct, may be misleading.*

Explanatory notes and supporting data follow the NSF budget forms. The following general notes apply to all tables and to the NSF format budget presentation:

Inflation. Entries are based upon actual, calculated or estimated FY88 data, as appropriate, and adjusted for inflation into the grant period of performance at a rate of 6% per year, except where otherwise noted.

Salaries. The staff for the LIGO Project is listed in Section VII. Actual FY88 salaries are used for existing personnel and estimates are used for salaries of personnel to be appointed. Salaries for Drs. Thorne and Tinto are paid fully by Caltech and Thorne's separate NSF grant, and are not included here.

Consultants. This item is used generically to identify and segregate anticipated costs associated with Design Review Board appointees, including travel cost reimbursement, and private or industrial consultants employed to resolve technical problems which arise outside of the scope of the preliminary engineering design subcontract. Design Review Board members will be selected from among technical experts in relevant disciplines and may be employees of Government or industry, or may be private consultants. Formal arrangements with these individuals or their employers will be made on a case-by-case basis, in accordance with all applicable NSF and FPR policies and regulations.

MIT subcontract. Level of effort, rates and amounts shown are budgetary estimates based upon informal discussions with MIT. Details are given in the budget explanatory notes. MIT will submit a proposal to Caltech supporting and justifying all proposed costs, and the resulting negotiated contract will reflect such supporting data.

Preliminary engineering design subcontract. The scope and intent of this proposed subcontract is described in Section VI. A budgetary estimate of \$3 million is included for this effort. This amount is based upon preliminary discussions with potential contractors and other users of A&E contractor services, as well as our own experience. Actual costs of the preliminary engineering design contract will depend on the selected contractor's labor and burden rates, proposed methods of approaching the design, and risk/cost trade-offs in the breadth, depth and quality of the work products. As explained in section VI-F above, the contractor will be competitively selected, and the contract will be a negotiated fixed price level of effort type to allow us to exercise risk/cost trade-offs as the work proceeds while giving us full control over contract costs.

Residual Funds Statement

We anticipate no residual funds in either the Caltech grant or the MIT grant at the end of the current funding period.

TABLE I:

TOTAL BUDGET SUMMARY (in \$K)

	6/88- 5/89	6/89- 5/90	6/90- 5/91	Total
LIGO Science, Management and Engineering	5216.3	2186.1	1846.5	9248.9
Caltech Science Group	1306.5	1370.2	1501.1	4177.8
MIT Science Group	1364.8	1561.6	1765.4	4691.7
TOTAL:	7887.6	5117.8	5113.0	18118.4

TABLE II:

LIGO SCIENCE, MANAGEMENT AND ENGINEERING

	6/88- 5/89	6/89- 5/90	6/90- 5/91	Total
Manloading (no./yr.)	-----man-months-----			
Professorial Faculty (2,2,2)				
Professional/Tech. Staff (8,8,8)	96	96	96	288
Secretarial/Clerical (2,2,2)	15	15	15	45
	COSTS (\$K)			
Salaries:				
Professorial Faculty	83.2	88.2	93.5	264.9
Professional/Tech. Staff	482.6	511.5	542.2	1536.3
Secretarial/Clerical	34.3	36.4	38.6	109.3
Total salaries	600.1	636.1	674.3	1910.5
Staff Benefits	177.0	187.6	198.9	563.6
Supplies and expenses:				
Materials and services	31.2	33.1	35.1	99.4
Graphic Arts	16.6	17.6	18.7	52.9
Telephone and Postage	12.5	13.2	14.0	39.7
Equipment maintenance/rental	20.8	21.6	22.9	65.3
Publications	2.1	2.2	2.3	6.6
Total supplies and expenses	83.2	87.7	93.0	263.9
Domestic Travel	60.2	61.6	65.4	187.2
Foreign Travel	9.4	9.9	10.5	29.8
Equipment	300.0	200.0	200.0	700.0
JPL Engineering Support	260.0	275.0		535.0
Consultants	100.0	100.0		200.0
Engr'g Design Subcontract	3000.0			3000.0
TOTAL DIRECT COST	4589.9	1557.9	1242.1	7390.0
Overhead	626.4	628.1	604.4	1858.9
TOTAL ESTIMATED COST	5216.3	2186.1	1846.5	9248.9

TABLE IV:
MIT SCIENCE GROUP

	6/88- 5/89	6/89- 5/90	6/90- 5/91	Total
Manloading (no./yr.)	-----man-months-----			
Professorial Faculty (2,2,2)				
Scientific Staff (5,5,6)	54	60	72	186
Professional/Tech. Staff (2,3,3)	24	36	36	96
Secretarial/Clerical (1,1,1)	6	6	6	18
Graduate Res. Ass't. (5,6,7)	60	72	84	216
Undergrad. Res. Ass't (3,3,3)	9	9	9	27
Other	9.7	10.4	10.5	30.6
	COSTS (\$K)			
Salaries:				
Professorial Faculty	25.8	36.2	38.3	100.3
Scientific Staff	175.9	195.7	242.5	614.1
Professional/Tech. Staff	70.7	119.0	126.1	315.8
Secretarial/Clerical	11.9	12.6	13.3	37.8
Graduate Res. Ass't.	59.8	76.1	94.1	230.0
Undergrad. Res. Ass't	11.0	11.6	12.3	34.9
Other	39.7	48.6	55.8	144.1
Total salaries	394.8	499.8	582.4	1477.0
Staff Benefits	152.4	195.3	228.0	575.7
Supplies and expenses:				
Materials and services	54.4	67.4	77.4	199.2
Telephone and Postage	8.4	8.4	8.4	25.2
Publications	2.0	2.0	2.0	6.0
Allocated expense	8.5	10.0	10.6	29.1
Total supplies and expenses	73.3	87.8	98.4	259.5
Domestic Travel	44.0	46.0	48.0	138.0
Foreign Travel	3.1	9.9	3.5	16.5
Equipment	300.0	200.0	200.0	700.0
	967.6	1038.8	1160.3	3166.7
TOTAL DIRECT COST	967.6	1038.8	1160.3	3166.7
Overhead	397.2	522.8	605.0	1525.0
	1364.8	1561.6	1765.4	4691.7
TOTAL ESTIMATED COST	1364.8	1561.6	1765.4	4691.7

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

6/1/88 - 5/31/91

SUMMARY PROPOSAL BUDGET

CUMULATIVE BUDGET - 6/88-5/91

ORGANIZATION		FOR NSF USE ONLY			
		PROPOSAL NO.	DURATION (MONTHS)		
California Institute of Technology			Proposed	Granted	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR		AWARD NO.			
R.E. Vogt					
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.S. show number in brackets)		NSF FUNDED PERSON-MOS.		FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
		CAL.	ACADSUMM		
1	PI and PD R.E. Vogt Professor of Physics			\$	\$
2	Co-I R.W.P. Drever Professor of Physics				
3	Co-I K.S. Thorne Professor of Theoretical Physics				
4	Co-I R. Weiss Professor of Physics, MIT (all MIT costs shown on line 65)				
9. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
9. (6) TOTAL SENIOR PERSONNEL (1-5)				413,900	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1.	() POST DOCTORAL ASSOCIATES	216		692,000	
2.	() OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	396		1,926,000	
3.	() GRADUATE STUDENTS			170,700	
4.	() UNDERGRADUATE STUDENTS			77,700	
5.	() SECRETARIAL-CLERICAL			146,300	
6.	() OTHER				
TOTAL SALARIES AND WAGES (A+B)				3,426,600	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 29.5% excluding undergraduates				987,926	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				4,414,526	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$1,000:)					
TOTAL PERMANENT EQUIPMENT				1,400,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				223,500	
2. FOREIGN				46,300	
F. PARTICIPANT SUPPORT COSTS					
1.	STIPENDS \$ _____				
2.	TRAVEL _____				
3.	SUBSISTENCE _____				
4.	OTHER _____				
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1.	MATERIALS AND SUPPLIES			458,600	
2.	PUBLICATION COSTS/PAGE CHARGES			13,200	
3.	CONSULTANT SERVICES			200,000	
4.	COMPUTER (ADPE) SERVICES				
5.	SUBCONTRACTS MIT, Preliminary Engineering Design			7,691,718	
6.	OTHER JPL Support Work Order			535,000	
TOTAL OTHER DIRECT COSTS				8,898,518	
H. TOTAL DIRECT COSTS (A THROUGH G)				14,982,844	
I. INDIRECT COSTS (SPECIFY) 58% of T.D.C. excluding equipment, JPL work order and subcontracted amounts beyond first \$25,000 of each subcontract (2)					
TOTAL INDIRECT COSTS				3,135,553	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				18,118,396	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 282 AND 283)				-0-	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$18,118,396	\$
PI/PD TYPED NAME & SIGNATURE*		DATE	FOR NSF USE ONLY		
INST. REP. TYPED NAME & SIGNATURE*		DATE	INDIRECT COST RATE VERIFICATION		
			Date Checked	Date of Rate Sheet	Initials: OGC
					Program

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FIRST YEAR
6/1/88 - 5/31/89

SUMMARY
PROPOSAL BUDGET

FIRST YEAR-6/88 - 5/89

		FOR NSF USE ONLY	
ORGANIZATION		PROPOSAL NO.	DURATION (MONTHS)
California Institute of Technology			Proposed Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR		AWARD NO.	
R.E. Vogt			
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.G. show number in brackets)		NSF FUNDED PERSON-MOS	FUNDS REQUESTED BY PROPOSER
		CAL. ACAD. SUM	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. PI and PD	R.E. Vogt Professor of Physics		\$
2. Co-I	R.W.P. Drever Professor of Physics		
3. Co-I	K.S. Thorne Professor of Theoretical Physics		
4. Co-I	R. Weiss Professor of Physics, MIT (all MIT costs shown on line G5)		
5. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)			
6. (6) TOTAL SENIOR PERSONNEL (1-5)			130,000
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)			
1. (5) POST DOCTORAL ASSOCIATES		60	187,800
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)		132	605,000
3. (4) GRADUATE STUDENTS			45,800
4. (3) UNDERGRADUATE STUDENTS			21,800
5. (3) SECRETARIAL-CLERICAL			45,900
6. (1) OTHER			
TOTAL SALARIES AND WAGES (A+B)			1,036,300
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 29.5% excluding undergraduates			299,278
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)			1,335,578
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$1,000:)			
TOTAL PERMANENT EQUIPMENT See budget explanation page 2			600,000
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)			71,600
2. FOREIGN			12,500
See budget explanation page 3			
F. PARTICIPANT SUPPORT COSTS			
1. STIPENDS	\$ _____		
2. TRAVEL	_____		
3. SUBSISTENCE	_____		
4. OTHER	_____		
TOTAL PARTICIPANT COSTS			
G. OTHER DIRECT COSTS			
1. MATERIALS AND SUPPLIES			143,100
2. PUBLICATION COSTS/PAGE CHARGES			4,200
3. CONSULTANT SERVICES			100,000
4. COMPUTER (AOPE) SERVICES			
5. SUBCONTRACTS MIT, Preliminary Engineering Design			4,364,772
6. OTHER JPL Support Work Order			260,000
TOTAL OTHER DIRECT COSTS			4,872,072
H. TOTAL DIRECT COSTS (A THROUGH G)			6,891,750
I. INDIRECT COSTS (SPECIFY) 58% of T.D.C. less equipment, JPL work order, and subcontracted amounts beyond first \$25,000 of each subcontract (2)			
TOTAL INDIRECT COSTS			995,847
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)			7,887,596
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)			-0-
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)			\$ 7,887,596
PI/PD TYPED NAME & SIGNATURE*		DATE	FOR NSF USE ONLY
			INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE*		DATE	Date Checked Date of Rate Sheet Initials: DGC
			Program

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(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING) SECOND YEAR 6/1/89 - 5/31/90

SUMMARY PROPOSAL BUDGET

SECOND YEAR-6/89 - 5/90

ORGANIZATION		FOR NSF USE ONLY			
		PROPOSAL NO.	DURATION (MONTHS)		AWARD NO.
California Institute of Technology			Proposed	Granted	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR					
R.E. Vogt					
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)		NSF FUNDED PERSONNEL NOS.		FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
		CAL.	ACAO	SUM	
1. PI and PD	R.E. Vogt Professor of Physics			\$	\$
2. Co-I	R.W.P. Dreyer Professor of Physics				
3. Co-I	K.S. Thorne Professor of Theoretical Physics				
4. Co-I	R. Weiss Professor of Physics, MIT (all MIT costs shown on line (5))				
5. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. (6) TOTAL SENIOR PERSONNEL (1-5)				137,800	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (6) POST DOCTORAL ASSOCIATES		72		230,800	
2. (11) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)		132		641,300	
3. (5) GRADUATE STUDENTS				60,600	
4. (3) UNDERGRADUATE STUDENTS				23,200	
5. (3) SECRETARIAL-CLERICAL				48,700	
6. () OTHER					
TOTAL SALARIES AND WAGES (A+B)				1,142,400	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 29.5% excluding undergraduates				330,164	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,472,564	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$1,000:)					
TOTAL PERMANENT EQUIPMENT See budget explanation page 2				400,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				73,700	
2. FOREIGN				19,800	
See budget explanation page 3					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS \$ _____					
2. TRAVEL _____					
3. SUBSISTENCE _____					
4. OTHER _____					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				153,100	
2. PUBLICATION COSTS/PAGE CHARGES				4,400	
3. CONSULTANT SERVICES				100,000	
4. COMPUTER (AOPE) SERVICES					
5. SUBCONTRACTS Massachusetts Institute of Technology				1,561,592	
6. OTHER JPL Support Work Order				275,000	
TOTAL OTHER DIRECT COSTS				2,094,092	
H. TOTAL DIRECT COSTS (A THROUGH G)				4,060,156	
I. INDIRECT COSTS (SPECIFY) 58% of T.D.C. less equipment, JPL work order, and subcontracted amounts (first \$25,000 incurred during first grant year)				1,057,667	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				5,117,823	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$ 5,117,823	
PI/PD TYPED NAME & SIGNATURE*		DATE	FOR NSF USE ONLY		
INST. REP. TYPED NAME & SIGNATURE*		DATE	INDIRECT COST RATE VERIFICATION		
			Date Checked	Date of Rate Sheet	Initials - OGC
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THIRD YEAR
6/1/90 - 5/31/91

SUMMARY
PROPOSAL BUDGET

THIRD YEAR-6/90 - 5/91

		FOR NSF USE ONLY			
ORGANIZATION		PROPOSAL NO.		DURATION (MONTHS)	
California Institute of Technology				Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR		AWARD NO.			
R.E. Vogt					
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)		NSF FUNDED PERSON-MOS		FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
		CAL.	ACAO	SUMR	
1. PI and PD	R.E. Vogt Professor of Physics			\$	\$
2. Co-I	R.W.P. Drever Professor of Physics				
3. Co-I	K.S. Thorne Professor of Theoretical Physics				
4. Co-I	R. Weiss Professor of Physics, MIT (all MIT costs shown on line G5)				
5. (2) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. (6) TOTAL SENIOR PERSONNEL (1-5)				146,100	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (7) POST DOCTORAL ASSOCIATES		84		273,400	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)		132		679,700	
3. (5) GRADUATE STUDENTS				64,300	
4. (4) UNDERGRADUATE STUDENTS				32,700	
5. (3) SECRETARIAL/CLERICAL				51,700	
6. () OTHER					
TOTAL SALARIES AND WAGES (A+B)				1,247,900	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 29.5% excluding undergraduates				358,484	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,606,384	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$1,000)					
TOTAL PERMANENT EQUIPMENT See budget explanation page 2				400,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				78,200	
2. FOREIGN				14,000	
See budget explanation page 3					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS \$ _____					
2. TRAVEL _____					
3. SUBSISTENCE _____					
4. OTHER _____					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				162,400	
2. PUBLICATION COSTS/PAGE CHARGES				4,600	
3. CONSULTANT SERVICES					
4. COMPUTER (AOPE) SERVICES					
5. SUBCONTRACTS Massachusetts Institute of Technology				1,765,354	
6. OTHER					
TOTAL OTHER DIRECT COSTS				1,932,354	
H. TOTAL DIRECT COSTS (A THROUGH G)				4,030,938	
I. INDIRECT COSTS (SPECIFY) 58% of T.D.C. less equipment and subcontracted amounts (first \$25,000 incurred during first grant year).					
TOTAL INDIRECT COSTS				1,082,039	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				5,112,977	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)				-0-	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				\$ 5,112,977	
PI/PD TYPED NAME & SIGNATURE*		DATE	FOR NSF USE ONLY		
INST. REP. TYPED NAME & SIGNATURE*		DATE	INDIRECT COST RATE VERIFICATION		
			Date Checked	Date of Rate Sheet	Initials - DGC
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Budget explanation page 1

Line A4 - Prof. R. Weiss, MIT

All MIT costs, including salary for professorial faculty, are shown on line G5.

Line A5 - Other Senior Personnel:

1. Assistant Professor, Caltech

(to be appointed; a search is currently in progress with the approval and assistance of the Caltech administration.)

2. Assistant Professor, MIT

(to be appointed; a search is currently in progress with the approval and assistance of the MIT administration.)

(Note that all MIT costs are shown on line G5.)

Line A6 - Total Senior Personnel

In accordance with Caltech policy, individual faculty man-months and salary data are furnished under separate cover to the NSF.

Lines B1-B6 - Other Personnel:

Staff are listed in section VII.

Line D - Equipment: (see discussion in sections VI-A,B of text)	year 1	year 2	year 3
1. Computing and data acquisition equip.			
Discless engineering work stations (6/yr)	30000	30000	
Color engineering work station with disc	16500	16500	
3D mechanical design software package	50000		
Upgrades for data acquisition computer - Additional memory, 300 Mbyte hard disc, ethernet communication board	30000		
CAMAC data acquisition modules, bin	85000	45000	25000
Ancillary electronics	7000	5000	1500
2. Upgrades to the 40 meter vacuum system			
4' diameter end tanks (2)	40000		
24" diameter beam pipe	90000		
24" gate valves	40000		
Seismic monitor beam pipes	10000		
Other vacuum components, pumps, etc.	10000	12000	12000
3. Optics, mirrors, test masses			
set of 4" dia. masses (9 mirrors)	65000	65000	65000
set of 8" (4 km size) masses		100000	170000
small low-loss mirrors (mode cleaners, beam steering, etc.)	37500	37500	37500
Argon lasers and tubes	65000	65000	65000
Small optical components	24000	24000	24000
Line D - Total equipment:	600000	400000	400000

		year 1	year 2	year 3
Line E1 - Domestic Travel:	Estimated base cost per trip* (FY88 \$)			
1. Trips to NSF, Wash., DC 4 trips/yr, 3 people	2000	24900	26400	28000
2. Trips to MIT 6 trips/yr, 2 people	2000	24900	26400	28000
3. Trips to Design Contractor 4 trips, 3 people	1500	18700		
4. Trips to LIGO sites 2 trips/yr, 4 people	2000		17600	18700
5. Trips to scientific conferences 1 trip/yr, 2 people	1500	3100	3300	3500
Line E1 Total:		71600	73700	78200

Line E2 - Foreign Travel:

1. Trips to potential European LIGO collaborators 1 trip/yr, 3 people	3000	9400	9900	10500
2. Trips to Int'l conferences 1 trip, 1 person (years 1 & 3) 1 trip, 3 people (year 2)	3000	3100	9900	3500
Line E2 Total:		12500	19800	14000

* Trip base costs are estimated as follows:

Destination	Bangor MN	Boston MA	Chicago IL	Wash,DC	Munich FRG
R/T coach air fare	1394	1260	780	1236	2234
Hotel, 5 nites @ \$50	250				
Hotel, 5 nites @ \$100		500	500	500	
per diem, 5 days @ \$28	140	140	140	140	
per diem, 5 days @ \$132					660
Rental car, 5 days @ \$40	200				
Ground trans., misc. exp.	16	100	80	124	106
Total trip cost	2000	2000	1500	2000	3000

year 1 year 2 year 3

Line G1 - Materials and Supplies:	Estimated amounts		
1. Office supplies	13700	15700	16500
2. Graphic arts - copying, illustration and engineering repro services	20800	23000	24400
3. Telephone and postage	16700	17600	18700
4. Computer supplies - tapes, printer toner and paper, etc.	20800	22000	23400
5. Equipment maintenance - computer maintenance, copy and FAX machine rental	20800	21600	22900
6. Miscellaneous lab supplies - elect. components, liquid nitrogen, shop materials, etc.	25000	26400	28100
7. Small equipment purchases (< \$500) - elect. and mech. components, mirror mounts, etc.	15600	16500	17500
8. Machine shop services - @ \$30/hr. (FY88 rate)	9700	10300	10900
Line G1 Total:	143100	153100	162400
Line G2 - Publications: Page charges: est. 40 pages per year at \$100 (FY88) per page	4200	4400	4600
Line G3 - Consultants: (see remarks in text)			
1. Design reviews - Assume 3 reviews/yr, 10 people each, 1 week duration; assume 5 people travel from East coast; use \$250/m-day, \$2000/m-trip	67500	67500	
2. Special problem studies	32500	32500	
Line G3 Total:	100000	100000	

Budget explanation page 5

Supporting detail, Line 65

MIT Subcontract

(see remarks in text)

year 1 year 2 year 3

6/88- 5/89	6/89- 5/90	6/90- 5/91	Total
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Manloading (no./yr.)

-----man-months-----

Professorial Faculty (2,2,2)				
Scientific Staff (5,5,6)	54	60	72	186
Professional/Tech. Staff (2,3,3)	24	36	36	96
Secretarial/Clerical (1,1,1)	6	6	6	18
Graduate Res. Ass't. (5,6,7)	60	72	84	216
Undergrad. Res. Ass't (3,3,3)	9	9	9	27
Other (CSR Admin. Support)	9.7	10.4	10.5	30.6

COSTS (\$K)

Salaries:

Professorial Faculty	25800	36200	38300	100300
Scientific Staff	175900	195700	242500	614100
Professional/Tech. Staff	70700	119000	126100	315800
Secretarial/Clerical	11900	12600	13300	37800
Graduate Res. Ass't.	59800	76100	94100	230000
Undergrad. Res. Ass't	11000	11600	12300	34900
Other	39700	48600	55800	144100

Total salaries	394800	499800	582400	1477000
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Staff Benefits	152369	195280	228040	575689
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Supplies and expenses:

Materials and services	54400	67400	77400	199200
Telephone and Postage	8400	8400	8400	25200
Publications	2000	2000	2000	6000
Allocated expense	8500	10000	10600	29100

Total supplies and expenses	73300	87800	98400	259500
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Domestic Travel	44000	46000	48000	138000
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Foreign Travel	3100	9900	3500	16500
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Equipment	300000	200000	200000	700000
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TOTAL DIRECT COST	967569	1038780	1160340	3166689
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Overhead	397203	522812	605014	1525029
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TOTAL ESTIMATED COST	1364772	1561592	1765354	4691718
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MIT Subcontract, con'd.

Salaries:

Amounts are based on the manloading shown. Actual salary FY88 rates are used, with estimates for people to be appointed. Staffing is identified in section VII. All salary amounts are inflated to future years at 6% per year.

Faculty salary allocations are in accordance with MIT policy.

Other direct costs:

Amounts shown for supplies and expenses, domestic and foreign travel, and equipment are budgetary estimates based upon informal discussions with MIT. MIT will submit a proposal to Caltech supporting and justifying these costs, and the resulting negotiated contract will reflect such supporting data.

Burden rates:

MIT staff benefits are based on total salaries except undergraduate students. MIT overhead rates are applied to total direct costs less equipment. Rates used for this estimate, obtained informally from MIT, are as follows:

	FY88	FY89	FY90	FY91
Staff benefit rate	0.391	0.400	0.400	0.400
Overhead rate	0.565	0.610	0.630	0.630

Rates are applied to appropriate estimated amounts by fiscal year, and then summed into the proposed grant performance periods.

MIT Subcontract, con'd.

		year 1	year 2	year 3
Domestic Travel:	Estimated base cost per trip* (FY88 \$)			
1. Trips to NSF, Wash., DC 4 man-trips/yr	600	2500	2600	2800
2. Trips to Caltech 16 man-trips/yr	2000	33200	35300	37400
3. Trips to Design Contractor 5 man-trips	1000	5200		
4. Trips to LIGO sites 3 man-trips/yr	1500		4900	4300
5. Trips to scientific conferences 2 man-trips/yr	1500	3100	3300	3500
Total Domestic Travel:		44000	46100	48000
Foreign Travel:				
1. Trips to Int'l conferences 1 trip, 1 person (years 1 & 3) 1 trip, 3 people (year 2)	3000	3100	9900	3500
Total Foreign Travel:		3100	9900	3500

Budget explanation page 8

Supporting detail, Line 65

MIT Subcontract, con'd.

Equipment:
(see discussion in sections VI-A,B of text)

year 1 year 2 year 3

1. Computing and data acquisition equip.

Discless engineering work stations (6)	30000		
CAMAC data acquisition modules, bin	75000	20000	20000
Ancillary electronics	7500	6000	6000

2. Optics, mirrors, test masses

set of 4" dia. masses (9 mirrors)	65000	65000	65000
small low-loss mirrors (mode cleaners; beam steering, etc.)	37500	24000	24000
Argon lasers and tubes	65000	65000	65000
Small optical components	20000	20000	20000

Total equipment:

300000 200000 200000

Budget explanation page 9

Supporting detail, line G6

	year 1	year 2	year 3
Line G5 - Subcontracts (con'd)			
1. MIT Subcontract Total (from page 5)	1364772	1561592	1765354
2. Preliminary engineering design subcontract -			
See section VI-F for work definition			
See section VIII text for discussion	3000000		
Line G5 Total:	4364772	1561592	1765354

Line G6 - Other:

1. JPL support work order -	260000	275000	
Assume 2 m-years/yr @ \$125K/yr (FY88)			
(includes JPL burdens)			

Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

I. Name of Principal Investigator	Source of Support	Project Title	Award Amount (or Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project		Location of Research
					ACAD.	CAL. YR.	
R. E. Vogt	NSF	Notes 1 & 2	\$3,196,719	3/1/87-2/29/88		100%	Caltech/MIT
A. Current Support List—if none, report none	NSF	Caltech/MIT LIGO	18,118,396	6/1/88-5/31/91		100%	Caltech/MIT
B. Proposals Pending 1. List this proposal	NONE						
2. Other pending proposals, including renewal applications, if none, report none.	NONE						
3. Proposals planned to be submitted in near future, if none, report none.	NONE						
II. Name of co-principal investigator and/or faculty associate A. See attached sheets							
B. _____							
III. Transfer of Support If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.							
IV. Other agencies to which this proposal has been/will be submitted							

USE ADDITIONAL SHEETS AS NECESSARY

1. "Investigations in Experimental Gravity and Gravitational Radiation" (Caltech: Drever PI)
2. "Interferometric Broadband Gravitational Antenna" (MIT: Weiss, PI)

Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

I. Name of Investigator	Source of Support	Project Title	Award Amount (or Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project		Location of Research
					ACAD.	SUMM. CAL. YR.	
R.W.P. Drever A. Current Support List—if none, report none B. Proposals Pending 1. List this proposal 2. Other pending proposals, including renewal applications. If none, report none. 3. Proposals planned to be submitted in near future. If none, report none.	NSF	Investigations in Experimental Gravity	\$1,896,719	3/1/87-2/29/88		80%	Caltech
	NSF	Caltech/MIT LIGO	18,118396	6/1/88-5/31/91		80%	Caltech/MIT
	NONE						
	NONE						
II. Name of co-principal investigator and/or faculty associate A. _____ B. _____							
III. Transfer of Support If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.							
IV. Other agencies to which this proposal has been/will be submitted							

USE ADDITIONAL SHEETS AS NECESSARY

Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

I. Name of Investigator	Source of Support	Project Title	Award Amount (or Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project		Location of Research
					ACAD.	SUMM. CAL. YR.	
K. S. Thorne A. Current Support List—if none, report none B. Proposals Pending 1. List this proposal 2. Other pending proposals, including renewal applications. If none, report none. 3. Proposals planned to be submitted in near future. If none, report none.	NSF	Relativistic Astrophysics	\$221,500	11/1/87-10/31/88		50%	Caltech
	NSF	Caltech/MIT LIGO	18,118,396	6/1/88-5/31/91		20%*	Caltech/MIT
	1. NASA **	Theoretical Studies of AGN	270,000	FY88-90		15%	Caltech and other institutions.
	2. NASA **	Investigations of Solar Oscillations	160,000	FY88-90		15%	Caltech and other institutions.
II. Name of co-principal investigator and/or faculty associate A. _____ B. _____	NONE						
III. Transfer of Support If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.							
IV. Other agencies to which this proposal has been/will be submitted							

*20% included in 50% shown for Thorne's current NSF grant; Thorne would receive no salary from this grant.
 **Thorne would receive no salary from these pending grants. PIs on these grants are 1) Roger Blandford and 2) Peter Goldreich, Thorne is a Co-I.

Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

I. Name of Investigator	Source of Support	Project Title	Award Amount (or Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project		Location of Research
					ACAD.	SUMM. CAL. YR.	
R, Weiss	1. NSF	Broadband Gravitational Antenna COBE Satellite Mission	\$1,300,000	3/1/87-2/29/88		65%	MIT
	2. NASA		1,516,771	8/83-8/89		15%	MIT
B. Proposals Pending	NSF	Caltech/MIT LIGO	18,118,396	6/1/88-5/31/91		65%	Caltech/MIT
	NONE						
2. Other pending proposals, including renewal applications. If none, report none.	NONE						
3. Proposals planned to be submitted in near future. If none, report none.	NONE						
II. Name of co-principal investigator and/or faculty associate							
A. _____							
B. _____							
III. Transfer of Support If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.							
IV. Other agencies to which this proposal has been/will be submitted							

USE ADDITIONAL SHEETS AS NECESSARY

Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

i. Name of Investigator To be appointed, Caltech	Source of Support	Project Title	Award Amount (for Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project		Location of Research
					ACAD.	SUMM. CAL. YR.	
A. <i>Current Support</i> List—if none, report none	NONE						
B. <i>Proposals Pending</i> 1. List this proposal	NSF	Caltech/MIT LIGO	\$18,118, 396	6/1/88 5/31/91		60%	Caltech/MIT
2. Other pending proposals, including renewal applica- tions. If none, report none.	NONE						
3. Proposals planned to be submitted in near future. If none, report none.	NONE						
ii. Name of co-principal investigator and/or faculty associate							
A. _____							
B. _____							
iii. <i>Transfer of Support</i> If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.							
iv. Other agencies to which this proposal has been/will be submitted							

USE ADDITIONAL SHEETS AS NECESSARY

NSF FORM 1238 (1-87)

Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

I. Name of Investigator To be appointed, MIT	Source of Support	Project Title	Award Amount (or Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project		Location of Research
					ACAD.	SUMM. CAL. YR.	
A. Current Support List—if none, report none	NONE						
B. Proposals Pending 1. List this proposal	NSF	Caltech/MIT LIGO	\$18,118 396	6/1/88 5/31/91		60%	Caltech/MIT
2. Other pending proposals, including renewal applications. If none, report none.	NONE						
3. Proposals planned to be submitted in near future. If none, report none.	NONE						
II. Name of co-principal investigator and/or faculty associate A. _____ B. _____							
III. Transfer of Support If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.							
IV. Other agencies to which this proposal has been/will be submitted							

USE ADDITIONAL SHEETS AS NECESSARY

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- V-2 R. W. P. Drever, J. Hough, A. J. Munley, S.-A. Lee, R. Spero, S. E. Whitcomb, H. Ward, G. M. Ford, M. Hereld, N. A. Robertson, I. Kerr, J. Pugh, G. P. Newton, B. Meers, E. D. Brooks, and Y. Gursel, *Laser Spectroscopy V*, ed. A. R. W. McKellar, T. Oka, and B. P. Stoicheff (Springer, New York 1981) 33.
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X. VITAE

Rochus E. Vogt

Born: December 21, 1929, Germany (FRG)
U.S. Citizen

Present Position: R. Stanton Avery Distinguished Service Professor and Professor of Physics
Director, Caltech/MIT Laser Interferometer Gravitational-Wave Observatory (LIGO) Project

Education: 1952—cand. phys. Technische Hochschule Karlsruhe, FRG
Universität Heidelberg, FRG
1957—S.M. University of Chicago
1961—Ph.D. University of Chicago

Positions: 1953–1961 Research Assistant, Enrico Fermi Institute for Nuclear Studies, University of Chicago
1961–1962 Research Associate, Enrico Fermi Institute for Nuclear Studies, University of Chicago
1962–1965 Assistant Professor of Physics, Caltech
1965–1970 Associate Professor of Physics, Caltech
1970–present Professor of Physics, Caltech
1975–1977 Chairman of the Faculty, Caltech
1977–1978 Chief Scientist, Jet Propulsion Laboratory (JPL), Caltech
1978–1983 Chairman, Division of Physics, Mathematics and Astronomy, Caltech
1980–1981 Acting Director, Owens Valley Radio Observatory, Caltech
1982–present R. Stanton Avery Distinguished Service Professor, Caltech
1983–1987 Vice President and Provost, Caltech
1987– Director, Caltech/MIT Laser Interferometer Gravitational-Wave Observatory (LIGO) Project

Research: Research on astrophysical aspects of cosmic radiation and in gamma-ray astronomy.
Gravitational Wave Astronomy.

Co-investigator (1962–1969) and Principal Investigator (1969–1983) on NASA grant supporting space research at Caltech. Principal Investigator on NASA's Voyagers 1 and 2 missions (1972–1984). Co-investigator on cosmic ray experiments on NASA's OGO-6, IMP 7 and 8, HEAO-3, ISEE-3 missions.

Other Activities:	1963–present	Various consultantships with government and industry
	1971–1973	Panel on Alternate Approaches to Graduate Education (Council of Graduate Schools in the US)
	1973–1976	Physical Sciences Committee (NASA)
	1984–present	Member of the Board of Directors, International Rectifier Corporation
	1985–1987	Member of the Board of Directors, California Association for Research in Astronomy
Professional Societies:	American Physical Society (Fellow)	
	American Association of Physics Teachers	
	American Association for the Advancement of Science	
Honors:	Member, Studienstiftung des deutschen Volkes (1950–1953)	
	Fulbright Fellow (1953–1954)	
	Professional Achievement Award (1981), University of Chicago Alumni Association	
	NASA Exceptional Scientific Achievement Medal (1981)	
	R. Stanton Avery Distinguished Service Professor, Caltech (1982)	

Ronald William Prest Drever

Born: October 26, 1931, Scotland
British Citizen

Present Position: Professor of Physics
California Institute of Technology (Caltech)

Education: 1953-B.S. Glasgow University
1958-Ph.D. Glasgow University

Positions: 1956-1960 Research Fellow, Glasgow University
1960-1967 Lecturer, Glasgow University
1960-1961 Research Fellow, Harvard University, (LOA, Glasgow University)
1967-1973 Senior Lecturer, Glasgow University
1973-1975 Reader, Glasgow University
1975-1979 Titular Professor, Glasgow University
10/77-1/78 Visiting Associate, Caltech
1979-1984 Professor of Physics, Part-time, Caltech
1979-1984 Professor of Physics, Part-time, Glasgow University
1984-present Professor of Physics, Caltech

Research:

Ph.D. and post-doctoral work in experimental nuclear physics and low energy beta spectroscopy, including experiments relevant to neutrino mass, and on spectrum and half-life of rhenium 187 setting limits to change of fine structure constant with geological time. Experiments on anisotropy of inertial mass by nuclear free precession in the earth's magnetic field. Work on Mossbauer effect, at Harvard; on studies of cosmic rays by atmospheric Cerenkov radiation, at Harwell; on pulse radio astronomy and other astronomical experiments.

Worked on gravitational radiation experiments since 1972. Developed wide-band gravity-wave bar detectors and made first extensive searches for pulses; stochastic background radiation with them. Developed laser interferometer gravity wave detection techniques using optical cavities, first at the University of Glasgow, subsequently at Caltech. Head of the Experimental Gravity Group at Caltech, and Co-investigator in proposed large scale Caltech/MIT LIGO project.

Other Activities: 1968-1972 Consultant and Vacation Assistant, Atomic Energy Research Establishment, Harwell (U.K. Atomic Energy Authority)
1972-1974 Member of the Astronomy Policy and Grants Committee, (U.K. Science Research Council)
1972-1976 Council Member of the Royal Astronomical Society
1973-1976 Vice President of the Royal Astronomical Society
1974 Consultant, National Science Foundation (U.S.A.)
1974-1976 Royal Astronomical Society Assessor to the Astronomy I Committee
1979 Morris Loeb Lectureship in Physics, Harvard University
1985 Ernest Guptill Memorial Lecturer, Dalhousie University, Canada

Professional Societies: Fellow of the Royal Society of Edinburgh
Member of the International Society of General Relativity on Gravitation

Kip S. Thorne

Born: June 1, 1940, Logan, Utah, USA
U.S. Citizen

Present Positions: The William R. Kenan, Jr., Professor, and Professor of Theoretical Physics, Caltech
Adjunct Professor Physics, University of Utah
Andrew D. White Professor at Large, Cornell University

Education: 1962 B.S. California Institute of Technology
1963 A.M. Princeton University
1965 Ph.D. Princeton University

Positions: 1965–1966 Postdoctoral Fellow in Physics, Princeton
1966–1967 Research Fellow in Physics, Caltech
1967–1970 Associate Professor of Theoretical Physics, Caltech
1970–present Professor of Theoretical Physics, Caltech
1971–present Adjunct Professor of Physics, University of Utah
1981–present The William R. Kenan, Jr., Professor, Caltech
1986–present Andrew D. White Professor at Large, Cornell

Research: Theoretical physics, gravitation physics, astrophysics.

Other Activities: International Committee on General Relativity and Gravitation, 1971–1980
Committee on US-USSR Cooperation in Physics, 1978–1979
Advisory Board, Institute for Theoretical Physics, Santa Barbara, 1978–1980
Space Science Board, 1980–1983

Honors: Fulbright Lecturer in France, 1966
Alfred P. Sloan Foundation Research Fellow in Physics, 1966–1968
John Simon Guggenheim Fellow, 1967–1968
AIP–U.S. Steel Foundation Science Writing Award in Physics and Astronomy, 1969
Fellow, American Academy of Arts and Sciences, 1972–present
Member, National Academy of Sciences, 1973–present
Honorary Doctor of Science, Illinois College, 1979
Doctoris Honoris Causa, Moscow University, 1981

Professional Societies: American Astronomical Society
International Astronomical Union
American Physical Society, Fellow
American Association for the Advancement of Science, Fellow

Rainer Weiss

Born: September 29, 1932, Berlin, Germany
U.S. Citizen

Present

Position: Professor of Physics, Massachusetts Institute of Technology

Education: 1955–B.S. Massachusetts Institute of Technology
1962–Ph.D. Massachusetts Institute of Technology

Positions: 1960–1961 Instructor of Physics, Tufts University
1961–1962 Assistant Professor of Physics, Tufts University
1962–1964 Research Associate in Physics, Princeton University
1964–1967 Assistant Professor of Physics, M.I.T.
1967–1973 Associate Professor of Physics, M.I.T.
1973–present Professor of Physics, M.I.T.

Research:

Experimental Atomic Physics, Atomic Clocks, Laser Physics, Experimental Gravitation, Millimeter and Sub-millimeter Astronomy, Cosmic Background Measurements, Major Projects: Atomic Clock development, Balloon program to measure Cosmic Background Radiation, Science Working Group Chairman, COBE satellite program, Laser Interferometer Gravitational-Wave Observatory (LIGO)

Professional Societies: American Association for the Advancement of Science
American Physical Society

Other

Activities: NASA Physical Science Committee, 1970–1974
National Academy Summer Study on Outer Planet Exploration, 1972
NASA Management Operations Working Group for Shuttle Astronomy, 1973–1976
NASA Management Operations Working Group for Airborne Astronomy, 1973–1986
Chairman, NASA Panel on Experimental Relativity and Gravitation, 1974–1976
NCAR Scientific Ballooning Advisory Panel, 1971–1978
Chairman, NCAR Scientific Ballooning Advisory Panel, 1974–1978
Members' Representative to NCAR from M.I.T., 1974–1982
Chairman, NSF Subcommittee on Gravitational Physics, 1978
NASA SSSC Committee, 1979–1982
NASA Infrared Detector Panel, 1978
NASA Space and Earth Science Advisory Committee, 1982
National Academy Space Science Board, 1983–1986
Panel Chairman on Fundamental Physics and Chemistry, National Academy Summer Study, Major Directions for Space Research 1995–2015, 1984–86
Panel for the Joint Institute of Laboratory Astrophysics, Board on Assessment of NBS Programs, National Academy of Sciences, 1985–

Alex Abramovici

Born: May 14th, 1945. U.S.S.R.
Israeli Citizen

Present Position: Staff Scientist, Gravitational Physics,
California Institute of Technology

Education: 1968-M.Sc. University of Timisoara, Romania
1985-Ph.D. Weizmann Institute of Science, Israel

Positions: 1985-1986 Postdoc, Weizmann Institute of Science
1986-1987 Scientist, Weizmann Institute of Science

Research:

Laser physics, laser stabilization, single mode operation of lasers, very low noise He-Ne lasers, laser heterodyne measurements, high efficiency seismic isolation systems, noise analysis, measurement of very small displacements using laser interferometers, laser gravitational wave detectors.

Honors: The Giora Yashinski Memorial Prize (1984)

William E. Althouse

Born: December 2, 1942, Los Angeles, California
U.S. Citizen

Present Position: Member of the Professional Staff, Caltech
Chief Engineer, Caltech/MIT Laser Interferometer
Gravitational-Wave Observatory (LIGO) Project

Education: 1968-B.S.E.E. California State Polytechnic University

Positions: 1963-1964 Electronics Technician, Caltech
1964-1965 Junior Engineer, Caltech
1965-1969 Associate Engineer, Caltech
1969-1972 Electronics Engineer, Caltech
1972-1979 Senior Engineer, Caltech
1979-1981 Technical Manager, Caltech
1981- Member of the Professional Staff, Caltech
1981-1987 Chief Engineer, Space Radiation Laboratory, Caltech
1987- Chief Engineer, Caltech/MIT Laser Interferometer
Gravitational-Wave Observatory (LIGO) Project

Research:

Developed, managed, supervised and/or participated in gamma-ray astronomy and high energy charged particle experiments: Team Leader, balloon-borne gamma-ray imaging observations of SN1987a; engineering supervisor, Heavy Ion Counter experiment, Galileo Project; engineering supervisor, Gamma-Ray Imaging Payload Project; Experiment Manager, Comprehensive Particle Analysis System, International Solar Polar Mission; Experiment Manager, Heavy Isotope Spectrometer Telescope experiment, International Sun-Earth Explorer Project; Deputy Experiment Manager, Cosmic Ray Subsystem, Voyager Project; Project Manager, Electron-Isotope Spectrometer, Interplanetary Monitoring Platforms 7 and 8; Project Engineer, Galactic Cosmic Ray Experiment, Orbiting Geophysical Observatory Project.

Other

Activities: Assistant Chairman, Nuclear Science Symposium, 1979-1985

Professional Societies: Institute of Electrical and Electronics Engineers
IEEE Nuclear Sciences and Plasma Society
IEEE Aerospace and Electronic Systems Society
IEEE Computer Society
IEEE Instrumentation and Measurement Society
IEEE Lasers and Electro-Optics Society

Richard L. Benford

Born: February 25, 1942
British Citizen

Present Position: Sponsored Research Technical Staff,
Massachusetts Institute of Technology

Education: 1962 Ordinary National Certificate Mechanical Engineering
Acton Technical College, Acton, London, England
1978 Bachelor of Engineering Technology Electrical Engineering,
Northeastern University

Positions: 1959-1963 Napier Aero Engines, Acton, London, England
1963-1965 Cryonetics Corporation, Burlington, MA., U.S.A.
1966-1967 Spembly Technical Products, Ltd., Sittingbourne, Kent, England
1967-1969 University of Western Ontario, London, Ontario, Canada
1969-present Massachusetts Institute of Technology, Cambridge MA, U.S.A.

Research:

Gravitational wave detection: Resident Engineer—worked with project leaders on Gravity wave antenna prototype and vacuum system design, liason with contractor and suppliers of raw materials. Measurement of cosmic background radiation: mechanical design and field support of balloon borne Infrared experiment. Technical aide to physics department head: maintained undergraduate physics laboratory. Lab Technician: research and development of liquid nitrogen level controllers and cryosurgical instruments for eye surgery. Testing, instrumenting and evaluating test data on miniaturised liquid helium and nitrogen compressors. Gas turbine aircraft engine fitting, inspection and certification, diesel electric engine repair and assembly.

E. Michael Burka

Born: October 17, 1957, Washington, D.C.
U.S. Citizen

**Present
Position:** Research Scientist, Massachusetts Institute of Technology

Education: 1979-B.A. University of Pennsylvania
1981-M.A. Johns Hopkins University
1985-Ph.D. Johns Hopkins University

Positions: 1979-1982 Teaching Assistant, Johns Hopkins University
1980-1985 Research Assistant, Johns Hopkins University
1985-1987 Postdoctoral Research Associate, MIT
1987-present Research Scientist, MIT

Research: High Energy Physics
Gravitational Wave Astrophysics

**Professional
Societies:** American Physical Society
American Association for the Advancement of Science

Honors: Pi Mu Epsilon, elected 1978

Andrej Marjan Čadež

- Born:** September 12, 1942, Yugoslavia
Yugoslav Citizenship
- Present Position:** Visiting Associate in Physics
California Institute of Technology (Caltech)
- Education:** -B.S. University Edvard Kardelj in Ljubljana
1971-Ph.D. University of North Carolina, Chappel Hill
- Positions:** 1974 Research Fellow, Meudon, France
1976 Research Fellow, Oxford University (U.K.)
9/86-8/87 Visiting Associate in Physics, Caltech
1983-present Director, Astronomical Observatory in Ljubljana
1982-present Professor of Physics, University Edvard Kardelj in Ljubljana
- Research:**
- Development of a gravity gradiometer.
 - Theoretical and experimental aspects of gravitational wave detection.
 - Development of mechanical oscillators with long relaxation times.
 - Experimental and theoretical studies in test masses used for detection of gravitational waves by laser interferometers.
 - Development of techniques for stabilizing and precisely controlling the position of suspended test masses.
- Honors:** Fulbright award for graduate study (1967)
Scholarship of Slovenian Science Foundation (1974)
Fellowship for 6 months research at Oxford University (U.K.)(1976)
Award of Boris Kidric Foundation (1976)
Fulbright Scholar at Caltech (9/86-8/87)

Ernest J. Franzgrote

Born: December 25, 1930, Peoria, Illinois

Present Position: Assistant to the Director, Caltech/MIT Laser Interferometer Gravitational-Wave Observatory (LIGO) Project

Education: 1957-MS California Institute of Technology
1959-1961 University of Munich

Positions: 1957-1959 Research Scientist and Engineer (JPL), Caltech
1961-1971 Co-Investigator, Surveyor Project (JPL), Caltech
1971-1974 Senior Research Scientist and Engineer (JPL), Caltech
1974-1981 Experiment Representative, Voyager Project (JPL), Caltech
1981-1986 Project Manager Representative (JPL), Caltech
1986-1987 Senior Executive Assistant to the Provost, Caltech
1987- Assistant to the Director, Caltech/MIT Laser Interferometer Gravitational-Wave Observatory (LIGO) Project

Research:

Research on chemical separation processes.
Development of methods for analysis of the Martian atmosphere.
Geo- and selenochemical studies.
First analysis of the lunar surface as co-investigator on NASA's Surveyor 5-7 missions.
Fields and particles studies on the outer planets.
Analysis of flights of remotely-piloted vehicles, human-powered and solar-powered airplanes, and of the Trochilidae.

Honors:

Letters of commendation from managers of the Remotely Piloted Vehicle Project, 1982 and 1985.
NASA's Exceptional Service Medal, Voyager Project, 1981.
Participant in three projects that have received the Collier Trophy in aviation and space flight.
Shared in the Kremer Prize for the first human-powered flight across the English Channel, 1980.

Halis Yekta Gürsel

Born: May 15, 1953, The city of Samsun, Turkey
Citizen of The Republic of Turkey
Permanent resident of the U.S., Visa # A24937520

Present Position: Staff Scientist
California Institute of Technology (Caltech)

Education: 1975-B.S. Middle East Technical University, Ankara, Turkey
1982-Ph.D. Caltech

Positions: 1982-1984 Associate Experimental Physicist, Caltech
9/84-7/87 Research Scientist, MIT
7/87-present Staff Scientist, Caltech

Research:

Conducted advanced experimental research in the area of gravitational and gravitational radiation.

Conducted work on the "Digital Orrery" Project.

Designed and constructed high speed computing machinery to solve physical problems, at MIT AI Laboratory.

Completed the layout of the Scheme86 processor.

Completed the design and the feasibility of the Fast Floating-Point Processor.

Jefferson H. Harman

Born: September 10, 1937, U.S.A.
U.S. Citizen

Present Position: Principal Electronic Engineer
California Institute of Technology

Education: 1959-B.E.E. Georgia Tech
1969-M.S. U.C.L.A.

Positions: 1959-1963 Junior Engineer, Collins Radio Company
1963-1965 Engineer, Spacecraft, Inc.
1965-1966 Engineer, Beckman Instrument Company
1966-1967 Project Engineer, Raytheon Computer
1967-1968 Group Leader, Analog Circuits; Allen Electric, UTI Division
1968-1970 Principal Member/Technical Staff, Scientific Data Systems, Inc.
1970-1973 Manager of Servomechanism Design, Wangco, Inc.
1973-1974 Manager of Electronics, General Systems International, Inc.
1974-1981 Chief Engineer, Director of R and D, Persci, Inc.
1974-1981 Director of Electrical Engineering, Persci, Inc.
1981-1983 Principal Consultant, Cambrian Consultants, Inc.
1983-1986 President, Harman Engineering Labs, Inc.
12/86-10/87 Electronic Engineer, Caltech
10/87-present Principal Electronic Engineer, Caltech

Research:

Industrial research leading to the following U.S. patents:
3,143,707 Gated Dual Identical Channel AGC
4,027,217 Speed Control for DC Motors
4,270,073 Position Control in Disk Drive Systems
4,300,174 Guard Band Control for Magnetic Disks
4,306,257 Processing Read-back Signals in Magnetic Disks
Other patents pending

Professional Societies: Institute of Electrical and Electronics Engineers (IEEE)

Andrew D. Jeffries

Born: December, 1951
U.S. Citizen

Education: 1983 Ph.D. Physics, Massachusetts Institute of Technology
Thesis title: "Angular and Spectral Distortions of the Cosmic Background"
1977 A.B. Physics, University of California, Berkeley

Present

Position: Experimental Research Physicist, MIT Center for Space Research

Positions: 1985 Research Staff, MIT Center for Space Research
1983 Postdoctoral Associate, MIT Physics
1979 Research Assistant, MIT Physics
1978 Teaching Assistant, MIT Physics

Other

Activities: 1985- Senior Thesis Advisor Physics, Electrical Engineering
1986- Project Supervisor, Modern Optics Laboratory
1984- Undergraduate Research Opportunity Supervisor
1982- Freshman Academic Advisor

Professional

Societies: American Physical Society

Research: Gravitational Wave Astronomy and Detectors
Modern Optics, Laser Physics
Experimental Cosmology, Cosmic Background Radiation

Paul S. Linsay

Born: August 13, 1947, Germany (FRG)
U.S. Citizen

Present Position: Principal Research Scientist, M.I.T.

Education: 1969-B.S. M.I.T.
1970-M.S. University of Chicago
1976-Ph.D. University of Chicago

Positions: 1969-1970 Teaching Assitant, University of Chicago
1970-1976 Research Assistant, University of Chicago
1976-1979 Research Fellow in Physics, Caltech
1979-1982 Research Scientist, M.I.T.
1982- Principal Research Scientist, M.I.T.

Research: Particle Physics: Kaon physics, neutrino scattering
Gravitational Wave Astronomy
Nonlinear Dynamics
Co-investigator (1980-) NSF grants supporting gravitational wave astronomy. Principal Investigator (1985-) ONR grant supporting studies in nonlinear dynamics.

Professional Societies: American Physical Society
American Astronomical Society

Jeffrey C. Livas

Born: March 27, 1959. Palmer, MA.
U.S. Citizen

Present Positions: Postdoctoral Associate, Massachusetts Institute of Technology
Scientist, MIT/Caltech Laser Interferometer
Gravitational Wave Observatory (LIGO) Project

Education: 1981 - S.B. Massachusetts Institute of Technology
1987 - Ph.D. Massachusetts Institute of Technology

Positions: 1981 - 1987 Research Assistant, Physics Department, MIT
1980 - 1981 Calculus recitation instructor, Concourse Program, MIT

Research:
Thesis research on experimental gravitational wave detection. Developed data analysis techniques to search for periodic sources of unknown period and direction.

Other Activities: 1986-present Educational Counselor
1982-1986 Freshman Adviser
1982-1986 Undergraduate Admissions Reader

Professional Societies: American Physical Society
American Association for the Advancement of Science
Sigma Xi

Boude C. Moore

Born: March 11, 1925, Nagasaki, Japan
U.S. Citizen

Present Position: Engineer, California Institute of Technology

Education: 1948-B.S.E.E. California Institute of Technology
1949-M.S.E.E. California Institute of Technology

Positions: 1943-1946 Radio Technician, U.S. Navy
1947 Electronics Technician, Jet Propulsion Laboratory
1948 Draftsman, Northrop Aircraft
1948-1949 Laboratory Assistant, Caltech
1949-1953 Instrumentation Engineer, Douglas Aircraft
1953-1965 Group Leader, Douglas Aircraft
1965-1974 Branch Chief, McDonnell-Douglas Co.
1974-1984 Section Chief, McDonnell-Douglas Co.
1984-1987 Consultant (self-employed)
1987 Engineer, LIGO Project, Caltech

Research:

Studied vacuum technology, both theoretical and experimental. Principal Investigator on NASA study of Molecular Wake Shield. Participated in the analysis and procurement of the McDonnell-Douglas 39-foot diameter space simulation chamber. Provided similar support for chambers at Westinghouse, RCA, Rockwell, etc., also the Library of Congress book preservation project.

Other Activities: Chairman, AIAA Working Group on Space Simulation, 1980
Member, AIAA Technical Committee on Ground Test and Simulation, 1973-1976
Member, AIAA Outlook for Space Committee, 1976
Chairman, Test Laboratory Managers Working Group, 1979
Member, ASTM E21 Committee on Space Simulation, 1981-1984

Professional Societies: American Vacuum Society
American Institute of Aeronautics and Astronautics
Institute of Electrical and Electronics Engineers

Peter R. Saulson

Born: October 30, 1954, Baltimore, Maryland

Present Position: Principal Research Scientist, MIT Department of Physics

Education: 1976–A.B. Magna cum laude in Physics, Harvard University
1978–M.A. Physics, Princeton University
1981–Ph.D. Physics, Princeton University
Thesis: "Optical and Infrared Search for Massive Halos of Spiral Galaxies"

Positions: 1978–1980 Assistant in Instruction, Freshman Lab, Princeton University
1980–1981 Assistant in Instruction, Modern Physics, Princeton University
1981–1984 Postdoctoral Research Associate, MIT Department of Physics
1984–1985 Sponsored Research Technical Staff, MIT Center for Space Research
1986 Recitation Instructor, Freshman Physics, MIT
1985–present Principal Research Scientist, MIT Department of Physics

Research: Observational Cosmology
Gravitational Wave Astronomy

Professional Societies: American Astronomical Society

Robert E. Spero

Born: September 12, 1951. California
U.S. Citizen

Present Position: Member of the Professional Staff,
California Institute of Technology (Caltech)

Education: 1973-B.S. U.C.L.A.
1976-M.A. U.C. Irvine
1979-Ph.D. U.C. Irvine

Positions: 1976-1979 Research Assistant
U.C. Irvine
1980-1983 Research Fellow
Caltech
1983-present Member of the Professional Staff
Caltech

Research:

Precision measurement of small forces and displacements, including use of laser-interferometry and torsion balance.
Stabilization of lasers and resonant optical cavities.
Analog and digital electronics for servocontrol and signal processing.
High vacuum technology.
Precision metrology.
Seismic isolation.

