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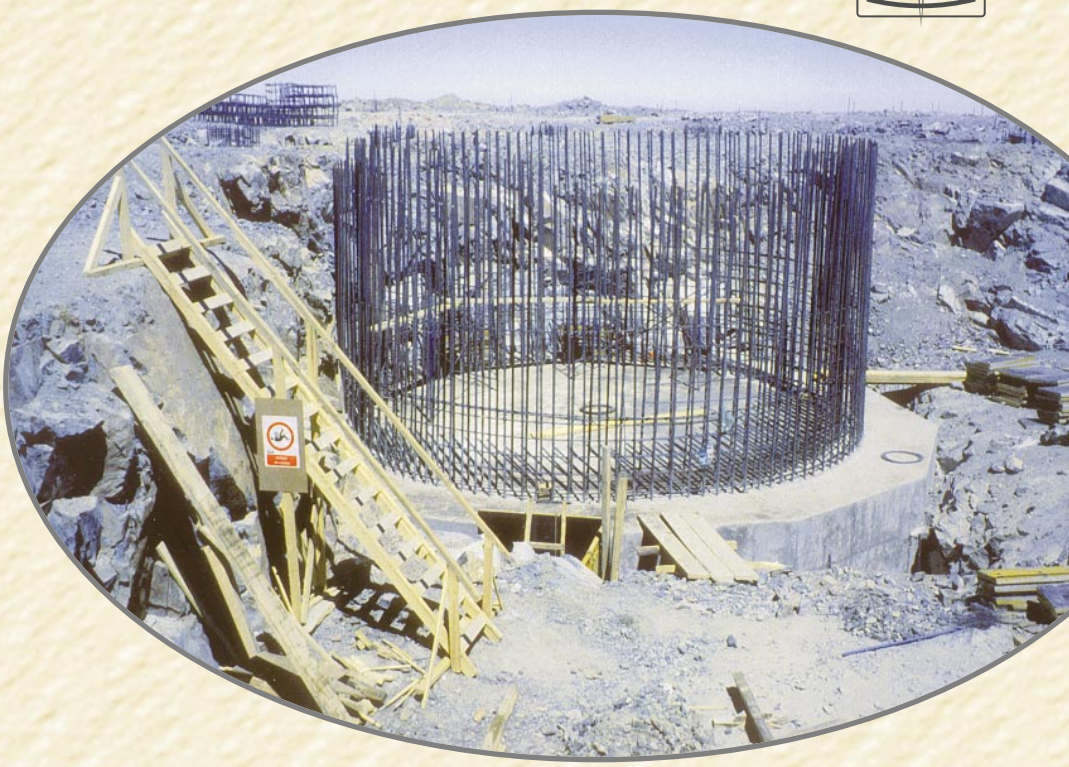
THE INTERNATIONAL GEMINI TELESCOPES

Annual Report 1995



United States

United Kingdom

Canada

Chile

Brazil

Argentina

The photographs above show the first primary mirror at the Corning plant at Canton, NY, at the completion ceremony in October 1995, and the mirror being loaded onto a barge at Odgensburg Port on the St. Lawrence Seaway in December 1995, en route to the REOSC polishing plant in France.

The cover photographs show (above) the Gemini site at Mauna Kea in October 1995 with the University of Hawaii telescope in the background, and (below) at Cerro Pachón in December 1995.

Photograph credits: Susan Kayser, the International Gemini Project Office

The Annual Report for 1995 was prepared by the National Science Foundation, the Executive Agency for the International Gemini 8-Meter Telescopes Project.

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Message from the Gemini Board

The year 1995 was particularly exciting and demanding for the Gemini Project. Many of the largest and most important contracts were let and progress in all areas has been excellent.

The Board took two key decisions during 1995. The first was to agree to a five-month delay in first light for the northern telescope. This was forced upon the project because of bad weather on Mauna Kea in the winter of 1994/95 and the need to restructure the building plans for the enclosure on that site. The second was that the Board agreed that the partners should provide the project contingency, furnishing essential relief to a very tight program. The Gemini Project Office has reassessed the whole program and has satisfied the Board that, with this decision, the project will be brought to completion on the revised schedule included in this report.

The next great challenge is the development of definitive plans for the operational phase of the project. At the November 1995 Board meeting, an imaginative and ambitious plan for operations was presented to the Board by the Project Director. This plan is designed to reduce operational costs to a minimum by using modern information technology, and to optimize the science carried out on the telescopes by requiring that at least 50% of the observations be obtained through queue observing.

The Board expresses its warm thanks to the many organizations and individuals involved in the project for enabling these changes and enhancements to the program to be made. The national agencies and their representatives have done everything they can to adapt to changing and often difficult circumstances. Their endeavors have enabled the project to be kept on schedule without loss of science capability. The project scientists in the partner countries have provided essential input to all aspects of the program and represented forcefully the aspirations of their communities in a spirit of genuine international partnership. Finally, the Gemini Project team, under the dynamic leadership of Dr. Mountain, has performed outstandingly during 1995. The team had to cope with a number of difficult issues but has shown imagination and ingenuity in finding solutions to taxing problems.

The proof of the pudding is of course in the eating, and cooking is still in progress. All the signs are that the Gemini telescopes will be the outstanding 8-meter optical-infrared facilities for the first decades of the 21st century.

Malcolm Longair
Chairman, Gemini Board
June, 1996

Introduction

In the past year, the International Gemini Telescopes Project has made giant steps forward, despite having undergone considerable reassessment. Construction at both the Mauna Kea and Cerro Pachón sites has progressed significantly. The telescope structure contract was placed with TELAS, and the first primary mirror blank was delivered by Corning and shipped to REOSC for polishing.

The project schedule was the first item to be reexamined. An early onset of winter in 1994 on Mauna Kea delayed the start of the road relocation work, and exceptionally high bids for the Mauna Kea construction work required a descoping of the Mauna Kea support facility and a complete restructuring of the Mauna Kea construction contracts. This reassessment led, with Board approval, to a slippage of the Mauna Kea first light date by five months, from July to December 1998.

As a second consequence of the changes in the Mauna Kea plans, a review of project costs was undertaken. Between an increase in construction costs and a restructuring of the Gemini partners' contribution schedule, a cash flow shortage was predicted for 1998-1999, making it advisable to increase the contingency in order to maintain scientific capability.

Lastly, the Gemini Operation Plan was extensively revised and a detailed integration, test, and commissioning plan devised.

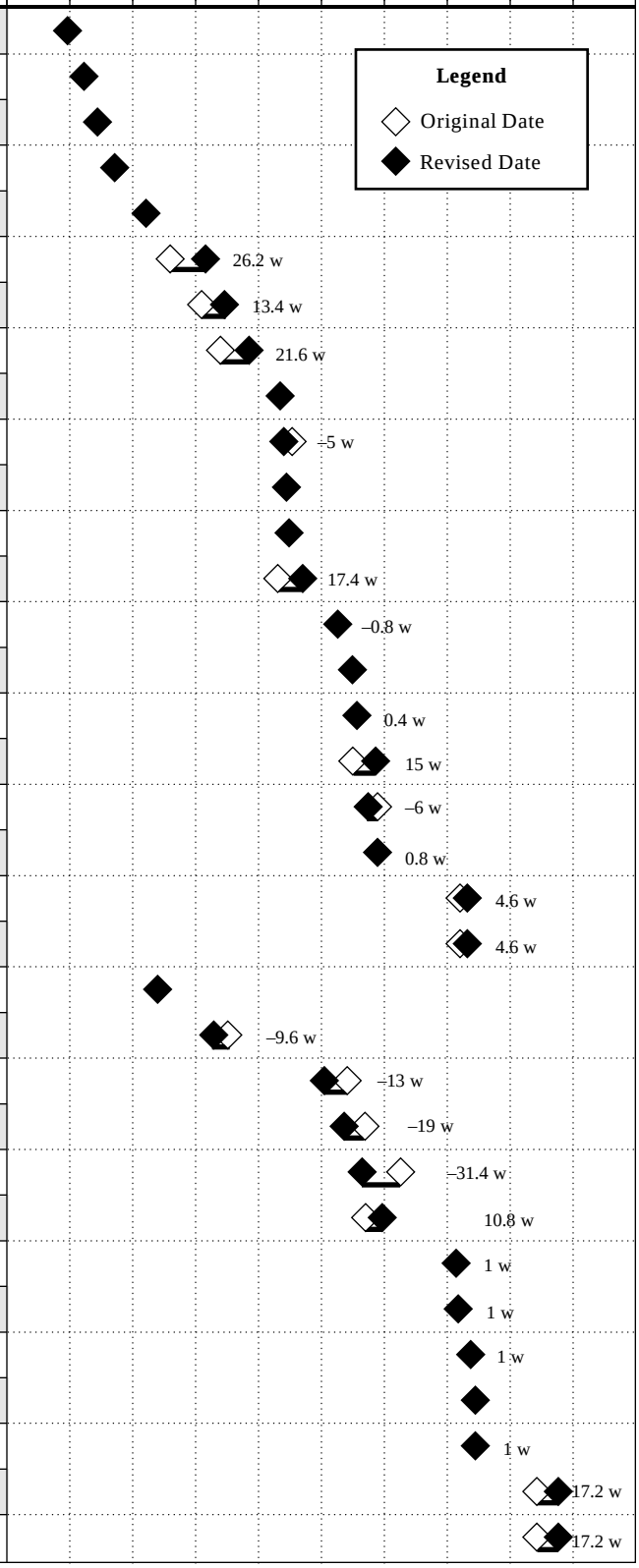
Schedule

The present schedule for the Gemini Project is shown in Table 1.

Table 1. Schedule for the Gemini Project as of December 1995

GEMINI PROJECT MAJOR MILESTONES LIST

ID	Name	Start
1	Submit CDUA - Mauna Kea	12/23/93
2	Award Primary Mirror Polishing Contract - Mauna Kea	3/14/94
3	Award Enclosure Contract - Mauna Kea	5/25/94
4	Obtain CDUP and ODSA. Start Site Construction - Mauna Kea	10/1/94
5	Award Telescope Fabrication Contract	3/15/95
6	Award Coating Plant Contract	2/15/96
7	Complete Foundations/Site - Mauna Kea	5/3/96
8	Completion of Control System Simulator	10/25/96
9	Complete Enclosure - Mauna Kea	4/18/97
10	Complete Coating Plant Site Acceptance - Mauna Kea	7/29/97
11	Deliver Telescope Structure - Mauna Kea	6/19/97
12	Complete Polishing Primary Mirror - Mauna Kea	6/30/97
13	Completion of Functional Control System	9/29/97
14	Delivery of Specification Control System	3/18/98
15	Installation of Acquisition Guiding Unit - Mauna Kea	6/17/98
16	Install Primary Mirror - Mauna Kea	7/27/98
17	Install Chopping Secondary Assembly - Mauna Kea	10/26/98
18	Final Acceptance of First Instrument - Mauna Kea	10/30/98
19	First Light - Mauna Kea	12/18/98
20	Acceptance of Control System - Mauna Kea	4/13/00
21	Handover of Operations - Mauna Kea	4/13/00
22	Complete Road Construction - Cerro Pachón	1/1/96
23	Complete Foundations/Site - Cerro Pachón	4/9/96
24	Complete Enclosure - Cerro Pachón	2/13/98
25	Deliver Telescope Structure - Cerro Pachón	5/22/98
26	Complete Polishing Primary Mirror - Cerro Pachón	8/21/98
27	Complete Coating Plant Site Acceptance - Cerro Pachón	12/16/98
28	Installation of Acquisition Guiding Unit - Cerro Pachón	1/12/00
29	Install Primary Mirror - Cerro Pachón	2/24/00
30	Install Chopping Secondary Assembly - Cerro Pachón	5/11/00
31	Final Acceptance of First Instrument - Cerro Pachón	6/7/00
32	First Light - Cerro Pachón	6/15/00
33	Acceptance of Control System - Cerro Pachón	10/11/01
34	Handover of Operations - Cerro Pachón	10/11/01



Organization

The Gemini Agreement establishes the management structure of the Gemini Project. The Gemini Board is the supervisory and regulatory body, an Executive Agency is empowered to act on behalf of the parties to arrange for construction and operations of Gemini, and a Managing Organization is responsible for day-to-day management of the Project.

The Gemini Board

Board members are appointed for two-year terms by the respective funding agencies of the partner nations. The members of the Gemini Board during 1995 were:

Board Member	**Institution**	**Country**
Dr. Alan Dressler	Carnegie Observatories	US
Dr. Robert Kirshner	Harvard University, CfA	US
Dr. James R. Houck	Cornell University	US
Dr. G. Wayne van Citters	NSF	US
Dr. Robert McLaren	University of Hawaii	UH (US)
Dr. Ian F. Corbett	PPARC	UK
Dr. Malcolm S. Longair *(Chair)*	University of Cambridge	UK
Dr. Donald C. Morton	NRC	Canada
Dr. Gordon A. H. Walker	Univ. of British Columbia	Canada
Dr. Enrique d'Étigny *(Vice Chair)*	CONICYT	Chile
Dr. João Steiner *(observer)*	University of São Paulo	Brazil
Dr. Oscar A. Campoli	SECYT	Argentina

Board members J. Houck, M. Longair, and O. Campoli were replaced in 1966 by Drs. Robert Gehrz (new Chair), Richard Ellis, and Jorge Sahade.

The Executive Agency: NSF

The Executive Agency for the Gemini Project is the National Science Foundation (NSF) of the United States. It is empowered to execute the decisions of the Gemini Board, to handle the financial contributions of the Gemini partners, and to communicate decisions of the Board to the Managing Organization.

Dr. G. Wayne van Citters, acting for NSF, is a member of the Gemini Board. Other personnel are the Executive Assistant, Dr. Susan Kayser, and the Executive Secretary, Mrs. Mary Lou Renninger. Several offices within NSF provide support to the Project.

The Managing Organization: AURA

The Association of Universities for Research in Astronomy, Inc. (AURA) was designated by the Board as the Managing Organization through the operations phase until 2000.

A Management Plan, describing AURA's responsibilities during construction and commissioning, was approved by the Board.

The senior key personnel in 1995 were:

Project Director:	Dr. C. Mattias Mountain
Project Scientist:	Dr. Fred Gillett *(acting until December 1995; then permanent)*
Project Manager:	Dr. Richard Kurz

The AURA corporate office contact is Mr. Richard Malow.

National Project Offices

Gemini can operate successfully only if the Project makes effective use of the infrastructure that already exists in the Partner countries. To facilitate this, each Partner to the Gemini Agreement has established a National Project Office. The functions of these offices are to formulate input to the Project through national Science Advisory Committees, to provide engineering support for managing instrumentation and other projects and for technical reviews, to support the user community in pre- and post-observing activities, to provide technical support beyond that available at the telescope sites, and to be responsible for instrumentation undertaken by the partner countries. The National Project Offices will also manage the national telescope time allocation.

A National Project Office typically has a Project Scientist and a Project Manager. The personnel during 1995 were:

US	Project Scientist	Dr. Todd Boroson
UK	Project Scientist	Dr. Roger Davies
	Project Manager	Dr. Adrian Russell
Canada	Project Scientist	Dr. Gordon Walker
	Project Manager	Dr. Andrew Woodsworth
Chile	Project Scientist	Dr. José Maza *(acting)*
Argentina	Project Scientist	Dr. Gustavo Carranza
Brazil	Project Scientist	Dr. Miriani Pastoriza
	Project Manager	Dr. Francisco Jablonski

Science Committee

The Gemini Science Committee (GSC) has the responsibility of making science policy recommendations to the Project Director, with an independent report to the Board. It meets twice a year.

The members of the Gemini Science Committee during 1995 were:

Dr. Fred Gillett *(Chair)*	International Gemini Project Office
Dr. Tim Davidge *(Secretary)*	Canadian Gemini Project Office
Dr. Charles Beichman	California Institute of Technology
Dr. Todd Boroson	US Gemini Project Office
Dr. Gustavo Carranza	Observatorio Astronómico
Dr. Roger Davies	University of Durham
Dr. Jay Gallagher	University of Wisconsin
Dr. Andrew Lawrence	University of Edinburgh
Dr. Simon Lilly	University of Toronto
Dr. José Maza *(acting)*	Universidad de Chile
Dr. Patrick Osmer	Ohio State University
Dr. Miriani Pastoriza	Instituto de Física, UFRGS
Dr. Max Pettini	Royal Greenwich Observatory
Dr. Stephen Strom	University of Massachusetts, Amherst
Dr. Alistair Walker	NOAO/CTIO
Dr. Gordon Walker	University of British Columbia

Finance Committee

The Gemini Finance Committee of the Gemini Board oversees the financial matters of the Gemini Project, meeting twice a year. It provides advice on keeping the budget within the constraints of cash flow and of total expenditure.

During 1995, the members of the Finance Committee were:

Mr. Michael Pawlowski *(Chair)*	NRC
Mr. Jeff Down	PPARC
Mr. Albert Muhlbauer	NSF
Mr. Aaron Asrael	NSF
Dr. G. Wayne van Citters	NSF
Dr. Donald Morton	NRC
Dr. Ian Corbett	PPARC
Dr. Guillermo Ramirez	CONICYT

1995 Accomplishments

Project Overview

The year 1995 was one of reassessment for the Gemini Project. In January the International Gemini Project Office (IGPO) undertook a major review of the project schedule. This was precipitated by a number of factors: an early winter on Mauna Kea which delayed the start of the road relocation work; continued lengthy negotiations with potential telescope contractors; and exceptionally high bids for the Mauna Kea construction work that required a descoping of the Mauna Kea support facility and a complete restructuring of the Mauna Kea construction contracts. This reassessment led, with Board approval, to the slippage of first light on Mauna Kea by five months, from July to December 1998.

In April of 1995, the IGPO began a thorough review of project costs. Though the new Mauna Kea bids were anticipated to be a factor of two lower than the previous quotations, this was still 13% higher than the original estimate. In addition, the cost of construction on Cerro Pachón increased from the original projection of November 1994. These cost increases, combined with significant restructuring of the Gemini Partners' contributions, resulted in a reduction of the project contingency to $2.2M and to a $2M-$3M cash shortage in 1998 and 1999. With $30M of outstanding subawards still to let, this would have given the project very little room in which to maneuver. Consequently, a detailed assessment was made of the costs of delivered scientific capabilities in order to determine which systems can be made available within the construction budget, given the current cash flow constraints. In addition, the Partners with outstanding commitments were asked to explore whether any of these contributions could be brought forward. Fortunately, due to substantial cash resources in 1995, no crucial decisions need to be made until the second or third quarter of 1996.

Throughout 1995 there was substantial revision of the Gemini Operations Plan as well as the development of a detailed integration, test, and commissioning plan for the Gemini telescopes. A key event in the development of the new Operations Plan was the organization of a workshop in Hawaii to discuss "New Observing Modes for the Next Century", which was attended by people from all the major observatories.

Despite these reassessments, construction on Mauna Kea has made significant progress, and completion of the foundations and telescope pier is expected five months ahead of the schedule set in early 1995. This will allow an early start on the base steel and enclosure work. Excavation work on Cerro Pachón was completed and work on the foundations and steel erection commenced in late October 1995. The telescope contract was placed with TELAS/Framatome, and a significant milestone was passed with the acceptance of the first primary mirror blank.

Coast Steel Fabricators began the test erection of the first Gemini enclosure and the first controls work package was delivered to the project, on budget and on schedule. The Critical Design Review (CDR) for the primary mirror assembly was successfully completed and followed by a successful review of the Lockheed tip/tilt and chopping mechanism for the secondary mirror. Lockheed has developed a system which exceeds Gemini's requirements and meets many of the goals using less power.

Science Requirements

Fred Gillett was appointed Gemini Project Scientist in December 1995 after a one year position as Interim Project Scientist. During 1995, the staff scientists (Doug Simons and Fred Gillett), the Project Scientists (PS) team—which includes the staff scientists and the National Project Scientists—and the Gemini Science Committee (GSC) focused on three principal activities:

- implementation and oversight of the Phase I Instrumentation Plan,
- development of the Science Operations concept, and
- scientific and technical support of project activities.

The staff scientists presented two papers at the SPIE conference *Infrared Detectors and Instrumentation for Astronomy* in April 1995 and participated in a Gemini "Town Meeting" at the AAS meeting in January 1995.

Two GSC meetings were held in 1995: 24-25 April in Tucson, AZ and 25-26 September in Hilo, HI. In addition to the GSC meetings, the PS Team met in January 1995 to participate in the enclosure redesign and project schedule discussions, at the time of the Systems Review in March, and in August to review and assess the instrumentation program and a draft Operations Plan.

Members of the USGPO, IGPO, and the Gemini Board participated in the *VIII Reunion Regional Latino Americana de Astronómia* during 27 November - 1 December in Montevideo, Uruguay.

Implementation and Oversight of the Phase I Instrumentation Plan.

The Instrumentation Program was reviewed in depth by the PS team in March and August, with their perspective providing the basis for the Instrument Science Working Group (ISWG) discussions. Several meetings of the ISWGs were held in 1995—the Optical ISWG (G. Walker, chair) in January, the InfraRed Imager SWG (F. Gillett, chair) in March and September, and the Adaptive Optics / Acquisition & Guiding SWG (D. Simons, chair) in March and August. Recommendations for changes to the scientific performance requirements were formulated by these groups for GSC consideration.

In addition, the staff scientists participated in planning for and support of the Instrumentation design reviews held in 1995, including the Conceptual Design Review (CoDR) for the Adaptive Optics system, the Near IR Imager and the Multi-Object Spectrometers, and the Cassegrain Assembly CDR.

Development of the Science Operations Concept.

An Operations SWG (Todd Boroson, chair) was formed in 1995 to assist in the definition, development, and assessment of Science Operations for the Gemini telescopes. The first meeting of this SWG was held in March 1995. In early July, the USGP, Gemini (IGPO), the Joint Astronomy Center (JAC), European Southern Observatory (ESO), and the University of Hawaii (UH) at Hilo, jointly sponsored a workshop on alternative modes of observing, with about 85 people from nine countries attending. The proceedings will be published as a volume in the conference series of the Astronomical Society of the Pacific. One output of these

activities was a Science Operations plan prepared by Todd Boroson, reviewed and revised by the Operations SWG and the PS team and considered by the GSC at the September meeting. The GSC recommended that this plan be adopted as the basis for further planning for science operations, and several resolutions concerning the principles of science operations were approved by the Board in November.

Doug Simons worked with the other Mauna Kea Observatories and UH to develop an environmental monitoring capability for Mauna Kea. Meetings were held in March and September 1995, with another planned for 1996.

A draft Integration and Commissioning Science Support Plan was also developed in 1995.

Scientific/Technical Support of Project Activities.

The staff scientists participated in all project design reviews and the PS Team participated in many of the 1995 design reviews, including the coating/cleaning system Preliminary Design Review (PDR), the coating plant CDR, System Review #2, the primary mirror (M1) Cell 80% design review, M1 Cell Assembly CDR, M2 (the secondary mirror) assembly PDR, and the Cassegrain Area CDR. Project Scientist reports on the coating/cleaning PDR, enclosure redesign, and System Review #2 are available. The staff scientists also participated in the M1 surface heating prototyping activity and provided oversight for the protected silver coating development program and the Excimer laser cleaning program.

System Review #2 was held in March 1995. This review emphasized the primary mirror assembly and related systems. The preliminary integration and test plans were also presented. The Review was supported by the Controls Group through higher fidelity simulation and modeling as well as updated performance predictions for image quality, image smear, and pointing. A total of 31 specific actions and recommendations resulted, along with a report covering general concerns.

Construction

Telescope Structure.

Contract negotiations were concluded and a contract signed with GIE TELAS / Framatome S.A. on 28 March 1995 for the fabrication, preassembly and shipping of the telescope structures and azimuth tracks. An introductory meeting was held 17-21 April 1995 in Lyon, and a design review held 31 July- 4 August. Following the review, AURA granted approval to TELAS to order materials for the fabrication of the telescopes.

The contract for the design and fabrication of the main telescope hydrostatic bearing system was awarded to SKF USA Inc. in November 1995. SKF will ship the “Telescope Test Components” for the Cerro Pachón Telescope Bearing System to France by 1 September 1996 for preassembly testing (AURA will be responsible for subsequent shipping to Cerro Pachón) and the remainder of the system to Chile by 1 April 1998. The Mauna Kea system will be shipped to Hilo by 1 April 1997.

M3 Engineering completed the design of the Primary Mirror Cell Cart that will be used during recoating of the primary mirror.

The design of the primary mirror covers, which is being performed within the telescope group, was all but completed.

The friction driven encoder test program was completed.

Enclosure.

Coast Steel Fabricators (CSF) made significant progress on the design and fabrication of the enclosures. They submitted to AURA for approval 68% of the enclosure fabrication submittals. One-third of the Mauna Kea and Cerro Pachón enclosures were fabricated, including the ring beams, arch girders, bogies, shell ribs, inner and outer skirts, tie beams and ventilation gate columns.

Preassembly of the first enclosure began, and the Mauna Kea ring beam was assembled on CSF premises.

CSF placed a subcontract with Shaflik for the design and fabrication of the enclosure control system. An introductory meeting was held on 25 May and a 65% design review on 18 October 1995.

Mauna Kea Site.

The road construction contractor (San Juan) was forced to leave the summit in November 1994 after an early snow fall, but returned to the site at the end of January 1995. Despite many days of high winds (exceeding 80 mph) and icing conditions, the road construction was completed in April 1995.

Keahou Kona Resort Company (KKRC) demolished the 24 inch telescope dome that resided on the Gemini site, in April 1995. Following this, they started the relocation of the utilities (power, communication) that crossed the Gemini site. HELCO and Hawaii Tel were responsible for pulling the new power cables and communication lines respectively through the new utility conduits and the mountain was switched over to the new services by 11 August.

After receiving the high cost proposals for construction of the Mauna Kea Support Facility and Enclosure Base in November 1994, the project and M3 Engineering redesigned the Mauna Kea Facility to minimize expensive construction features, without significantly impacting the scientific capability. The size of the Support Facility was reduced (with allowance for expansion later) and construction on the west side of the site that required large retaining walls was minimized. To reduce costs by increasing competition, the construction documents were divided into three main bid packages: (a) the grading, foundations, and telescope pier construction; (b) steel fabrication and erection; and (c) completion of the buildings, including the architectural mechanical and electrical finishing. The first bid package (a) was completed and released as an IFB (Invitation for Bid) on 23 January 1995. San Juan offered the lowest bid and was awarded the contract. Due to San Juan's experience in the winter of 94/95 on the road construction, they decided to start the construction early, mobilized in late May 1995, and completed the construction by December 1995, five months ahead of schedule.

M3 Engineering completed the Mauna Kea steel construction documents for the new facility in February 1995. This work was awarded to CSF, the contractor responsible for constructing the enclosures. This has allowed the project to maintain an aggressive construction schedule on Mauna Kea.

M3 Engineering completed the Mauna Kea Support Facility and Enclosure Base design, and an IFB for the construction was released on 8 August 1995. Bids are presently under consideration.

A consultant, Aqua Waste, was used to prepare Individual Waste Water Design reports to submit to the Hawaiian State Department of Health for approval of Gemini's waste water system design.

Cerro Pachón Site.

M3 Engineering completed the construction documents for the Cerro Pachón Site Work and Support Facility. In a similar manner to the preparation of the Mauna Kea design documents, three sets of documents were prepared. IFBs for (a) the foundation and telescope pier, and (b) the site steel work, were released in February 1995. Work to be performed on the site (foundation work and steel erection) was bid in Chile only, but the steel fabrication was bid in all three of the Gemini South American partners.

While the foundations and steel work were being bid and the process was underway for awarding the construction contract, CTIO completed the excavation of the Support Facility, Enclosure Base, and Telescope pier. On October 18, 1995, the contract for the foundations, telescope pier, and steel work was awarded to Con-Pax, and site work was started on October 23. Road improvements necessary for transporting 10-meter loads to Cerro Pachón were completed.

Relocation of the 20-unit dormitory to Cerro Pachón was completed.

Coating Plant.

Royal Observatories (RO) finished the sputtering test programs that were performed in the William Herschel Telescope 4-m coating plant on La Palma. These tests were performed to provide information necessary to specify the aluminum coating process parameters and to develop the sputtering hardware design.

The Coating Plant CDR was held in Tucson 27-28 April 1995.

The procurement of the Coating Plant is being divided into three main contracts: (a) coating vessel, (b) pumping system, and (c) sputtering head, mirror support, and rotation system. Items (a) and (b) will be released for international bid. RO will perform the detailed design of item (c), procure the elements of the system, and perform the assembly and testing of the completed system.

RO released the bid package for the Coating Chamber Vessel on 8 September.

Protected Silver Coating.

The work to develop a protected silver coating for the primary mirror, under contract to Optical Data Associates (ODA) for an 18-month program, was completed.

Two coatings were investigated. The first was a silicon-nitride-protected silver coating developed by AIRCO under subcontract to ODA. The second was a hafnia-protected silver coating developed by Deposition Sciences Incorporated, again under subcontract to ODA. The coatings were optimized to meet the Gemini Science Requirements and the results indicated that either coating degrades the bare silver emissivity only by about 0.1%.

Both coatings so far were deposited with net emissivities approaching 0.9%. The coatings were characterized and tested for adhesion, abrasion, and durability. The coating removal procedures were verified to ensure the substrate was not damaged during the coating removal process.

In-Situ Mirror Cleaning.

STI Optronics is undertaking tests to investigate the performance of Excimer lasers for cleaning the protected silver coatings developed by ODA's subcontractors.

Optics

Primary Mirror Blanks.

Corning completed the first primary mirror blank on 17 October 1995, ahead of schedule. This mirror blank is of excellent quality, meeting or exceeding all specifications. All the glass for the second primary mirror was produced. As in the first blank, the glass for the second blank meets all specifications by a considerable margin. The boules of glass were generated, fused into two-boule stacks, and machined into hexagonal segments. The second mirror blank will be fused into a monolith in January 1996.

Primary Mirror Polishing.

REOSC fabricated the shipping container for the primary mirror blanks and transported the first blank to France, arriving 16 December 1995. They also completed modifications to their lifting fixture to handle the Gemini mirrors.

Primary Mirror Lifting Fixture.

The detailed design drawings of the Gemini M1 lifting fixture were completed.

Primary Mirror Cell Assembly.

The CDR for the primary mirror cell assembly was held in September. This was later than originally planned—the change in schedule allowed development of a test facility at Royal Greenwich Observatory (RGO) to test the performance of the prototype mirror support units as a system. In the original schedule, much of this work would have been done after the CDR. The current approach allowed questions raised at the PDR to be answered by actual test results rather than by predictions and estimates. Selection of the contractor for fabrication of the cell structure slipped by several months and will be completed in 1996.

Baffle Design.

A detailed stray-light analysis of the telescope was performed by Breault Research. This analysis included the primary and secondary baffles, using the versatile design chosen at the baffle Conceptual Design Review. The enclosure dome, telescope structure, and instrumentation areas were also included in the modeling. The results of the analysis show that the stray light performance of the telescopes will be satisfactory.

Secondary Mirror.

Selection of the contractor for fabrication and polishing of the secondary mirrors was delayed. Extended negotiations with bidders were required, partly because of the developmental nature of the work, but primarily because of the need to negotiate reductions in the bid prices to meet the Gemini budget. The vendor will be selected in early 1996.

Secondary Mirror Assembly.

The contract for design and fabrication of the M2 Tilt Systems was awarded to Lockheed Martin in May 1995. The PDR for the secondary mirror assembly was held in October 1995. This PDR covered the Lockheed Martin design of the tilt system as well as the designs of the M2 positioning system and deployable baffle, which were done by Gemini project staff.

Instrumentation

Cassegrain Rotator and Instrument Support Structure.

The detailed design, analysis and fabrication feasibility of the Instrument Support Structure, detailed design of the Cassegrain Cable Wrap and associated M1 cell interfaces, and detailed design of the Cassegrain Rotator including mechanical design, electrical design and control system analysis, were all performed this year. The CDR was held on 20 October 1995, and the Instrumentation Group is addressing the issues raised at the CDR prior to the preparation of the hardware procurement documentation.

Acquisition and Guiding (A&G).

Following the A&G PDR, considerable effort was put into determining the most cost-effective approach to producing the A&G systems. This resulted in a reduction in scope of the A&G work to include only the optical, mechanical, and controls aspects of the A&G system. (Wavefront Sensing, Calibration, etc. were separated off into discrete Work Packages.) In the newly defined A&G Work Package, the fabrication will be performed as a commercial contract, which will be managed by RGO. This approach has allowed minimization of the impact on the instrumentation budget while maintaining the required functionality and performance of the A&G systems.

Adaptive Optics (AO).

The Conceptual Design Review was held in mid-March and resulted in a recommendation from the review committee that the project develop an AO system comprised of a Shack-Hartmann wavefront sensor in con-

junction with a stacked actuator deformable mirror. DAO has performed a number of cost / functionality / performance tradeoffs in an effort to get the estimated AO system price within the current budget.

Near InfraRed Imager (NIRI).

The Conceptual Design Review was held in March, and the work to date has produced a design with good performance that meets all the science requirements. Work is continuing on the next part of the design phase with a cost and schedule to completion that was agreed with the University of Hawaii.

Near InfraRed Spectrograph (NIRS).

The selection committee for the Near IR Spectrograph met in January 1995, and after careful deliberation chose the NOAO proposal as providing the design most likely to meet the Gemini requirements within the available budget. At the request of NOAO, the start of the Work Package was delayed. The Work Scope was agreed and signed allowing work to commence in October.

Gemini Multi-Object Spectrograph (GMOS).

A Phase 1 Work Scope to cover the Conceptual Design phase was agreed in April. Work on the Conceptual Design was already in progress, and the Conceptual Design Review (CoDR) was held in June. The Work Package team produced a cost and plan to completion which incorporates the CoDR recommendations. The detailed design phase of the activity has commenced.

High Resolution Optical Spectrograph (HROS).

Approval was given to commit to the conceptual design of HROS. The Conceptual Design phase commenced on October 1 and will continue until October 1996. The majority of the conceptual design work is being performed by University College London in conjunction with the Royal Observatories of Edinburgh (ROE), who are acting as engineering consultant.

IR Arrays and Controllers.

Following the selection of NOAO to build the Near IR Spectrograph, the requirements for the IR Arrays and IR Array Controllers were developed by IGPO in conjunction with NOAO and University of Hawaii. The Aladdin array currently under development at the Santa Barbara Research Center was chosen as the baseline Near IR Array and the NOAO controller was chosen as the standard Gemini Near IR Array Controller.

CCD Controllers.

The project undertook a review of the ArCon controller in conjunction with the Chilean Project Office and external reviewers during September. The review panel concluded that although the ArCon system was well built and performed to CTIO's current requirements, it fell short of meeting the Gemini requirements in areas of performance and cost. A recommendation was made that the IGPO investigate alternatives to ArCon.

Systems Engineering

Top Down Interface Organization.

The Gemini system interfaces were reorganized from the top down. A systems engineering graphical representation named an "N^2 diagram" was used to accomplish this. This provides a graphical overview of all system interfaces by defining the subsystems based upon subcontract and work package boundaries. A database was set up to represent this chart and allow for ease in tracking the status of the various interface control documents (ICD) as they are produced, put under control, and modified. Systems engineering maintains the N^2 chart and the ICD database in addition to the project documentation and drawing databases. From this process (and after several major revisions), 284 interfaces were identified. Approximately 70 are under formal control and about 150 are in process. This is not as far along as it should be at this time. To remedy this, priorities were set on formalizing interfaces for major subcontracts currently under way and for interfaces that cross Gemini group boundaries. IGPO is also considering ways to provide more manpower in this area.

Integration and Test Planning.

A preliminary integration and test plan was generated, in the form of an integration flow chart and an integration schedule. Each of the group schedules and the overall integration schedule are reconciled and reviewed monthly. The ICD process and the integration and test plans (in preliminary form) were reviewed and endorsed by the system review committee, the oversight committee, the project scientist team, the GSC, and the Board.

Operations Ramp-up Planning.

From the integration schedule, the resources were identified (working with all groups and the project scientist team) that are required to support this effort. This served as the basis for the manpower ramp-up for the operations plan presented to the Board in November. The operations ramp-up plan was also endorsed by the project scientists and by the GSC.

Electronic System Engineering.

The electronic system engineering position, approved at the end of last year, was filled in the spring. There has been significant progress in the effort to organize electronic and services interfaces and in defining and designing the system cables and breakouts, as well as in several subsystem design efforts, such as the M1 Cell cabling and services and the secondary positioning system control design.

Documentation Log.

A document log database, similar to the new drawing log database, was completed to ease assignment of control numbers and tracking of documents.

Work Package Definition.

Participation in key work package definitions and negotiations is necessary to ensure that interface concerns are addressed. The IGPO participated in the A&G work package reorganization and negotiations and the Adaptive Optics work package discussions.

f/16 Optical Error Budget.

Work to extend the nominal error budget for specific cases of usage with the A&G system was initiated and completed. This work defined the differences between guiding with on-instrument wavefront sensors or peripheral wavefront sensors, allowing more reasonable tolerances to be placed on the A&G system by comparison to the performance with the best possible atmospheric effects while guiding at substantial off-axis distances. This process involved iteration and agreement from a wide variety of people including the project scientist team, the A&G project scientist, and various other project personnel.

Performance Estimates.

Performance estimates were updated, including atmospheric effects, for presentation at a systems review. The analysis also included bounding the uncertainties (error bars). The worst case was slightly worse than the requirements, but it was considered reasonable by the system review committee and the project scientists. For nominal conditions, all of the top-level image-quality requirements are met.

Reviews and Meetings.

Systems Engineering continued to participate in most detailed reviews, usually as a reviewer. The new electronic system engineer has also participated in a number of reviews (both as a presenter to help a particular group, and as a reviewer in other cases).

Weekly meetings are held with various groups, scientific staff, and partner-country project managers (by conference call) for discussion of any systems concerns. These meetings are held regularly to address specific interface / performance concerns, other system concerns, and to ensure frequent communications between various parts of the project.

Software and Controls

Most of the software and control systems underwent review in 1995— PDRs, CDRs, or System Design Reviews—all successfully. The systems are listed in Table 2.

Table 2. Software and Control Systems

System	Purpose
Standard Control	Standard hardware and software system, which is the building block for all Gemini real-time control systems.
Observatory Control	Includes the queue observing system and command sequencer and provides the user interface.
Core Science Instrument	Standard hardware and software system (based on the standard control system), which provides the infrastructure needed to control a science instrument and a detector.
Primary Control	Includes all of the subsystems involved in support and thermal control of the primary.
Telescope Control	Sequences the subsystems needed to maintain the telescope system's pointing and image quality.
Mount Control	Controls the altitude and azimuth drives, brakes, and cable wraps.
Data Handling	Handles the display, storage, archiving, and transport of data.
Secondary Control	Handles the articulation of the secondary to remove tip, tilt, and focus errors in the wavefront and to implement chopping.
Telescope Encoders	Provide the encoding systems for altitude and azimuth axes. An encoder option was selected in December 1995.
Enclosure Control	Controls the mechanisms on the movable part of the enclosure as well as critical systems within the support building.
Interlock Safety	Prevents injury to personnel and damage to equipment through removing power and setting brakes on critical systems.

The **Hydraulic Bearing System**, which controls the Hydraulic Bearing systems for the azimuth and altitude axes, was defined to aid the Telescope Group in the preparation of the RFP for the hydraulic bearing hardware.

The **ControlSystem Simulator**, which provides a subset of the control systems that will be interconnected at the telescope sites, was designed and the hardware was purchased during 1995. This system was recommended by the Software Critical Design Review Committee as a means of reducing the risk of integrating the software packages.

The **Visual User Interface**, which is a prototype of the user interface and reflects the philosophy of observer interaction with the Gemini Control System, was defined, fabricated, and received favorable comments from a number of committees, including the Operations Science Working Group and the Gemini Science Committee. This constituted the delivery of the first operational element of the Control System Simulator #1.

Telescope Simulation continues to be a major focus of the Controls Group. As the selection of control systems vendors approaches, and difficult design choices are needed, this effort is being supported by simulation.

The **Communications System**, which provides the communication and network infrastructure needed at the two sites, was the center of discussions with the Chileans as a potential Chilean work package. Chile is at the leading edge of a number of communication architectures and has systems installed which could be used as test beds in the years leading up to the installation of similar equipment on Mauna Kea.

World Wide Web

The Gemini WWW page has been greatly expanded. This provides information on the project in general, and presents many photographs showing progress in each of the areas. A particularly informative feature is the digital image which is automatically updated every 15 minutes from a camera monitoring construction on Mauna Kea. The URL of the page is http://www.gemini.edu/.

Contracts

The contracts listed below are described in more detail in the previous section.

Major contracts in 1995

- To TELAS/Framatome for the telescope and azimuth track assemblies.
- To Lockheed for the secondary mirror tip/tilt systems.
- To San Juan Construction. for the foundation and telescope pier on Mauna Kea.
- To Coast Steel for the enclosure base and support facility on Mauna Kea, and the enclosure base ring girder for Cerro Pachón.
- To Con-Pax for the foundation construction and steel work on Cerro Pachón.
- To SKF for the telescope hydrostatic bearing systems.
- Work Scope to NOAO for the Near InfraRed Spectrograph.

Contracts between $250,000 and $1,000,000 in 1995.

- To Corning for acid etching of the primary mirrors.
- Four Work Scopes to the UK for the Mount Control System, Telescope Control System, Secondary Control System, and Acquisition and Guiding, Phase 2.
- Work Scope to Canada for the data handling system.

Planned Contracts in 1996

The contract for the secondary mirror blanks has been under negotiation for much of 1995 and will be carried over into the next year. Table 3 is a list of all other contracts expected to be let in 1996.

Table 3. 1996 Contract Schedule

Contract Item	Source Contractor	Type	Planned Contract Approval Date
Secondary Mirrors	Int'l	Bid	2/96
Telescope Encoders	Int'l	Bid	3/96
Near Infrared Imager - Phase 2	US	Bid	4/96
M1 Cell Structure	Int'l	Bid	4/96
General Contracting - MK	Int'l	Bid	4/96
High Resol. Optical Spectrograph - Phase I	UK	WP	4/96
Wavefront Sensors	UK/Canada	WP	4/96
GMOS - Phase 2	UK/Canada	WP	4/96
IR Arrays & Controller	US	WP	5/96
Primary Mirror Cart	Int'l	Bid	6/96
Primary Mirror Covers	Int'l	Bid	6/96
Rotator and Instrument Mounting	Int'l	Bid	6/96
M1 Ancillary Equipment	Int'l	Bid	7/96
General Contracting - CP	Chile	Bid	7/96
Cable Wraps	Int'l	Bid	7/96
Adaptive Optics - Phase 2	Canada	WP	9/96
CCD Program	US	WP	9/96
Coating Stripping Equipment	Int'l	Bid	9/96
Telescope Components	Int'l	Bid	9/96
Communications	Chile	WP	12/96
Total estimated 1996 Contracts — $25,854.886			

In Table 3, "Int'l" indicates an internationally selected contractor, and WP is a Work Package which is part of a Partner's share of Gemini work.

Financial Status

The following Tables 4-6 show the actual and projected contributions from the partners from 1991 to 2001, the annual and projected expenditures during this period, the actual and budgeted expenditure breakdown for 1995, and the 1996 proposed budget as of 31 December 1995. These figures include the $8 M authorized by the Board for planning purposes, at the November 1995 meeting.

Contributions and outlays

The actual contributions from each nation through 1995, and the projected contributions thereafter, are shown in Table 4a. The bottom line gives the total cumulative contributions. For the United Kingdom, all contributions include work credits.

Table 4. Project Funding and Expenditure Tables

a) Calendar Year Annual Contributions (US $000)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
United States	3,815	12,063	14,000	17,120	41,002	0	0	0	0	0	0	88,000
United Kingdom	0	0	3,638	6,622	2,761	3,191	7,092	7,118	5,985	6,313	1,280	44,000
Canada	0	0	6,813	2,722	2,870	2,495	5,200	5,200	1,100	0	0	26,400
Chile	0	0	0	0	0	2,200	1,320	1,320	1,320	1,320	1,320	8,800
Brazil	0	0	0	550	550	550	2,750	0	0	0	0	4,400
Argentina	0	0	0	400	0	1,142	571	571	571	571	574	4,400
Additional Funds [1]	0	0	0	0	0	0	3,055	4,415	530	0	0	8,000
Total Ann. Contrib.	3,815	12,063	24,451	27,414	47,183	9,578	19,988	18,624	9,506	8,204	3,174	184,000
Cumulative Funding	**3,815**	**15,878**	**40,329**	**67,743**	**114,926**	**124,504**	**144,492**	**163,116**	**172,622**	**180,826**	**184,000**	**184,000**

Note[1] Additional funding of $8.0M approved for planning purposes, to be divided proportionally among all partners, on a schedule to be agreed upon in 11/96.

b) Calendar Year Expenditures (cumulative in US $000)

Spending Profile	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	TOTAL
Cash	2,156	7,243	15,290	30,074	55,410	99,916	125,095	141,074	147,820	153,301	155,897	155,897
UK Credits			138	955	2,620	5,810	10,858	16,078	17,951	18,531	18,729	18,729
Funds Carried Fwd	1,659	8,635	24,901	36,715	56,895	19,308	8,968	6,294	6,851	8,994	9,374	9,374
Cumulative Funding	**3,815**	**15,878**	**40,329**	**67,743**	**114,924**	**125,034**	**144,922**	**163,446**	**172,622**	**180,826**	**184,000**	**184,000**

The “spend” profile, including work credits for the UK, is shown in Table 4b. The entries for 1991-1995 are actual expenditures; the remainder are projections. The last line in Table 4b is repeated from Table 4a—the cumulative total funding. The projected spend profile (“Cash” plus “UK Credits”) does not include the major portion of the additional $8 M that the Project has not yet allocated to the budget. The difference between the total funding and the spend profile is the cash-in-hand, shown in the penultimate line; the unallocated portion of the $8 M is included here. Note that the cash-in-hand falls below $8 M in 1998 and 1999, indicating a potential cash flow shortfall in those years without the $8 M.

1995 Expenditures

Table 5 shows the cumulative actual expenses through 1994, the budgeted and actual expenditures for 1995, and the difference between the budgeted and actual expenditures.

The $8.3 M underspend carries over into 1996. Of this, $7.6 M in delayed subcontract / work package payments is due to slower than anticipated receipt of invoices for subcontracts currently underway and to delays in awarding new contracts. The $167 K for labor is primarily due to the unavailability of some NOAO personnel to work on Gemini in 1995. Underspending on equipment, supplies and materials is due to deferred acquisition of computer equipment for control systems. The actual overhead cost reflects the underspend in other areas.

The financial data shown in Table 5 have been examined by AURA’s auditors (Coopers & Lybrand LLP) through 30 September, 1995. AURA’s fiscal year coincides with that of the US; the next audit will cover 1 October 1995 - 30 September 1996.

Table 5. Actual and Budgeted Expenditures for 1995 and Prior Years (US $000)

	Prior Years 1991 - 1994	CY 1995 Expenditures		
		Budgeted	Actual	Difference
Subcontracts / Work Packages	15,731	28,141	20,513	7,628
Work Packages (for UK Credit)	838	1,577	1,577	0
Direct Labor [1]	8,973	3,179	3,012	167
Supplies and Material	703	385	335	50
Travel [1]	1,027	475	439	36
Purchased Services	1,238	640	613	27
Equipment	957	316	132	184
Overhead	1,564	533	388	145
Managers Reserve	0	16	0	16
Contingency	0	9	0	9
Revenue	(2)	0	(8)	8
Grand Total	**31,029**	**35,271**	**27,001**	**8,270**

[1] *Includes UK contribution credits of $205.1K for direct labor and $15.1K for travel.*

Proposed Budget for 1996

A summary of the 1996 proposed budget is shown in Table 6. These figures include the $8.3 M carryover from 1995. The column labeled "New Commitments" shows the part of the cash-plus-credit expenditure that represents commitments to be started in 1996.

Table 6. Summary of Calendar Year 1996 Proposed Budget (US $000)

Expense Category	Cash Expenditures	New Commitments	Contribution Credit
Subcontracts / Work Packages	36,853	21,162	0
Work Packages (for UK Credit)	1,208	4,693	3,138
Direct Labor	3,252	3,304	53
Supplies and Material	583	583	0
Travel	514	514	0
Purchased Services	564	564	0
Equipment	785	785	0
Overhead	748	748	0
Pending Allocations & Contingency	785	785	0
Grand Total	**45,292**	**33,138**	**3,191**

Calendar of Events for the Gemini Board

According to the International Agreement and the Rules for Procedure, the annual calendar of activities for the Gemini Board is as follows:

March In early March, the official date and venue of the May meeting is communicated to Board members by the Executive Secretary.

April Before mid-April, meetings should take place of the Finance Committee, the Science Committee and the Management Committee.

May In first week of May, papers for the May meeting and a draft Agenda are sent to Board members.

At least one week before the Board Meeting, attendance at the meeting is confirmed by Board members or their alternates.

The Board Meeting takes place in the 3rd or 4th week of May. The following items must be undertaken at the May meeting:

Accept the auditors' report.

Take formal note of the projected financial status of the previous calendar year.

The Executive Agency provides an annual report of payments and accepted Work Packages credited to the Parties' contributions, sums transferred to the Managing Organization, and contributions received but not yet provided to the Managing Organization.

Review of the Managing Organization.

June In mid-June, the minutes and actions and decision list of the May meeting are sent to Board members. (Note: a draft set of decisions should be recorded at the May meeting as a basis for action by the Board, the Executive Agency, the Managing Organization and the Project).

September In early September, the official date and venue of the November meeting is communicated to Board members by the Executive Secretary.

October Before mid-October, meetings should take place of the Finance Committee, the Science Committee, and the Management Committee.

November In first week of November, papers for the November meeting and a draft Agenda are sent to Board members.

At least one week before the Board Meeting, attendance at the meeting is confirmed by Board members or their alternates.

The Board Meeting takes place in the 2nd or 3rd week of November. (Note: the budget for the following year has to be approved by 30 November of each year.) The following items must be undertaken at the November meeting:

Approve the budget and work program for the following year.

Note the long-range plans for the completion of the construction and commissioning phase of the project.

Note the likely projected financial status at the end of the current calendar year.

December In mid-December, the minutes and action and decision list of the November meeting are sent to Board members. (Note: a draft set of decisions should be recorded at the December meeting as a basis for action by the Board, the Executive Agency, the Managing Organization and the Project).

The Chairman and Executive Secretary write the Annual Report, which is sent to all parties involved in the project. The report describes progress, expenditure, long-range plans, usage of manpower and schedules for the project.

Note: There is one important variant in this proposal as compared with the Gemini Agreement. According to the Agreement, the proposed budget for the following year is only to be made available to the Board by the 31 October of each year. This would not allow enough time for the Finance Committee to iterate with the Project and agree upon a set of recommendations to the Board in time for inclusion in the papers which have to be sent out in the first week of November. The Board, therefore, requests the Project to bring forward the date of submission of the proposed budget for the following year to 30 September, thus allowing iteration with the Finance Committee and allowing the papers to be included among those to be circulated during the first week of November.

List of Publications in 1995

Doc_No	Author	Date	Title
CON-RGO-G0030	Mack	04/01/95	Technical report on the evaluation of the use of magnetron sputtering in a large vacuum environment
CON-NOR-G0034	NORCO Consulting	01/31/95	A Review of Acoustical Noise Emission Systems
CON-ARA-G0035	A.R.Astudillo	02/07/95	Cerro Pachón Technical Specifications for Sub-Station and Tension Lines (in Spanish)
CON-RGO-G0036	Mack	04/01/95	Technical Report on the Design of the M1 Mirror Coating Plant
CON-BRO-G0039	Breault	03/17/95	Preliminary Optical Design and Stray Light Analysis of Gemini Camera
CON-BRO-G0040	Schweyen	08/30/95	Stray Light Analysis of the Gemini Telescope
ICD-G0012	McGonegal	06/28/95	Fast Tip-Tilt Loop Latency Document
PG-A-G0007	Krohn	04/12/95	Gemini Contract Procedures
REV-O-G0028		01/19/95	Background Information for the M1 80% Design Review
REV-S-G0029		01/20/95	Background Material for System Review #2
REV-O-G0031	Optics Group	02/02/95	M1 Cell Assembly 80% Design Review Presentation Materials
REV-C-G0032	Maclean, John	01/19/95	Primary Control System - System Design Review Documents
REV-S-G0033	Oschmann	02/27/95	Update to the Reviewer's Comment Sheets - Gemini Systems Review #1
REV-S-G0034	Oschmann	03/06/95	System Review #2 Presentation Materials
REV-C-G0036	McGonegal	03/10/95	Mount Control System Design Review Report
REV-I-G0037	Robertson	03/15/95	Near IR Imager Conceptual Design Review Material
REV-S-G0039	Kurz	03/17/95	System Review #2 Results
REV-S-G0040		03/18/95	System Review #2 Committee Report
REV-I-G0041	Ellerbroek	04/14/95	Committee Report for the Adaptive Optics Conceptual Design Review
REV-C-G0042	McGonegal	05/23/95	Gemini Interlock System Design Review Report
REV-C-G0043	McGonegal	06/12/95	Observatory Control System Design Review Document
REV-C-G0044	McGonegal	06/13/95	Standard Controller Acceptance Testing System Design Review Documents
REV-I-G0045		06/06/95	GMOS Critical Design Review (2 vols)
REV-I-G0048	Craig, S	08/04/95	A&G Phase 2 Interim Review Material
REV-O-G0049	Stepp	08/29/95	M1 Assembly CDR Material (2 vols)
REV-I-G0051	Wieland	10/06/95	Cassegrain Area CDR Documentation

List of Publications in 1995 (Continued)

Doc_No	Author	Date	Title
REV-C-G0053	Wampler	11/30/95	The OCS PDR Review Report
REV-C-G0054	Wampler	11/30/95	The TCS SDR Review Report
RPT-I-G0058	Simons	04/01/95	Gemini Telescopes' Instrumentation
RPT-PS-G0061	Mountain	10/27/95	New Observing Modes Workshop for the Next Century - A Summary
SPE-C-G0053	Wilkes, John	01/19/95	Mount Control System - Package Requirements Specification
SPE-TE-G0055	Raybould	06/12/95	Primary Mirror Cell Cart Design Requirements Specification
TN-PS-G0024	Simons	03/01/95	Availability of Digital Sky Surveys for Gemini
TN-PS-G0029	Simons	07/01/95	The Use of the Hipparcos Catalog as Gemini's Pointing Basis
TN-PS-G0030	Simons	07/31/95	Longitudinally Averaged R-Band Field Star Counts Across the Entire Sky
TN-PS-G0031	Gillett, F	08/01/95	Near-IR Wavefront Sensing
TN-PS-G0032	Simons	09/01/95	Remote Sensing of Atmospheric Emissivity over Mauna Kea Using Satellite Imagery
TN-PS-G0033	Simons	10/11/95	Availability of Infrared Guide Stars in Dark Clouds

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