

LUNAR AND PLANETARY INSTITUTE

Semi-Annual Status Report

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1 January 1984 - 30 June 1984



UNIVERSITIES SPACE RESEARCH ASSOCIATION

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Respectfully submitted,

*Oct 25 1984*

Date

*Kevin Burke*

Kevin Burke, Director  
Lunar and Planetary Institute

*Nov 4, 1984*

Date

*Paul J. Coleman, Jr.*

Paul J. Coleman, Jr., President  
Universities Space Research Association

## TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	i
ACTIVITIES AT THE LUNAR AND PLANETARY INSTITUTE FOR PERIOD 1 JANUARY 1984 - 30 JUNE 1984	1
A. PLANETARY IMAGE CENTER (PIC)	1
B. LIBRARY/INFORMATION CENTER (L/IC)	2
C. COMPUTER CENTER	3
D. PRODUCTION SERVICES	4
E. SCIENTIFIC STAFF	5
F. VISITOR PROGRAM	6
G. SCIENTIFIC PROJECTS, CONFERENCES, WORKSHOPS AND SEMINARS	7
H. PUBLICATIONS AND COMMUNICATIONS	11
I. PANELS, TEAMS, COMMITTEES, AND WORKING GROUPS	13
J. NASA-AMES VERTICAL GUN RANGE (AVGR)	14
K. LUNAR AND PLANETARY SCIENCE COUNCIL	14
ANTICIPATED EFFORT DURING NEXT REPORT PERIOD (7/1/84 - 12/31/84)	16
APPENDIX I	
PART A: SCIENTIFIC STAFF AND LONG-TERM VISITOR APPOINTMENTS AND PUBLICATIONS	
PART B: VISITOR ROSTER	
PART C: STAFF AND VISITOR OFF-SITE SCIENTIFIC ACTIVITIES	
APPENDIX II	PROJECTS, CONFERENCES, WORKSHOPS, SEMINARS
APPENDIX III	OTHER MEETINGS AND ACTIVITIES HELD AT LPI
APPENDIX IV	LPI CONTRIBUTIONS AND TECHNICAL REPORTS
APPENDIX V	NASA-AMES VERTICAL GUN STATUS REPORT
APPENDIX VI	COMPUTING CENTER FOR PLANETARY DATA ANALYSIS (C <sup>2</sup> PDA) NEWSLETTER
APPENDIX VII	NASA'S SESAC REPORT ON R&A IN SPACE AND EARTH SCIENCES

## INTRODUCTION

This report covers the scientific and administrative activities at the Lunar and Planetary Institute during the period 1 January 1984 through 30 June 1984.

During the period 1 January 1984 through 30 June 1984 the Institute was under the direction of Dr. Kevin Burke, Director.

This report has been prepared and submitted by the Staff of the Office of the Director, LPI.

ACTIVITIES AT THE LUNAR AND PLANETARY INSTITUTE FOR PERIOD

1 JANUARY 1984 - 30 JUNE 1984

A. PLANETARY IMAGE CENTER (PIC)

The Planetary Image Center (PIC) is part of the Planetary Geology Program's network of Regional Planetary Image Facilities. As such, PIC maintains an up-to-date reference and working collection of planetary images and support data; disseminates information through an active interlibrary loan program; provides planetary slide sets at cost; conducts annual open houses; assists scientists, students, and educators in acquiring access to, or loan of, image products; and provides daily reference services to users both in house and throughout the country. Requests for materials were received from the scientific community and a variety of users, including publishers of textbooks, popular books, and magazines, film producers, planetarium and museum directors, students, and teachers.

Materials on loan or purchased from the Image Center during this reporting period are as follows:

On Loan

Photographs	4349
Maps	179
Slides	873
Movies	6
Globes	6

New acquisitions included 109 maps.

Our darkroom facility continues to handle small-volume requests in a timely manner. In addition to providing custom prints for photo interpretation and routine prints for other departments at the Institute, the facility produces slides for the in-house scientific staff for use in lectures.

During this reporting period, approximately 200 visitors were received at PIC.

PIC's staffing consists of a full-time Data Manager, a half-time Special Assistant, and a half-time Darkroom Technician. A Senior Staff Scientist serves as Science Advisor to PIC.

## B. LIBRARY/INFORMATION CENTER (L/IC)

The Library/Information Center continues to be an information resource for our staff, scientists at JSC and neighboring universities, and to the research community and public who utilize our services through letters and telephone calls.

There has been continued interest in the remote and personal access to the Lunar and Planetary Bibliography which has been made possible through the development of SEARCH. There is active use by the Planetary Materials Branch at JSC, students at University of Houston and Rice, as well as by users in the U.S. and foreign countries who query us by letter or telephone. We now have 22 remote users who have established their own accounts on SEARCH. During this period electronic bibliographic data bases were accessed a total of 136 times. The in-house data base was accessed 122 times and commercial data bases 14 times. Our in-house data base was accessed 77 times by LIC personnel and 45 times by our remote users. At present these figures count just the times that the bibliography was accessed. We have no statistics for the number of searches run during each session.

In addition, work on the LPB and the Antarctic Meteorites bibliography continues. Forty-six citations were added to the Antarctic Meteorite Bibliography and approximately 750 to the Lunar and Planetary bibliography during this period. This brings the total number of citations in the Antarctic Meteorite Bibliography to over 500 and the total number of citations in the Lunar and Planetary bibliography to approximately 20,500.

In March, LIC personnel participated in the XVth LPSC by the preparation and staffing of the LPI exhibit. In addition to distributing many copies of technical reports and previous conference abstracts, 84 sets of the XVth abstracts were mailed out, 49 new names were added to the mailing list, 16 people specifically requested to receive the SEARCH II manual and the form for establishing user accounts. The exhibit consisted of a showing of the NASA Display "Shuttle in the Future"; a Combined Publishers Exhibit consisting of 58 books and posters, and 8 journals representing 11 publishers; and demonstrations of the on-line SEARCH and PATRON services of the LIC and the usual give-away publications.

After much deliberation, Kin Leung and Fran Waranius completed the first phase of the telephone system evaluation, by recommending to administration that the action be tabled until late 1984. Technology is changing so rapidly and communication companies are becoming more and more competitive in the equipment and services being offered and the costs that it would be to our advantage to remain uncommitted to a new system until there is a bit more technological fall-out.

In June Mrs. Waranius attended the annual meeting of the Special Libraries Association in New York. The theme of the meeting was "Information in the Electronic Revolution".

Circulation records maintained for this reporting period show an average monthly circulation of 478 items to an average of 75 users.

With regard to the distribution of other publications which is handled by the L/IC, 263 requests for reprints of LPI Contributions were filled. Requests for LPI Technical Reports and special Contributions which are abstract volumes for topical conferences, totaled 157 requests for 239 publications.

During this period, 11 LPI Contributions were processed into the series. (See Appendix IV.)

Two issues of the Bulletin were published during this reporting period. The February issue (no. 37) included information and preliminary program for the 15th Lunar and Planetary Science Conference and announcements of several workshops and conferences. The May issue (no. 38) contained the Conference wrap-up, several news items on space program activities, announcements of the LPI summer interns, and information on a number of workshops and conference. The first issue of MECA, a newsletter for the NASA-sponsored LPI study project entitled: "Mars: The Evolution of its climate and atmosphere" was included with the May issue. The regular features: new publications, calendar of events, and current awareness bibliography were included in each issue. Total circulation of the Bulletin now exceeds 4700.

### C. COMPUTER CENTER

The Computer Center continued its steady growth during this reporting period. An Analogic AP 500 32 bit floating point array processor with 2 mega bytes of memory was installed in January to be used in conjunction with the DEC Vax 11/780 for fast complex calculation in the GDF, Geophysical Data Facility. A second Gould/De Anza IP8500 Imaging Processing station was installed in April to provide better on-line access to users of the IPF, the Image Processing Facility. Seven additional terminals were added to achieve the goal of putting a terminal on each staff and scientist's desk. During the 15th Lunar and Planetary Science Conference, the capabilities of both the IPF and GDF were highlighted in a series of lunch time demonstrations for the conference attendees.

### Research Projects

The remote access capability of the GDF was fully operational and GDF was heavily used by in-house and remote access scientists as well as summer interns. Work was carried out on planetary modelling, spherical harmonics modelling for Venus gravity, isostatic compensation modelling of Venus gravity data, gravity and magnetic anomaly field data for the Earth and the terrestrial planets, modelling of formation of duricrust on the surface of Mars, investigation on the morphology and distribution of Martian narrow valley channels, analysis of Martian ridge systems and relation to global tectonics and basin-controlled tectonics, and analysis of ejecta trajectory

in impact crater experiments under different atmospheric conditions.

#### Research-related Activities

The LPI computer system also provided computer and word processing support to various departments in research support areas and to Institute related administrative functions. In all, nine departments in the Institute utilized the VAX 11/780 computer system in various aspects of their operation. Complete on-line log-in process of the 15th Lunar and Planetary Science Conference and the subsequent publication of the Abstract volumes was performed on the LPI computer. The computer was used in the information retrieval in the lunar and planetary bibliography search maintained by the library; in BIRP, the on-line information retrieval of Viking images; in the computerized subject index search of the slides and maps collection of the Planetary Image center; and in the maintenance of the world directory of lunar and planetary scientists and laboratories.

#### Staff

The Computer Center was operated with a technical staff under the Computer Systems Manager, with LPI scientists acting as scientific Advisors to different facilities within C<sup>2</sup>PDA. They included the Computer Systems Manager, a Scientific Programmer/Analyst (IPF), a Scientific Programmer/Analyst (GDF), a Programmer/User Support and a temporary Scientific Programmer (GDF).

#### D. PRODUCTION SERVICES

The department reached agreement with AM International on a plan to upgrade the typesetting equipment. EPICS, a clustered, front-end system with a Winchester (hard) disk drive and tape streamer is used to drive the Comp/Edit 5810 typesetter, providing faster composition, vastly improved file management and archiving, and software capable of producing camera-ready documents without manual paste-up. The system is expandable; its central processing unit can support up to eight peripherals, disk capacity can be increased to 30 megabytes, and a digital typesetting unit can replace the photo unit currently in use. A more comprehensive and flexible telecommunications software package should arrive in the fall of 1984, replacing the present telecom package. The graphics office has added a Seal 500T drymount press to its equipment for permanent mounting or laminating of standard and oversized photographs, maps, charts, displays, etc. The department produced 352 pieces of artwork for scientists and staff during the reporting period as well as 18 larger projects including journal articles, reports, proposals, proceedings, extended programs and the like. A variety of materials were produced in support of the annual Lunar and Planetary Science Conference and (on a charge-back, noninterference basis) for USRA Headquarters and its Division of Space Biomedicine.

## E. SCIENTIFIC STAFF

In addition to the Director, the in-house scientific staff (during this report period) consisted of five scientists working in different areas of lunar and planetary research and assisting in implementation of service functions of the Institute -- names and areas of activity are as follows:

Dr. Kevin Burke -- Geology -- Research in the application of the findings of plate tectonics to interpretation of the geological history of the earth. Currently pursuing research on the operation of the Wilson cycle of the opening and closing of oceans on earth, concentrating on: 1) Caribbean evolution over the last 200 my; 2) the way this cycle operated to make early crusting in the Archean; 3) preparation of a revised catalogue of rifts and sutures of the world. Serves as Director.

Dr. Lewis D. Ashwal -- Petrology/Geochemistry -- Origin and evolution of planetary crusts and mantles; Precambrian geologic history; petrology, mineralogy, and geochemistry of anorthosites and related rocks; origin of magmatic ore deposits; role of volatiles in igneous and metamorphic processes; Rb-Sr and Sm-Nd isotope geochronology; fluid inclusion studies; meteorites as possible martian samples. Serves as Project Scientist for the LPI project: Early Crustal Genesis of the Terrestrial Planets. On leave at Yale September 1983 to June 1984 teaching.

Dr. Bruce Bills -- Planetary Geophysics -- determination and interpretation of global scale planetary gravity and topography, with emphasis towards tectonic processes (mostly thermal) and attention to terrestrial problems. Plays key role in the expansion of the Geophysical Data Facility.

Dr. Paul Morgan -- Geophysics -- Research in heat flow and seismic studies in active tectonic environments; the genesis, structure, and evolution of continental rifts, and geothermal systems. Served as Project Scientist for the LPI project on continental rifts. Chairman of the LPI Seminar Series.

Dr. Graham Ryder -- Geology -- Research in igneous and metamorphic petrology, planetology - petrographic, petrochemical, microprobe studies. Co-Editor of the Proceedings of the 15th Lunar and Planetary Science Conference. Member of the Lunar and Planetary Sample Team.

Dr. Peter H. Schultz -- Planetary Geology -- Problems in atmospheric effects of impact crater formation; emplacement mechanics of ejecta on the Moon and Mars; experimental impact cratering; structure and evolution of multi-ring impact basins; martian polar wandering; computer-code simulation of impact cratering. Serves as LPI Science Coordinator for the NASA/Ames Vertical Ballistic Gun Range. LPI representative on Regional Planetary-Image Facility



Committee and serves as Science Advisor for Planetary Image Center at LPI. Chairman of the "Working Group for the Preservation of Planetary Products." Member of Lunar and Planetary Review Panel. Chairman of the in-house Visiting Scientist Review Panel.

The in-house scientific staff members are of vital importance in their service roles in LPI programs and activities, and also as experienced lunar and planetary scientists who help in initiating and formulating new programs using their research experience. In this context, the resident staff and both long- and short-term visiting scientists have been jointly active in phases of program development and implementation requiring broad scientific expertise.

Further details on scientific staff and long-term visitor appointments and publications and on off-site scientific and/or programmatic activities (during the report period) are given in Appendices I.A. and I.C.

#### F. VISITOR PROGRAM

LPI visitors are classified into six major categories: Visiting Scientists (VS), Visiting Research Scientists (VRS), Visiting Post-Doctoral Fellows (VPDF), Visiting Graduate Fellows (VGF), Visiting Undergraduate Fellows (VUF), and Visiting Undergraduate Interns (VUI). At any one time the facility can accommodate approximately 25 visitors. During the period 1 January 1984 - 30 June 1984, 35 visitors will have been in residence at LPI for a combined total of about 3.96 man-years. The visitor group consisted of 8 Visiting Scientists, 3 Visiting Post-Doctoral Fellows, 10 Visiting Graduate Fellows, and 14 Visiting Undergraduate Interns. A summary of the level of effort, accomplishments, and costs for each category is shown in the Table that follows:

SUMMARY OF VISITOR PROGRAM\*  
January 1, 1984 - June 30, 1984

CATEGORY	NO. OF PERSONS	TOTAL MAN YRS.	COSTS		
			AVERAGE LENGTH OF STAY (WEEKS)	SALARY AND BENEFITS	TRAVEL, RE-LOCATION & DISLOCATION EXPENSES
Domestic V.S.	5	.02	.23	-0-	444.98
Foreign V.S.	3	.28	4.81	10,089.17	5,129.66
V.P.D.F.	3	1.06	18.33	27,552.77	6,053.68
V.G.F.	10	1.86	9.69	4,162.08	13,985.50
V.U.I. (Summer Interns)	14	.74	2.74	-0-	11,268.58
TOTALS	35	3.96		\$41,804.02	\$36,882.40

\*See Appendix I.B for Visitor Roster

### Summer Undergraduate Intern Program

During the month of January 1984, the Lunar and Planetary Institute offered students world-wide an opportunity to work closely with scientists active in lunar and planetary research. Out of 200 highly qualified applicants from throughout the United States, Canada, Germany, Italy, Japan and the United Kingdom, fourteen undergraduate or newly-graduated students were chosen to take part in the eighth Summer Undergraduate Intern Program. Scientists from the Lunar and Planetary Institute and the NASA Johnson Space Center are directing the interns in a variety of research projects. Interns will have opportunities to present a profile of their research to their colleagues and advisors, and to interact with scientists from JSC, LPI, and with visiting researchers from the lunar and planetary science community. It is anticipated that many of these projects and interactions will produce publishable results. A roster of students and their advisors is included in Appendix I.B.

#### G. SCIENTIFIC PROJECTS, CONFERENCES, WORKSHOPS, AND SEMINARS

##### 1. Topical Conferences, Workshops and Seminars

Conferences, workshops and special projects on various subjects are arranged and conducted in-house by LPI. Available facilities can accommodate approximately 75 participants for discussion conferences; however, LPI can accommodate larger groups through closed-circuit television. Television monitors and audio system in the Hess Room allow remote auditing of presentations (one sound and two video inputs) from the Berkner Room.

Summary tables of conferences, workshops and seminars are contained in Appendix II.

##### Study Project on "Mars: The Evolution of its Climate and Atmosphere"

A new NASA-sponsored LPI study project entitled "Mars: The Evolution of its Climate and Atmosphere" (MECA) has been initiated. An organizational meeting was held at LPI on March 10-11, 1984, which was attended by a working group composed of all the investigators who were funded as part of the program. A Steering Committee, chaired by Ronald Greeley of Arizona State University, was established, some general guidelines were defined, and three major subgroups were formed on the topics "Seasonal Cycles", "Surface Processes and Climate History" and "Bulk Chemical Composition and Outgassing History." The purpose of the subgroups was to formulate questions that each group recognized as important for focusing future discussions. The approach in meeting the objectives of MECA will be to guide the research through a series of Topical Workshop/Conferences, each of which will have focused objectives. The principal mode of reporting MECA results will be via journal publication. Most of the goals of MECA are directly relevant to the Mars Geoscience/Climatology Orbiter.

Communications concerning upcoming workshops/conferences, subgroup reports, and listings of recent review articles will be published in a newsletter and mailed to all interested researchers. The first newsletter was distributed in May 1984 announcing the newly organized study project to the scientific research community.

### Early Crustal Genesis Project

A topical conference on the "Origin of the Moon" scheduled for October 1984 and two field/workshops, the 1985 Manitoba Field Workshop "Lower Crustal Processes" and the "Field Workshop in the Godthab district of west Greenland on the "World's Oldest Rocks" scheduled for the summer of 1985, are future meetings resulting from the continuing study project on "Early Crustal Genesis" (ECG). Further details on the October 1984 conference and the summer 1985 field workshops are provided in this report. The ECG Newsletter, produced and distributed by the LPI, will continue to serve as a means of reporting the results of research and future plans related to this study project.

### Workshop on "Cosmogenic Nuclides"

Dr. Robert C. Reedy, Los Alamos National Laboratory, and Dr. Peter Englert, University of Cologne, are co-conveners of a workshop on "Cosmogenic Nuclides" which is to be held July 26-27, 1984 in Los Alamos, New Mexico. Over 30 participants from a wide range of fields are expected to attend this two-day workshop on the nuclides made by the cosmic rays. Sponsors for the workshop are the Los Alamos National Laboratory and the Lunar and Planetary Institute. A volume of abstracts submitted by participants will be prepared at LPI and distributed at the meeting. An LPI Technical Report summarizing the workshop and including submitted abstracts will be published by LPI following the workshop.

### 47th Annual Meteoritical Society Meeting

This year's Meteoritical Society Meeting is scheduled for July 30 - August 2, 1984, at the University of New Mexico, Albuquerque, New Mexico. The meeting will be hosted by the Institute of Meteoritics, Department of Geology, of the University of New Mexico who will also co-sponsor the meeting with the Lunar and Planetary Institute. Additional support is to be provided by the Los Alamos National Laboratory. An abstract volume and formal program of presentations is being produced by LPI for distribution to the approximately 300 expected attendees. The papers presented will be published in the December issue of Meteoritics.

### Solid Earth Sciences Workshop

Tentative plans are being made for a workshop on "Solid Earth

Sciences" to be held at LPI September 10-14, 1984. The workshop convener is Dr. Thomas Feshetti of NASA Headquarters. The LPI Production Services Department, Publications Department, and Projects Office have been requested to provide the necessary administrative, logistic, and publication/production support for the workshop. Publication of a post-workshop report (200 copies), to be printed through the Government Printing Office, and an executive summary (1000 copies) produced locally, are expected products of this workshop.

#### Conference on the "Origin of the Moon"

An ECG-related conference on the "Origin of the Moon" is planned for October 13-16, 1984, in Kona, Hawaii following the Division for Planetary Sciences Meeting at that location. Conference conveners are Dr. G. Jeffrey Taylor (Chair), University of New Mexico, Dr. Roger Phillips, Southern Methodist University, and Dr. William K. Hartmann, Planetary Science Institute. The conference will be co-sponsored by the Lunar and Planetary Institute and the Division for Planetary Sciences of the American Astronomical Society. Abstracts received for presentation will be published in a volume to be distributed to conference attendees. Proceedings of the conference will be published in book form, with papers due December 15, 1984. Major goals of the conference are to assess the present understanding of lunar formation and to reveal areas where current knowledge is meager with the expectation that the conference will lead to research designed to test specific models and possibly to help in planning new planetary exploration missions.

#### Conference on "Water on Mars"

The first MECA topical conference will be held November 30 - December 1, 1984, prior to the Fall American Geophysical Union meeting in San Francisco. The meeting will be hosted by Dr. Robert Haberle at NASA Ames Research Center with co-sponsorship from the Lunar and Planetary Institute. Contributed papers from the MECA Study Group are expected to form the core of the program. An abstract volume of papers to be presented as well as a post-meeting publication will be produced by LPI.

#### Field Workshop on the "World's Oldest Rocks"

An ECG related field workshop on the "World's Oldest Rocks" is being planned by Drs. Kevin Burke and Lewis Ashwal, Lunar and Planetary Institute, with Drs. Victor R. McGregor and Allen P. Nutman, Greenland Geological Survey, to lead the 7-8 day series of field trips. The field workshop is scheduled for June 1985 in the Godthaab district of west Greenland. The objective of this workshop is to bring together 25-40 scientists in the fields of terrestrial and planetary geochemistry, geology, and geophysics to examine firsthand the remnants of the earliest terrestrial crust available. In addition to the 7-8 days of field work, a

2-day workshop of technical sessions with contributed and invited presentations is planned. A field guide, abstract volume, and a post-workshop technical report including the field guide, abstract volume and summary will be produced by LPI. There is also a possibility of a workshop volume or special journal issue with contributed papers, if enough participants show interest.

#### 1985 Manitoba Field Workshop on "Lower Crustal Processes"

Dr. Werner Weber, Manitoba Department of Energy and Mines, is organizing a field workshop scheduled for August 1985 in Winnipeg and the Northwest Superior greenstone belts, Pikwitonei granulite domain and adjacent reworked Thompson belt of Manitoba, Canada. Dr. Lewis Ashwal, Lunar and Planetary Institute and Dr. William Phinney, NASA Johnson Space Center, are assisting in the planning of this ECG related field workshop. This field workshop is a continuation of work initiated at the successful LPI sponsored 1983 Archean Geochemistry - Early Crustal Genesis Field Workshop held in August 1983 in Ontario, Canada.

#### Workshop on "Lunar Surface Materials"

A proposed book on Lunar Surface Materials was the subject for discussion at an LPI sponsored workshop held February 14-15, 1984, at the Lunar and Planetary Institute. Fifteen invited scientists participated in the workshop convened by Grant Heiken and David Vaniman of Los Alamos National Laboratory and Larry Taylor of the University of Tennessee. The purpose of this meeting was to gather representatives from each discipline and potential users of the book to determine what information the book might provide and how it might set out areas of needed research. A second meeting including the attendees to the February workshop and an additional 12 participants was held March 14, 1984 at LPI in order to bring together all of those involved in writing for the book. Writing assignments, funding and scheduling for the book were discussed at this second meeting.

#### Annual Lunar and Planetary Science Conference

The Fifteenth Lunar and Planetary Science Conference was held in Houston March 12-16, 1984, under the joint sponsorship of the American Geophysical Union, the Division for Planetary Sciences of the American Astronomical Society, the Geological Society of America, the Lunar and Planetary Institute, the Meteoritical Society and the NASA Johnson Space Center. The conference was attended by 500 scientists representing 14 different countries.

Abstracts submitted for the Conference were considered by a Program Committee for inclusion in Lunar and Planetary Science XV and/or for oral presentation at the Conference. Of the total abstracts submitted, 491 were printed; 333 of these were selected for oral presentation and 32 were selected for poster presentation.

Special sessions held during the Conference included: a session entitled "Planetary Program Status Review" held March 12 in the evening at the Gilruth Center which was open to the public and all conference participants; in the early evening of March 12, a meeting of European Planetary Scientists was convened by K. Runcorn; an informal discussion on the age of multi-ring basins convened by K. Runcorn March 14 in the early evening at LPI; and an evening session held March 14, organized by C. Wood, G. Ryder, and A. Binder was held at the Gilruth Center for the purpose of discussing the question "Do we need a Lunar and planetary Geoscience Society?" and to review the method of publication for the LPSC Proceedings.

Workshop on the "Early Earth: The Interval from Accretion to the Older Archean"

Fifty-seven scientists attended the Workshop on the "Early Earth: The Interval from Accretion to the Older Archean" which was held April 23-25, 1984, at the Lunar and Planetary Institute in Houston. The workshop, convened by Dr. Kevin Burke, LPI Director, was a contribution to NASA's current ECG study project. Abstracts submitted for the meeting were distributed to the participants and a technical report including revised abstracts, summations of the sessions, etc. will be published and distributed by the LPI Publications Office.

#### H. PUBLICATIONS AND COMMUNICATIONS

During this report period, the following projects were completed.

1. Proceedings of the Fourteenth Lunar and Planetary Science Conference (second supplement) was published in February by the American Geophysical Union. Published as a supplement to JGR-red, this first section of the Proceedings contained 32 papers and 327 pages.

2. Abstract Volumes

- a. Lunar and Planetary Science XV was published in March. Copies of the 2-volume, 968-page set were distributed at the 15th LPSC held at the Johnson Space Center in March.
- b. Press Abstracts for LPSC XV was published in March. Distributed to members of the press who attended the 15th LPSC, this volume contained 15 abstracts that were chosen from the abstracts published in Lunar and Planetary Science XV to be rewritten in lay language for distribution to the press.

3. Other Publications

- a. CHRONDULES AND THEIR ORIGINS was published by the Lunar and Planetary Institute in January. The book, which resulted from a topical conference on the subject held at the LPI in November,

1982, contains 25 papers, a thorough bibliography, and subject and author indexes. LPI personnel sent the manuscripts for review, copyedited all papers, typeset the contents, prepared the indexes, and produced camera-ready copy of the book for printing. Scientific editor for the book was Dr. Elbert A. King.

- b. A compilation of abstracts was prepared for attendees of the Workshop on the Early Earth: The Interval from Accretion to the Older Archean. The workshop, convened by Dr. Kevin Burke, was held at the LPI April 23-25. A technical report will be published in late 1984.

#### 4. Lunar and Planetary Institute Contributions

To document the activities of the visiting and staff scientists and other work supported by the Institute, this formal series called "Lunar and Planetary Institute Contributions" was initiated in September 1969 while the Institute was under the auspices of the National Academy of Sciences.

The following table shows a periodic listing of the contributions since implementation of the program:

PERIOD	CONTRIBUTIONS	LPI NUMBERS
Prior to 11 December 1969	1	1
11 December to 31 May 1971	68*	2-69
1 June 1971 to 30 June 1972	34	70-103
1 July 1972 to 30 June 1973	49	104-152
1 July 1973 to 30 June 1974	32	153-184
1 July 1974 to 30 June 1975	32	185-216
1 July 1975 to 30 June 1976	30	217-246
1 July 1976 to 30 June 1977	3	247-279
1 July 1977 to 30 June 1978	48	280-327
1 July 1978 to 30 June 1979	54	328-382
1 July 1979 to 30 June 1980	27	383-409
1 July 1980 to 30 June 1981	31	410-440
1 July 1981 to 30 June 1982	39	441-479
1 July 1982 to 30 June 1983	39	480-518
1 July 1983 to 31 Dec 1983	7	519-525
1 January to 30 June 1984	11	526-536

\*Includes 28 contributed papers to LPI's Meteorite Impact and Volcanism Conference

During the current period, of the 11 papers numbered in the series through 30 June 1984 1 was authored by LPI staff member, 3 were by visiting scientists, and 7 were co-authored by staff scientists and visiting scientists, or staff scientists and scientists at other institutions. (See Appendix IV for list of LPI Contributions for the period January to June 1984.

## 5. Lunar and Planetary Information Bulletin

Two issues of the Bulletin was published during this reporting period. The February issue (no.37) included information and preliminary program for the 15th Lunar and Planetary Science Conference and announcements of several workshops and conferences. The May issue (no. 38) contained the Conference wrap-up, several news items on space program activities, announcements of the LPI summer interns, and information on a number of workshops and conferences. The first issue of MECA, a newsletter for the NASA-sponsored LPI study project entitled: "Mars: the Evolution of its climate and atmosphere" was included with the May issue. The regular features: new publications, calendar of events, and current awareness bibliography were included in each issue. Total circulation of the Bulletin now exceeds 4700.

### I. PANELS, TEAMS, WORKING GROUPS, AND COMMITTEES

#### Lunar and Planetary Sample Team (LAPST)

The Lunar and Planetary Sample Team met at the LPI on June 8 and 9. At this meeting the Team considered nine requests for lunar samples and generated three memoranda to the Chief of the Solar System Exploration Division, JSC, and two letters to NASA Headquarters. An unusual request for lunar soil to be used in the preparation and testing of concrete also was approved by the Team. The next meeting of the LAPST will be held September 21-23 at the LPI.

#### Meteorite Working Group (MWG)

The Meteorite Working Group met at the LPI on April 8-10 under the leadership of the new chairman, Dr. Louis Rancitelli. The group acted on 38 requests for samples. Among the many items they discussed at this meeting were sample transfers, plans for the next field season in Antarctica, and consortia studies. This was the final meeting for Dr. William Boynton; Dr. Robin Brett will be his replacement at the fall meeting to be held at the Smithsonian Institution in Washington, D. C., September 8-10.

#### Mission Operations and Information Systems Subcommittee of the Solar System Exploration Committee (MOIS/SSEC)

The Mission Operations and Information Systems Subcommittee of the Solar System Exploration Committee met May 9-11 at the Jet Propulsion Laboratory, Pasadena. They are concerned with maintaining high quality science while reducing costs such as low to moderate cost planetary missions that are to be flown through the end of this century.



## J. NASA-AMES VERTICAL GUN RANGE (AVGR)

The NASA-Ames Vertical Gun Facility (AVGF) continued to provide support for on-going experimental programs, including studies concerned with projectile volatilization, projectile deformation, atmospheric effects, and cratering efficiency. Six papers describing these results were presented at the Lunar and Planetary Conference XV. An overview of selected experimental results was presented at both Brown University and JPL. During the report period three new inquiries were made about potential use of the AVGF. The Science Coordinator (P. Schultz) discussed short-term and long-term AVGF plans with the Facilities Manager at Ames in May. An informal tour of the Facility was given to the PGGP Discipline Scientist (Joe Boyce) during the same time period. An updated status report of AVGF activities was presented to him at that time and is included as Appendix V.

## K. LUNAR AND PLANETARY SCIENCE COUNCIL

The Lunar and Planetary Science Council reports directly to the USRA Board of Trustees. It has been charged with the responsibility for advising the Board on all matters relating to USRA activities in lunar and planetary science. Accordingly, it is the principal USRA group reviewing, in association with the Director, the programs of the LPI and making recommendations to the Board on policy matters relating to technical or scientific programs at the Institute.

Council members during this report period were:

Dr. Klaus Keil (Convener), Institute of Meteoritics, University of New Mexico, Albuquerque.

Dr. Raymond E. Arvidson, Department of Earth and Planetary Sciences, Washington University, St. Louis.

Dr. Albert W. Bally, Department of Geology, Rice University, Houston.

Dr. Richard A. F. Grieve, Division of Gravity. Geotherm, Ottawa, Ontario.

Dr. William M. Kaula, Department of Earth and Planetary Sciences, University of California, Los Angeles and National Oceanic and Atmospheric Administration's National Geodetic Survey Division..

Dr. Gunter Lugmair, Chemistry Department, University of California, San Diego.

Dr. Harry McSweens, Department Geological Sciences, University of Tennessee, Knoxville.

Dr. Richard O'Connell, Department of Geological Sciences, Harvard University, Cambridge.

Dr. Stanton J. Peale, Department of Physics, University of California,  
Santa Barbara.

Dr. Laurence A. Soderblom, U. S. Geological Survey, Flagstaff.

## ANTICIPATED EFFORT DURING NEXT REPORT PERIOD

1 July 1984 - 31 December 1984

Innovations in the Institute are anticipated that relate to the Director's involvement in global geology and in the entire history of the Earth. Early completion of a technical report embodying a catalogue of rifts and sutures of the Earth represents a first step in this direction and it is hoped that these and related efforts might prove helpful to NASA in its current effort to define its overall role in the study of the Earth.

The Lunar and Planetary Science Conference has settled into its new structure with sponsorship by AGU, DPS, Meteoritical Society and GSA. The possibility of international sponsorship in addition has been raised. The Planetary Meetings Steering Committee (with representation of the four societies, LPI and JSC) has instructed the Director to set up a publications subcommittee to review how well the present arrangement with AGU is working.

The Geophysical Data processing capability is beginning to be used remotely. The further development of this resource for the Lunar and Planetary Science community continues to be one of the Institute's main aims. The current C<sup>2</sup>PDA newsletter gives further particulars (see Appendix VI).

The departure of Pete Schultz, the senior scientist, to assume a professorship at Brown University marks the end of a long and productive association with the Institute. Although Dr. Schultz's departure leaves an obvious gap, it also represents an opportunity for reassessment of the organization of the scientific staff. An advertisement drawing attention to the new staff opportunities of the Institute has been issued.

We have completed a comprehensive reorganization of LPRP and PGRP Review Panel structure. The new arrangement looks very strong and the Institute and its staff look forward to participating in its operation starting this fall.

The two innovative Solar System Exploration Division Research projects being operated by the Institute: The Mars Data Analysis--Mars, Evolution of Climate and Atmosphere (MECA) and Early Crustal Genesis (ECG) have now both been running for about a year. A workshop related to the ECG project met in April and considered the history of the earth between accretion and the oldest rocks and a workshop on the theme "Water on Mars", related to MECA, is planned for December.

Contract negotiations have secured the final year of renewal (Apr. 84 to Mar. 85) under the current options and are now in progress with a view to establishment of a further three year commitment from NASA, Apr. 85 - Mar. 88.

Workshops, Meetings, and Conferences (as of this date) for remainder of 1984 and into 1985 are:

Workshop on Cosmogenic Nuclides - 7/26-27/84

47th Annual Meteoritical Society Meeting - 7/30-8/2/84

Conference on the Origin of the Moon - 10/13-16/84

Conference on Water on Mars - 11/30-12/1/84

16th Lunar and Planetary Science Conference - 3/11-15/85

Workshop on the World's Oldest Rocks - 6/85

1985 Manitoba Field Workshop - 8/85

Conference on Heat and Detachment in Crustal Extension on Continents and Planets -  
10/10-12/85

For more information (conveners, locations, publications) on Workshops and Conferences, please see Summary Table in Appendix II, Part A.

*[Handwritten scribbles and marks]*

APPENDIX I

- PART A: SCIENTIFIC STAFF AND LONG-TERM VISITOR APPOINTMENTS AND PUBLICATIONS
- PART B: VISITOR ROSTER
- PART C: STAFF AND VISITOR OFF-SITE SCIENTIFIC ACTIVITIES

APPENDIX I\*

SCIENTIFIC STAFF FY 1984

1 January 1984 - 30 June 1984

Ashwal, Lewis D. (Appointment: 3 September 1980 - 2 September 1985)  
Field: PETROLOGY/GEOCHEMISTRY - origin and evolution of planetary crusts and mantles; Precambrian geologic history; petrology, mineralogy, and geochemistry of anorthosite and related rocks; origin of magmatic ore deposits; role of volatiles in igneous and metamorphic processes; Rb-Sr and Sm-Nd isotope geochronology; fluid inclusion studies; meteorites as possible martian samples.

Publications\*

Ashwal, L. D. (with P. Morgan), 1984. Comment on "Uplift rate of Adirondack anorthosite measured by fission track analysis of apatite," by D. S. Miller and S. Lakatos, Geology 11, 284-286, 1983. Geology, v. 12, pp. 124-125.

Ashwal, L. D. (with J. Longhi) 1984. A two-stage model for lunar anorthosites: An alternative to the magma ocean hypothesis. Lunar and Planetary Science XV, The Lunar and Planetary Institute, Houston, p. 491-492.

Ashwal, L. D. (with P. Morgan) 1984. Crustal radiogenic heat production and the stability of ancient continental crust. Lunar and Planetary Science XV, The Lunar and Planetary Institute, Houston, p. 564-565.

Ashwal, L. D. (with R. L. Rudnick, D. J. Henry, and E. K. Gibson) 1984. Fluid inclusions in stony meteorites - a cautionary note. Lunar and Planetary Science XV, The Lunar and Planetary Institute, Houston, p. 701-702.

Ashwal, L. D. (with P. Morgan and S. P. Clark, Jr.) 1984. High pressure granulite metamorphism of supracrustal rocks: implications for the Adirondack highlands. EOS v. 65, p. 288.

Ashwal, L. D. (with A. F. Trial, R. L. Rudnick, and D. J. Henry) 1984. Fluid inclusions in mantle xenoliths from Ichinomegata, Japan: Evidence for subducted H<sub>2</sub>O? EOS, v. 65, p. 306.

\*Appendix I lists only those publications that have appeared in print or were in progress during the report period and which were not included in the previous report.

- Ashwal, L. D. (with J. Longhi) 1984. Two-stage models for lunar and terrestrial anorthosites: Petrogenesis without a magma ocean. Proc. Lunar Planet. Sci. Conf. 15th, in press.
- Ashwal, L. D. (with R. L. Rudnick, D. J. Henry, E. K. Gibson, E. Roedder and H. E. Belkin) 1984. Fluid inclusions in stony meteorites--a cautionary note. Proc. Lunar Planet. Sci. Conf. 15th, in press.
- Ashwal, L. D. (with P. Morgan, S. A. Kelley and J. A. Percival) 1984. An Archean crustal radioactivity profile: The Kapuskasing Structural Zone, Ontario. Geol. Soc. Amer. Abstracts with Programs, in press.
- Ashwal, L. D. (with R. L. Rudnick and D. L. Henry) 1984. Fluid inclusions in high-grade gneisses of the Kapuskasing Structural Zone, Ontario: Metamorphic fluids and uplift/erosion path. Contr. Mineral. Petrol., in press.
- Ashwal, L. D. (with J. L. Wooden) 1984. Sm-Nd isotopic studies of Proterozoic anorthosites: Systematics and implications. Proc. NATO Adv. Study Institute, "The Deep Proterozoic Crust in the North Atlantic Provinces, Norway, July, 1984, in review.

Bills, Bruce (Appointment: 13 February 1984 - 13 February 1985)

Field: PLANETARY GEOPHYSICS - determination and interpretation of global scale planetary gravity and topography, with emphasis towards tectonic processes (mostly thermal) and attention to terrestrial problems.

Publications

Bills, B. G. (with W. L. Sjogren) and N. A. Mottinger) 1984. Venus: Ishtar Gravity Anomaly. Geophys. Res. Lett., 11, 489-491.

Bills, B. G. (with M. Kобрick) 1984. Venus Topography: A Harmonic Analysis. J. Geophys. Res., in press.

Bills, B. G. (with N. A. Mottinger and W. L. Sjogren) 1984. Venus Gravity: A Harmonic Analysis. J. Geophys. Res., in press.

Bills, B. G., 1984. Venus Rotation: Resonance and Wobble, in preparation.

Bills, B. G. (with W. S. Kiefer) 1984. A Harmonic Analysis of Venus Gravity, in preparation.

Bills, B. G. (with M. Kобрick) 1984. Topographic Spectral Similarity of Terrestrial Planets, in preparation.



Burke, Kevin (Appointment: 1 September 1983-)

Field: GEOLOGY - research in plate tectonics to interpret geological history of the earth; research on operation of Wilson cycle of the opening and closing of oceans on earth, concentrating on Caribbean evolution over the last 200 my and early crust in the Archean.

Publications

- Burke, K. (with P. Mann, F. W. Taylor and R. Kulstad), 1984. Subaerially exposed holocene coral reef, Enriquillo Valley, Dominican Republic. Geol. Soc. of Amer. Bull., 95, 1084-1092.
- Burke, K. (with C. Cooper, J. F. Dewey, W. P. Mann and J. L. Pindell), 1984. Caribbean Tectonics and Relative Plate Motions, in GSA Memoir 162, p. 31-63, eds. W. Bonini, R. Hargraves and R. Shagam.
- Burke, K., 1984. Revised Catalogue of Rifts and Sutures of the World. in preparation.
- Burke, K., A. B. Thompson, F. M. Richter, H. Ahrendt, M. J. Bickle, R. F. Dymek, W. Frisch, R. D. Gee, A. Kroner, R. K. O'Nions, E. R. Oxburgh and K. Weber, 1984. The Long-term Evolution of the Crust and Mantle in Patterns of Change in Earth Evolution, eds. Holland and Trendall, pp. 389-406.

Morgan, Paul (Appointment: 2 September 1980 - 12 August 1984)  
 Field: GEOPHYSICS - heat flow and seismic studies in active tectonic environments, the genesis, structure and evolution of continental rifts, and geothermal systems.

Publications

- Morgan, P. (and J. H. Sass) 1984. Thermal regime of the continental lithosphere. Journal of Geodynamics, Vol. 1, pp. 143-166.
- Morgan, P. (with I. B. Ramberg), 1984. Physical characteristics and evolutionary trends of continental rifts. Proceedings 27th International Geological Congress, VNU Science Press BV, Utrecht, in press.
- Morgan, P., 1984. The thermal structure and thermal evolution of the continental lithosphere. Phys. Chem. Earth, in press.
- Morgan, P. (with W. J. Hinze and L. W. Braile) 1984. Exploration for hot dry rock geothermal resources in a the midcontinent USA. Los Alamos National Laboratory Report (3 volumes), in press.
- Morgan, P. (with M. P. Golombek) 1984. Two Phases and two styles of extension in the Northern Rio Grande rift. New Mexico Geological Society 35th Field Conference Guidebook in press.
- Morgan, P. (with P. H. Daggett and F. K. Boulos) 1984. Seismicity and active tectonics of the Egyptian Red Sea margin and the Northern Red Sea. Journal of Geophysical Research, in press.
- Morgan, P., 1984. Crustal radiogenic heat production and the selective survival of ancient continental crust. Proceedings 15th LPSC; Journal of Geophysical Research, in press.
- Morgan, P. (with C. A. Swanberg) 1984. Heat flow in the Colorado plateau and adjacent areas. Submitted to 1983 Hamburg IUGG "Plateau Uplift, Rifts and Volcanism" volume. Journal of Geodynamics, in press.
- Morgan, P. (with C. A. Swanberg) 1984. On the cenozoic uplift and tectonic stability of the Colorado plateau. Submitted to 1983 Hamburg IUGG "Plateau Uplift, Rifts and Volcanism" Volume. Journal of Geodynamics, in press.

Ryder, Graham (Appointment: 3 November 1983--)  
 Field: GEOLOGIST - igneous and metamorphic petrology, planetology.  
 Petrographic, petrochemical, microprobe studies.

Publications

- Ryder, G., 1984. Most olivine in the lunar highlands is of shallow origin (Abs.) Lunar Plan. Sci. XV, 707-708.
- Ryder, G., 1984. Olivine in lunar tunitite 72415, a rather shallow origin cumulate (Abs.) Lunar Plan. Sci. XV, 709-710.
- Ryder, G. (with B. Spettel) 1984. Towards understanding lunar pristine rocks: pursuing petrogenesis in Stillwater Norite I (Abs.) Lunar Plan. Sci. XV, 711-712.
- Ryder, G., 1984. Chemistry and origin of oikocrysts in the Stillwater (Abs.). Trans. Am. Geophys. Union, v. 65, p. 294-295.
- Ryder, G., 1984. Minor elements in Marjalaht olivine. Meteorites 19, 79-83.
- Ryder, G. (with B. Spettel) 1984. Petrogenesis of Norite 1:1 Whole Rock Chemistry. Proc. Lunar Planet. Sci. Conf. 15th, in press.
- Ryder, G., 1984. Oxidation and layering in the Stillwater intrusion (Abs.)  
Geol. Soc. Am. Abs. with Prog., in press.

Schultz, Peter H. (Appointment: 1 September 1976 - 31 August 1985)  
 Field: PLANETARY GEOLOGY - atmospheric effects on impact crater formation; emplacement mechanics of ejecta on the Moon and Mars; experimental impact cratering; structure and evolution of multi-ring impact basins; Martian polar wandering; computer-code simulation of impact cratering.

#### Publications

- Schultz, P. H. (with R. A. Arvidson, E. Levinthal and R. S. Saunders), 1983. Remote sensing of the surfaces of terrestrial moons and planets. In Manual of Remote Sensing, vol. II, second edition, in press.
- Schultz, P. H. (with T. Matsui), 1984. On the brittle-ductile behavior of iron meteorites: New experimental constraints. J. Geophys. Res., in press.
- Schultz, P. H. (with D. E. Gault), 1984. Clustered impacts: Experiments and implications. J. Geophys. Res., in press.
- Schultz, P. H. (with A. B. Lutz), 1984. Polar wandering on Mars. Scientific American, in press.
- Schultz, P. H. (with D. E. Gault) 1984. Effects of projectile deformation on cratering efficiency and morphology. Lunar and Planetary Science XV, p. 730-731, Lunar and Planetary Institute, Houston.
- Schultz, P. H. (with J. Rogers) 1984. Evolution of erosional styles of martian impact basins. Lunar and Planetary Science XV, p. 734-735, Lunar and Planetary Institute, Houston.
- Schultz, P. H., 1984. Impact basin control of volcanic and tectonic provinces on Mars. Lunar and Planetary Science XV, p. 728-729, Lunar and Planetary Institute, Houston.
- Schultz, P. H. (with G. McGill) 1984. Martian impact basins: Morphology differences and tectonic provinces. Lunar and Planetary Science XV, p. 818-819, Lunar and Planetary Institute, Houston.
- Schultz, P. H. (with A. F. Chicarro) 1984. Global and regional ridge patterns on Mars. Lunar and Planetary Science XV, p. 146-147, Lunar and Planetary Institute, Houston.
- Schultz, P. H. (with A. F. Chicarro and P. Masson) 1984. Global and regional ridge patterns on Mars. Icarus, in press.
- Schultz, P. H., 1984. Lunar and martian impact basins: Exposed records of terrestrial bombardment? Abstract. In Workshop on the Early Earth, Lunar and Planetary Institute, p. 69-70.

LONG TERM VISITORS, THEIR APPOINTMENTS AND PUBLICATIONS DURING  
THIS REPORT PERIOD

Cintala, Mark J., Visiting Post-Doctoral Fellow (Appointment: 1 December  
1983 - 30 June 1984)  
Field: GEOLOGY - Impact Cratering

Publications

- Cintala, M. J., 1984. A method for evaluating shock propagation and its thermal effects during impact events. Lunar and Planetary Science Conference XV, pp. 154-155 (abstract).
- Cintala, M. J. (with A. F. Grieve), 1984. Energy partitioning during terrestrial impact events: melt production and scaling laws. Lunar and Planetary Science Conference XV, pp. 156-157 (abstract).
- Cintala, M. J. (with F. Horz), 1984. Catastrophic rupture experiments: Fragment-size analysis and energy considerations. Lunar and Planetary Science Conference XV, pp. 158-159 (abstract).
- Cintala, M. J. (with F. Horz, T. H. See, F. Cardenas and T. D. Thompson), 1984. Regolith evolution experiments I: Grain-size evolution. Lunar and Planetary Science Conference XV, pp. 160-161.
- Cintala, M. J. (with T. H. See and F. Horz), 1984. Regolith evolution experiments II: Modal and chemical analysis. Lunar and Planetary Science Conference XV, pp. 742-743 (abstract).
- Cintala, M. J. (with P. D. Spudis and R. A. F. Grieve), 1984. The early Moon: Implications of a large impact into a hot target. Lunar and Planetary Science Conference XV, pp. 810-811 (abstract).
- Cintala, M. J., 1984. A technique for evaluating shock propagation and its thermal effects during impact events. J. Geophys. Res., in preparation.
- Cintala, M. J. (with R. A. F. Grieve) 1984. Thermodynamics of planetary impact events: relevance to crater scaling laws, Jour. Geophys. Res., in preparation.
- Cintala, M. J. (with F. Horz, T. H. See, F. Cardenas, and T. D. Thompson) 1984. Grain size evolution and fractionation in an experimental gabbro regolith, Proc. Lunar Sci. Conf. 15th, Jour. Geophys. Res., in press.

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Clifford, Stephen M., Visiting Post-Doctoral (Appointment: 31 January - 31 January 1985).

Field: PLANETARY VOLATILES/GEOLOGY - physics of H<sub>2</sub>O and solute transport in cold planetary regoliths.

Publications

Clifford, S. M. (with D. Hillel), 1983. The stability of ground ice in the equatorial region of Mars. J. Geophys. Res. 88, pp. 2456-2474.

Clifford, S. M., 1983. Ground ice in the equatorial region of Mars: A fossil remnant of an ancient climate or a replenished steady-state inventory? In.: Proceedings of the Fourth International Conference on Permafrost, National Academy Press, Washington, D. C.

Clifford, S. M. (with D. Hillel), 1983. Knudsen diffusion: Gaseous transport in small soil pores, submitted to Soil Science.

Clifford, S. M., 1983. Mars: Hydraulics of a subpermafrost groundwater system driven by polar basal melting. Bull. Amer. Astron. Soc. 15, p. 845.

Clifford, S. M., 1983. Polar basal lakes on Mars: Possible isolated habitats of primitive Martian life? Bull. Amer. Astron. Soc. 15 pp. 845-846.

Clifford, S. M. (with M. L. Allison), 1984. Ice-covered volcanic water flows on Ganymede. Reports of the Planetary Geology Program - 1983 (NASA TM 86246), pp. 3-5.

Clifford, S. M. (with M. L. Allison), 1984. Ice-covered volcanic water flows on Ganymede. Lunar and Planetary Science Conference XV, pp. 5-6.

Clifford, S. M., 1984. A model for the climatic behavior of water on Mars. Ph. D. dissertation, Dept. of Physics and Astronomy, University of Massachusetts, 286 pp.

Clifford, S. M., 1984. Polar basal melting on Mars. Submitted to J. Geophys. Res.

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Francis, Peter, Visiting Senior Scientist (Appointment: 16 February 1981 - 14 March 1984)

Field: GEOLOGY - early crustal genesis on terrestrial planets.

Publications

- Francis, P. W. (with R. S. Thorpe and L. J. O'Callaghan), 1984. Relative roles of source composition, fractional crystallization and crustal contamination in the petrogenesis of Andean volcanic rocks (Abs.). Phil. Trans. Roy. Soc. Lond., in press.
- Francis, P. W. (with R. S. Thorpe and L. O'Callaghan), 1984. Relative roles of source compositional fractional crystallization and crustal contamination in the petrogenesis of Andean volcanic rocks. Phil. Trans. Roy. Soc. Lond. A., in press.
- Francis, P. W. (with C. A. Wood), 1984. Volcanism and the Greenland Ice Record. Geology, in press.
- Francis, P. W. (with R. S. J. Sparks, L. J. O'Callaghan and R. S. Thorpe), 1984. Ignimbrites of the Cerro Galan Caldera, N. W. Argentina. J. Geophys. Res., in press.
- Francis, P. W., 1984. The origin of the 1883 Krakatau tsunamis. J. Volcanol. Res., in press.
- Francis, P. W. (with W. McDonough, M. Hammill, L. J. O'Callaghan and R. S. J. Thorpe), 1984. The Cerro Purico Shield Complex, north Chile: chemical and isotopic variations in a single volcanic centre. In Chemical and Isotopic Constraints on Andean Magmatism (B. Barreiro and R. Harmon, eds.), Shiva Publications, p. 106-.
- Francis, P. W. (with R. S. Harmon, B. Barreiro, S. Moor bath, R. S. Thorpe, J. Hoefs and B. Deruelle), 1984. Regional O-, Sr- and Pb- isotope relations in late cenozoic calc-alkaline lavas in the Andean cordillera. J. Geological Soc., 141, 803-822.
- Francis, P. W., 1984. The Socompa volcano, north Chile and its avalanche deposits. J. Geophys. Res., in press.
- Francis, P. W., 1984. Frost tree rings and the volcanic eruption record. Nature, Matters Arising, in press.

LUNAR AND PLANETARY INSTITUTE  
DOMESTIC VISITING SCIENTIST (VS)  
January 1, 1984 — June 30, 1984

NAME	APPT. PERIOD	IN RESIDENCE (this period)		PURPOSE OF VISIT	AFFILIATION
		DATES	NO. WKS.		
Basu, A.	06/25/84-	06/25/84-	.86	To complete a study on the analysis of agglutinitic glass.	Indiana University, Bloomington
	07/08/84	06/30/84			
Lutz, A.	01/01/83-	-0-	-0-	To complete research and a paper dealing with polar wandering on Mars.	Computer Sciences Corpor- ation, Houston
	06/30/84				
Pepin, R.	03/06/82-	03/07/84-	.29	To continue research on the origin and history of the early solar system and to participate in projects related to his field of expertise.	University of Minnesota, Minneapolis
	03/31/85	03/08/84			
Srnka, L.	10/01/79-	-0-	-0-	To continue research on the origins of planetary magnetism.	EXXON Production Research Co., Houston
	10/02/84				
Wendlandt, R.	10/09/82-	-0-	-0-	To continue research in the Effects of Volatiles of Magmatic Processes and Planetary Evolution: F, Cl, CH <sub>4</sub> , and S.	EXXON Production Research Co., Houston
	10/09/84				



LUNAR AND PLANETARY INSTITUTE  
FOREIGN VISITING SCIENTISTS (FVS)  
January 1, 1984 — June 30, 1984

NAME	APPT. PERIOD	IN RESIDENCE		PURPOSE OF VISIT	AFFILIATION
		DATES	(this period) NO. WKS.		
Compston, W.	03/05/84- 03/16/84	03/05/84-	1.86	To conduct discussions with C. Meyer/JSC on joint ion-probe study of lunar zircon ages, to conduct discussions with J. Wooden/USGS on Minnesota R. Valley zircon ages, and to conduct discussions with L. Nyquist/JSC on possible zircon studies of shergottites (martian rocks?)	Australian National University, Canberra
		03/17/84			
Francis, P.	01/06/83- 02/16/85	01/01/84-	10.86	To conduct LPI related research in planetary and regional geology, and provide leadership and play key role in the organization and execution of the science project concerning Early Crustal Genesis on the Terrestrial Planets. Also, to make significant use of the Image Processing Facility.	The Open University, England
		03/16/84			
Sengor, C.	05/07/84- 05/29/84	05/12/84-	1.71	To collaborate with LPI Director on "Rifts and Sutures of the World".	Istanbul Technical University
		05/16/84			
		05/19/84-			
		05/20/84			
		05/22/84-			
05/26/84					

LUNAR AND PLANETARY INSTITUTE  
VISITING POST-DOCTORAL FELLOWS (VPDF)  
January 1, 1984 — June 30, 1984

<u>NAME</u>	<u>APPT. PERIOD</u>	<u>IN RESIDENCE</u> (this period)		<u>PURPOSE OF VISIT</u>	<u>AFFILIATION</u>
		<u>DATES</u>	<u>NO. WKS.</u>		
Cintala, M.	12/01/83- 12/01/84	01/01/84- 04/27/84	16.86	The primary purpose is to carry out theoretical and experimental research on impact cratering.	LPI (formerly JSC/NRC Fellow)
Clifford, S.	01/31/84- 02/01/85	01/31/84- 06/30/84	21.71	The primary purpose is to work in planetary volatiles.	LPI (formerly Univ. Massachusetts, Amherst)
Gust, D.	03/08/84- 03/08/85	03/08/84- 06/30/84	16.43	To conduct research centered around mantle petrology, utilizing experimental techniques to study mineral stabilities and partition coefficients.	LPI (formerly JSC/NRC Fellow)

LUNAR AND PLANETARY INSTITUTE  
VISITING GRADUATE FELLOWS (VGF)  
January 1, 1984 — June 30, 1984

NAME	APPT. PERIOD	IN RESIDENCE		PURPOSE OF VISIT	S	AFFILIATION
		DATES	(this period) NO. WKS.			
Agosto, Y.	03/12/84- 09/12/84	03/12/84- 06/30/84	15.86	To conduct research on the extraction and processing of lunar and asteroidal meetings.		University of Houston, Central Campus
Brown, C.	10/10/83- 10/10/84	-0-	-0-	To work with R. Phillips/LPI on the North African Lithosphere Project using the LPI Image Processing Facility.		Southern Methodist Univ. Dallas
Chicarro, A.	12/01/83- 06/30/84	01/01/84- 06/30/84	26.00	To select from a previous compilation of a massive computerized data set of ridges on Mars aspects suitable for publication.		University of Paris, Orsay
Liffman, K.	05/15/84- 08/15/84	05/15/84- 06/30/84	6.71	To work with D. Heyman/Rice and D. Bogard/JSC on isotopic anomalies in carbonaceous chondrites.		Rice University, Houston
Marriott, K.	06/14/84- 08/10/84	06/14/84- 06/30/84	2.43	Primary purpose of visit will be digitizing and data reduction of impact experiments and surface process studies under guidance of P. Schultz/LPI.		University of Houston, Central Campus
Meier, T.	05/11/81- 05/11/84	02/02/84 02/07/84 02/28/84 03/22/84 04/05/84 04/18/84	.86	To conduct M.S. Thesis research on multispectral and geomorphic investigations of the surface of Europa.		University of Houston, Central Campus

LUNAR AND PLANETARY INSTITUTE  
VISITING GRADUATE FELLOWS (VGF)  
January 1, 1984 — June 30, 1984

NAME	APPT. PERIOD	IN RESIDENCE (this period)		PURPOSE OF VISIT	AFFILIATION
		DATES	NO. WKS.		
Meloy, A.	04/04/83- 07/01/84	01/01/84-	26.00	To assist P. Schultz/LPI with a variety of projects involving image-processing applications, data reduction from impact experiments, and map digitizing.	LPI Vis. Res. Assistant (formerly Res. Assoc. Hawaii Inst. Geophys. Honolulu)
		06/30/84			
Russell, J.	03/01/84- 08/03/84	03/01/84-	17.43	To continue research on experimental and petrographic study of two lava flows from the Taas Plateau, under the direction of G. Lofgren/JSC.	University of Manitoba, Canada
		06/30/84			
Silver, L.	10/24/83 03/31/84	03/12/84-	.86	To study the role of water in silicate magmas — a Ph. D. Thesis research project under the guidance of E. Stolper/Cal Tech.	California Institute of Technology
		03/17/84			
Stam, M.	06/26/84- 07/17/84	06/26/84-	.71	To add some final touches to thesis on martian impact basins that require the use of a digitizer and high resolution Viking Orbiter images.	University of Massachusetts, Amherst
		06/30/84			

LUNAR AND PLANETARY INSTITUTE  
VISITING UNDERGRADUATE INTERNS (VUI)  
January 1, 1984 \_\_\_\_\_ June 30, 1984

NAME	APPT. PERIOD	IN RESIDENCE		PROJECT & ADVISOR	AFFILIATION
		DATES	(this period) NO. WFS.		
Bertka, C.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	To clarify crystallization mechanisms in terrestrial and lunar basic plutonic systems. (G. Ryder/LPI)	University of Cincinnati, Ohio
Block, L.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	The construction and testing of Geophysical models to test the hypothesis that Venus is a planet without plate tectonics. (P. Morgan/LPI)	Texas A & M University, College Station
Bollinger, J.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	To compile orbital, chemical, and physical observations in order to address fundamental questions concerning how comets may be related. (C. Wood/JSC)	Cornell University, Ithaca
Bonner, R.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	To work in geodynamics to review the tectonic evolution of hinge zones - more places where subducta zones and boundaries join. (K. Burke/LPI)	State University of New York, Albany
Fuller, J.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	To analyse some of the lunar spectra on hand, using existing LPI computer programs, and assist in interpreting the results. (A. Potter/JSC)	University of Washington, Seattle
Haber, S.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	To determine regional differences in drainage densities not only due to changes in lithology but also due to subsequent geologic processes. (P. Schultz/LPI)	Hofstra University, Hempstead, N.Y.
Johnson, P.	06/01/84- 08/17/84	06/01/84- 06/07/84 06/23/84- 06/30/84	2.14	To construct a detailed numerical model for the development and subsequent evolution of a duricrust layer on Mars. (S. Clifford/LPI)	Duke University, Durham, N.C.
Kiefer, W.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	To use Pioneer Venus Orbiter tracking data to derive a high resolution spherical harmonic model of the gravitational potential of Venus for use in compensation. (E. Bills/LPI)	Texas Christian University, Fort Worth

LUNAR AND PLANETARY INSTITUTE  
VISITING UNDERGRADUATE INTERNS (VUI)  
January 1, 1984 — June 30, 1984

<u>NAME</u>	<u>APPT. PERIOD</u>	<u>IN RESIDENCE DATES</u>	<u>NO. WKS.</u>	<u>PROJECT &amp; ADVISOR</u>	<u>AFFILIATION</u>
Marks, G.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	Samples will be searched for both primary and secondary fluid inclusions. Heating and cooling experiments will be carried out on selected samples in order to determine homogenization and freezing temperatures. (F. Gibson/JSC)	Ohio State University, Columbus
McDowell, A.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	Development of a semi-empirical production model for spallogenic noble gases in chondritic meteorites. (L. Nyquist/JSC)	Rice University, Houston
Olds, S.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	Support and conduct impact experiments with the vertical gun in order to address the differential comminution of planetary regoliths via suitable terrestrial analogs. (F. Horz/JSC)	University of Colorado, Boulder
Rhudy, L.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	Fluid inclusions in proterozoic charnockites including microthermometry of fluid inclusions in granitic rocks associated with Labrador anorthosites. (L. Ashwal/LPI & W. Phinney/JSC)	University of Texas, Austin
Smrekar, S.	06/11/84- 08/17/84	06/18/84- 06/30/84	1.86	The execution of a series of laboratory impacts into target rocks at various low temperatures in an effort to understand the differences between the hot and cold cases. (M. Cintulla/JSC)	Brown University, Providence
Young, C.	06/11/84- 08/17/84	06/11/84- 06/30/84	2.86	Experimental study of the diopside-jadeite system at intermediate and high pressures. Experiments analyzed by optical, XRD and electron microprobe methods. (D. Gust/LPI)	University of Washington, Seattle

APPENDIX I - PART C

STAFF & VISITOR OFF-SITE SCIENTIFIC ACTIVITIES

1 January 1984 - 30 June 1984

Dr. Peter Schultz presented a lecture on "Polar Wandering on Mars" at the Houston Astronomical Society at the University of Houston on January 6.

Dr. Paul Morgan visited Purdue University to present two seminars on the subject of "Development of Continental Rifts" on January 16 and 17. (This visit was at no cost to the LPI.)

Dr. Peter Francis delivered a lecture at the Southern Methodist University, Department of Geological Sciences, on "Remote Seising of Andean Volcanoes" on January 20. (This visit was at no cost to the LPI.)

Dr. Kevin Burke served as an examiner for Carolyn Brown's Ph. D orals at SMU, Department of Geological Sciences, on January 20 at no cost to the LPI.

Dr. Kevin Burke attended the NASA Space and Earth Science Advisory Committee (SESAC) meeting in Washington, D. C. on January 23 and 24.

Mr. Kin Leung, Mr. Ron Weber, and Mr. Carl Grossman attended the IBM-PC World Exposition in Houston, Texas on February 3.

Dr. Peter Francis addressed a professional group in Bellaire, Texas on February 9 on "Earth Observations from the Space Shuttle".

Mr. Kin Leung and Mrs. Fran Waranius attended a demonstration of the Rolm Telephone System (as a possible replacement for the LPI phone system) in Houston on February 9.

Dr. Paul Morgan presented two seminars on the "Physical Characteristics and Evolutionary Trends of Continental Rifts" to the Department of Geosciences, Purdue University, West Lafayette, Indiana, on February 13 and 14. (The visit was at no cost to the LPI.)

Dr. Peter Schultz gave a lecture on "The Earth: yesterday, Today and Tomorrow--Clues from the Planets" at the Clear Lake City Chemical and Mineral Show in Houston on February 19.

Dr. Peter Schultz participated in a thesis review for Marianne Stamm at the Univ. of Mass., Amherst, and presented a seminar on "Polar Wandering on Mars" on February 24. (This visit was at no cost to the LPI.)

Mr. Carl Grossman and Ms. Pam Thompson attended a demonstration of the Quadex phototypesetting system, which incorporates software for setting complex equations and tables, at Compugraphic, Inc., in Houston on March 16. (The only cost involved was for gas.)

Dr. Paul Morgan visited Purdue University, Geoscience Department, Indiana, and presented two seminars on "Evolution and Mechanisms of Continental Rifting" on March 19 and 20. (Visit was at no cost to LPI.)

Dr. David Gust visited Alfred University in New York on March 20 and gave a lecture entitled "Volcanism of the Colorado Plateau, Arizona". While in New York he visited SUNY in Albany, March 21-23, where he gave a lecture entitled "Partial Melting of Eclogite: Experimental Problems and Geological Implications" and discussed research projects with Dr. T. M. Harrison. (Visits were at no cost to LPI.)

Dr. Paul Morgan visited the Department of Geosciences, Southern Methodist University, Dallas, March 21-23, for experimental studies associated with fission track dating of samples from eastern Egypt. (Visit was at no cost to the LPI.)

Dr. Kevin Burke attended the 1984 South-Central GSA meeting in Dallas on March 27 where he co-chaired a symposium on "Tectonics and Stratigraphy of the Caribbean Region: Bearing on Its Origin".

Mrs. Pam Jones conducted a site inspection of Kona conference centers in preparation for the "Origin of the Moon" Conference to be held in October of this year in Kona, Hawaii. Mrs. Jones departed on March 29 and returned April 3; site inspection was at the request of the Conf. Program Committee.

Mr. Ron Weber presented a slide talk on "Planets and Stars" to 60 Sixth Grade students at the Bay Elementary School on March 30 at the request of Mr. Gary Brown.

Mr. Ron Weber gave a slide presentation, "Stars and Planets" to 125 5th-grade students at the Armand Bayou Elementary School, Houston, on April 3.

Dr. Peter Schultz presented a seminar at Brown University on April 10 entitled "Understanding Planetary Impact Cratering through Laboratory Experiments". (Cost of visit was paid for by Brown Univ., Providence.)

Dr. Peter Schultz presented a seminar at JPL, Pasadena, on April 20 entitled "Planetary Impact Cratering: Clues from Laboratory Experiments." (Cost of visit was paid for by JPL.)

Dr. Kevin Burke attended the Conference on Collisional Tectonics at Texas A&M on April 26 and 27.

Mr. Kin Leung attended Spectrum '84, a computer hardware and software exhibition sponsored by DEC on May 2 in Houston.

Ms. Pam Jones visited Flagstaff, May 6-9, to determine a suitable facility (and conduct site inspection) for the "Extensional Tectonism" conference to be held in April 1985.



Dr. Peter Schultz conducted experiments at the NASA-Ames Vertical Gun Range; presented status report and review of Ames Gun Facility to Mr. Joe Boyce; presented a seminar at NASA-Ames, Space Science Division; and visited JPL to discuss research with Dr. W. Ward, Mountain View, Calif. and Pasadena, Calif., May 6-18.

Dr. Kevin Burke attended the AGU meeting in Cincinnati, Ohio, May 13-15. He presented a paper (co-authored with Paul Morgan) entitled "Thermal Regime of the Lower Crust"; chaired the session on Lower Crustal Processes I and presented a paper (co-authored with William Phinney) entitled "Can We Lure the Lower Crust to Yield its Secrets?"; presented a paper (co-authored with J. Casey and P. Robertson) entitled "Deformation of Orinoco Delta Mud Diapirs in the South Caribbean Strike-Slip Plate Boundary Zone".

Ms. Rebecca McAllister attended the National Computer Graphics Association (NCGA) Conference and Exposition in Anaheim, California on May 14-17.

Dr. Graham Ryder attended the AGU meeting in Cincinnati, Ohio, May 14-17. He presented a paper entitled "Chemistry and Origin of Oikocrysts in the Stillwater". While in Cincinnati, he attended the Journal of Geophysical Research (red) Associate Editors luncheon meeting in his capacity as an Associate Editor and also as an Editor of the Proceedings of the 15th Lunar and Planetary Science Conference. A substantial part of the discussion concerned aspects of the publication of the Proceedings.

Dr. Kevin Burke conducted field work in connection with the thermal history of the Rio Grande Rift in New Mexico, May 20-22, and attended the Venus Workshop in Malibu and Los Angeles, May 23-25. (The field work was funded by the State University of New York.)

Ms. Pam Thompson, Ms. Sharon Adlis, Ms. Donna Chady, and Mr. Carl Grossman toured the Drake Company Printing plant in Pasadena, Texas. Discussions were held and demonstrations by the owner/manager were provided of pre-press, printing, and finishing techniques. Also discussed were low-cost options for color printing of anticipated LPI materials. The tour took place on May 24.

Dr. Bruce Bills attended a Venus Tectonics Workshop in Los Angeles on May 24-25.

Mr. Kin Leung was present at a demonstration of CTOS, a DEC compatible word processing package, in Houston on May 29.

Dr. Kevin Burke attended a NASA Space and Earth Sciences Advisory Committee (SESAC) meeting in Washington, D. C., May 30-June 1. (The cost of the trip was paid for by NASA.) See Appendix VII for Committee Report Chaired by Burke.

Ms. Pam Jones conducted a site inspection of Tamarron, a potential conference site in Durango, Colorado, and attended a program committee meeting for the 47th Meteoritical Society meeting to be held in late July, June 7-12, Durango and Albuquerque, N. M., respectively.

Ms. Fran Waranius attended the Special Libraries Association meeting in New York June 10-14.

Mr. Ron Weber attended the Special Libraries Association meeting in New York and met with members of the Map, Picture, and Management Divisions, June 10-14.

Dr. Kevin Burke spent the period June 15-30 in Albany New York working with graduate students on problems of the Geodynamic history of the earth (funded through the Geodynamics Program of NASA).

Mr. Kin Leung attended a Digital Equipment Corporation Product Seminar in Clear Lake on June 19-20.

Dr. Kevin Burke gave a presentation to Dr. Burton Edelson, Associate Administrator for Space Science and Applications, on June 22 at NASA Headquarters. (Expenses were covered by NASA.)

Dr. Kevin Burke attended the International Symposium on Deep Structure of the Continental Crust at Cornell University, Ithaca, June 26-28.

Dr. Lew Ashwal conducted field work in the Adirondacks, New York, Superior Province of Ontario, beginning June 26 and will continue on to July 12. From there he will proceed to Toronto to depart for Norway to attend the NATO Advanced Study Institute (partially funded by NATO), July 15-30; will confer with officials at the Geological Survey of Greenland, Copenhagen, Denmark on Early Crustal Genesis related studies, July 31 - August 2, before returning to Houston.

APPENDIX II

PART A: PROJECTS, CONFERENCES, AND  
WORKSHOPS

PART B: SEMINARS

APPENDIX II - PART A

Lunar and Planetary Institute Workshops and Conferences

March 1982—October 1985

Topic	Dates	Conveners	Attendance-Sponsor	Publication
13th Lunar and Planetary Science Conference	3/15-19/82	M. Duke R. Phillips	557—LPI/JSC hosted by JSC	Abstract Volume Proceedings Volumes
Workshop on Antarctic Glaciology and Meteorites	4/19-21/82	M. Lipchut C. Bull	39—LPI	Abs.—LPI Tech. Rpt.
Workshop on Planetary Tectonics	4/19-21/82	R. Phillips	12—LPI in Burnet, TX	
45th Annual Meeting of the Meteoritical Society	9/13-16/82	R. Walker G. Crozatz	210—LPI, Washington U. McDonnell Ctr for the Space Sci	Abstract Volume
Conference on Planetary Volatiles	10/9-12/82	R. Pepin R. O'Connell	100—LPI Arrowwood Conference Ctr. Alexandria, MN	Abstract Volume LPI Technical Report
Workshop on Pristine Lunar Highlands Rocks and the Early History of the Moon	10/15-17/82	J. Longhi G. Ryder	41—LPI Travelodge New Orleans	Abstracts LPI Technical Report
Conference on Chondrules and their Origins	11/15-18/82	E. King	64—LPI	Abstract Volume Proceedings Volume
14th Lunar and Planetary Science Conference	3/14-18/83	M. Duke R. Phillips	525—LPI, AGU JSC -hosted by JSC	Abstract Volume Proceedings Volume
1983 Archean Geochemistry — Early Crustal Genesis Field Workshop	8, 10-16/83	L. Ashwal K. Card	46—LPI/Geol Survey of Canada	Abstracts, Field Guide LPI Technical Report
Workshop on Past and Present Solar Radiation Record in Meteoritic and Lunar Regolith Material	9/3-4/83	D. McKay R. Pepin	60—LPI at Max-Planck-Inst in Mainz, F.R.G	Abstracts Volume Technical Report
46th Annual Meeting of the Meteoritical Society	9, 5-9/83	F. Begeemann H. Wanke	300—LPI, Max Planck Inst., in Mainz, F.R.G	
Annual Meeting of the Association of Earth Science Editors	10/9-12/83	R. Ridings R. Merrill	93—LPI/AESE hosted by LPI w/sessions at Nassau Bay Hilton Houston, TX	
Workshop on Lunar Surface Materials	2/14-15/84	G. Heiken L. Taylor	15—LPI	Book
15th Lunar and Planetary Science Conference	3/12-16/84	M. Duke K. Burke	550—LPI, JSC, AGU/DPS, Met Soc. hosted by JSC	Abstract Volume Proceedings Volume
Workshop on Early Earth: The Interval from Accretion to the Older Archean	4/23-25/84	K. Burke	80—LPI	Abstract Volume Technical Report
Workshop on Cosmogenic Nuclides	7/26-27/84	R. Reedy	40—LPI	Technical Report
47th Annual Meteoritical Society Meeting	7/30-8/2/84	K. Keil	~300—LPI, Inst. Meteoritics & Dept. Geology at Univ. NM	Abstract Volume
Conference on the Origin of the Moon	10/13-16/84	W. Hartmann R. Phillips J. Taylor	~120—LPI & DPS Kona, Hawaii	Abstract Volume Proceedings Volume
Conference on Water on Mars	11/30-12/1/84	R. Greeley R. Haberle	~60—LPI & NASA Ames	Abstract Volume
16th Lunar and Planetary Science Conference	3/11-15/85	K. Burke M. Duke	~500—LPI	Abstract Volume Proceedings Volume
Workshop on the World's Oldest Rocks	6/85	L. Ashwal V. McGregor	~25—LPI Godthaab, Greenland	Technical Report
1985 Manitoba Field Workshop	8/85	W. Weber	~44—LPI & GSC	Technical Report
Conference on Heat and Detachment in Crustal Extension on Continents and Planets	10/10-12/85	I. Lucchitta P. Morgan	~75—LPI & USGS	Abstract Volume Proceedings Volume

APPENDIX II - PART B

SEMINAR SERIES

1 January 1984 - 30 June 1984

<u>DATE</u>	<u>SPEAKER(S)</u>	<u>TOPIC</u>
January 9	Dr. Horton Newsom Max-Planck Institut fur Chemie	"Accretion and Core Formation in the Earth and Moon--New Evidence from Molybdenum and Tungsten"
January 13	Dr. Graham Ryder LPI	"Petrogenesis in the Stillwater Complex and the Moon"
January 18	Dr. Mark Harrison SUNY - Albany	"Thermal Histories of Granites, Metamorphic Rocks, Sedimentary Basins and Chondrites from Ar <sup>40</sup> / <sub>39</sub> Studies"
January 27	Dr. Paul Morgan LPI	"Thermal Structure and Evolution of Continental Lithosphere"
February 3	Dr. David Gust LPI	"Eclogite Melting - Subduction and Recycling"
February 10	Dr. Alan Binder NRC Senior Fellow/JSC	"Evidence for Recent Tectonic Activity on the Moon"
February 17	Dr. James R. Zimelman Arizona State Univ.	"Remote Sensing and Data Analysis of Martian Volcanoes"
February 24	Dr. Russell Harmon Southern Methodist Univ.	"Stable and Radiogenic Isotope Systematics: A Fingerprint to Magma Source Region and Crustal Composition in the Classic Scottish Igneous Province"
March 27	Dr. V. R. McGregor Geological Survey of Greenland	"Isotopic Resetting Associated with Late Archean Granulites in Greenland"
March 30	Dr. Christopher Scotese Univ. Texas at Austin	"Evolution of the Southern Oceans"
April 6	Dr. Peter Schultz LPI	"Polar Wandering on Mars"

APPENDIX II - PART B (continued)

SEMINAR SERIES

1 January 1984 - 30 June 1984

<u>DATE</u>	<u>SPEAKER(S)</u>	<u>TOPIC</u>
April 13	Dr. Akira Tsuchiyama JSC	"Melting Dissolution Kinetics of Plagioclase and Diopside"
April 16	Dr. Laurence Lawver Univ. Texas at Austin	"Tectonics of the Arctic"
May 4	Dr. Raymond J. Willemann Texas A & M Univ.	"Tectonics on One Plate Planets: Forces that Don't Drive the Plates"
May 11	Dr. Donald A. Morrison NASA/JSC	"The Mulcahy Intrusion, NW Ontario: Implications for the Evolution of Greenstone-Granite Terrains"
May 21	Dr. John Stephens Los Alamos Nat'l Lab.	"Interstellar Dust: Experiments in the Laboratory, the Stratosphere and Low Earth Orbits"
June 8	Dr. Mark Cintala NASA/JSC	"Impact Experiments at JSC: Gratification Through Planetary Demolition"
June 14	Dr. William J. Hinze Purdue Univ.	"Crustal Mapping with Magsat"
June 29	Dr. Frans Rietmeijer NRC Fellow/JSC	"Stratospheric Dust Collections and the Search of Extraterrestrial Materials"



APPENDIX III  
OTHER MEETINGS AND ACTIVITIES  
(held at LPI)



### APPENDIX III

#### OTHER SCIENCE RELATED MEETINGS AND ACTIVITIES HELD AT LPI

1 January 1984 - 30 June 1984

The JSC Life Sciences Project Division held a flight experiments program meeting at the LPI on January 7 and 8.

Dr. Peter Francis participated in the debriefing of Shuttle Mission STS 9 crew in connection with the Earth Observations Program on January 10.

JSC Life Sciences Directorate held a Proposal Review meeting at the LPI on January 17.

The Program Committee for the 15th Lunar and Planetary Science Conference met at the LPI on January 25-27.

The JSC NASA Industrial Productivity Council met at the LPI on February 8-9.

The Remote Sensing Research Branch of the JSC Earth Sciences and Applications Division held a meeting at the LPI February 13-17.

NASA/JSC conducted a debriefing of the Astronauts of the STS-11 Mission at the LPI on February 13-14.

A Spaceweek 84 Board of Directors' meeting was held at the LPI on February 14.

Drs. Paul Morgan and Kevin Burke conducted an informal discussion at the LPI on February 21 of the paper by Dr. Don Anderson entitled "The Earth as a Planet: Paradigms and Paradoxes".

An informal discussion of the paper by R. K. O'Nions and E. R. Oxburgh, entitled "Heat and Helium in the Earth" was held at the LPI on March 6.

A NASA Space Station Inter-Center Management meeting was held at the LPI March 7-9.

Dr. B. Lucchitta held a Ganymede Mappers' meeting at the LPI on March 11.

The Meteoritical Society Council (chaired by D. Bogard) met at the LPI on March 12.

Mr. J. Boyce held a Planetary Geology Working Group meeting at the LPI on March 12.

The USRA Lunar and Planetary Science Council (chaired by K. Keil) met at the LPI on March 14.



A Lunar Materials meeting (chaired by G. Heiken) was held at the LPI on March 15.

The Early Earth Workshop Program Committee (chaired by K. Burke) met at the LPI on March 15.

Dr. Mark Cintala co-chaired a meeting at the LPI on March 15 to discuss plans for planetary geology on NASA's Space Station.

The Steering Committee for Planetary Meetings (chaired by K. Burke) met at the LPI on March 16.

A JSC Space Biomedical Peer Review Panel met at the LPI on March 31.

An administrative debriefing of the 15th Lunar and Planetary Science Conference was held at the LPI on April 5th. The debriefing was conducted by Mr. James Townsend/JSC Solar System Exploration Division.

NASA/JSC conducted a post mission debriefing of STS 13 at LPI on April 16-17.

An informal discussion of J. B. Pollack's and D. C. Black's article on "Implications of the Gas Compositional Measurements of Pioneer Venus for the Origin of Planetary Atmospheres" (Science, v. 205, p. 56-59, 1979) was held at the LPI on May 6.

NASA's Space and Earth Sciences Advisory Committee (SESAC) met at the LPI on May 10 and 11. See Appendix VII for Committee Report Chaired by Burke.

The JSC Solar System Exploration Division held discussions, under the direction of Dr. W. Phinney/JSC, on the exploration of the solar system on May 19 at the LPI.

The USRA Board of Directors met at the LPI on June 5.

The Summer Interns conducted Brown Bag (lunch) seminars on June 15, 22, and 29.

The Biomedical Applications Branch of the JSC Medical Sciences Division held a Medical Investigation Module Working Group meeting at the LPI June 28-29.

APPENDIX IV

LPI CONTRIBUTIONS AND TECHNICAL REPORTS

APPENDIX IV

LUNAR AND PLANETARY INSTITUTE CONTRIBUTIONS  
1 JANUARY 1984 TO 30 JUNE 1984

- 526 LPI EDITORIAL BOARD  
PRESS ABSTRACTS - XV LUNAR AND PLANETARY SCIENCE CONFERENCE  
MARCH 12-16, 1984  
HOUSTON, TEXAS, LPI, 1984.
- 527 HINZE, W.J. + BRAILE, L.W. + ... + MORGAN, P. ET. AL  
EXPLORATION FOR HOT DRY ROCK GEOTHERMAL RESOURCES IN THE  
MIDCONTINENT USA  
ACCEPTED FOR PUBLICATION IN LOS ALAMOS NATIONAL LABORATORY  
REPORT - 3 VOLUMES
- 528 HENRY, D.J. + GUIDOTTI, C.V.  
TOURMALINE AS A PETROGENETIC INDICATOR MINERAL: AN EXAMPLE  
FROM THE STAUROLITE GRADE METAPELITES OF NW MAINE  
ACCEPTED FOR PUBLICATION IN AMERICAN MINERALOGIST
- 529 STOFFLER, D.  
GLASSES FORMED BY HYPERVELOCITY IMPACT  
ACCEPTED FOR PUBLICATION IN PROCEEDINGS OF THE CONFERENCE  
ON NATURAL GLASSES TO BE PUBLISHED IN JOURNAL OF  
NONCRYSTALLINE SOLIDS
- 530 MORGAN, P. + SASS, J.H.  
THERMAL REGIME OF THE CONTINENTAL LITHOSPHERE  
ACCEPTED FOR PUBLICATION IN JOURNAL OF GEODYNAMICS
- 531 SENGOR, A.M.C. + SATIR, M. + AKKOK, R.  
TIMING OF TECTONIC EVENTS IN THE MENDERES MASSIF, WESTERN  
TURKEY: IMPLICATIONS FOR TECTONIC EVOLUTION AND  
EVIDENCE FOR PAN-AFRICAN BASEMENT IN TURKEY  
ACCEPTED FOR PUBLICATION IN: TECTONICS
- 532 MORGAN, P. + GOLOBEK, M.P.  
TWO PHASES AND TWO STYLES OF EXTENSION IN THE NORTHERN  
RIO GRANDE RIFT  
ACCEPTED FOR PUBLICATION IN: NEW MEXICO GEOLOGICAL SOCIETY  
35TH FIELD CONFERENCE GUIDEBOOK
- 533 RUDNICK, R.L. + ASHWAL, L.D. + HENRY, D.J.  
FLUID INCLUSIONS IN HIGH-GRADE GNEISSES OF THE KAPUSKASING  
STRUCTURAL ZONE, ONTARIO: METAMORPHIC FLUIDS AND  
UPLIFT/EROSION PATH  
ACCEPTED FOR PUBLICATION IN: CONTRIBUTIONS IN MINERALOGY  
AND PETROLOGY
- 534 MANN, P. + BURKE, K.  
NEO-TECTONICS OF THE CARIBBEAN  
ACCEPTED FOR PUBLICATION IN: REVIEWS OF GEOPHYSICS AND  
SPACE PHYSICS

535 MANN, P. + BURKE, K.  
CENOZOIC RIFT FORMATION IN THE NORTHERN CARIBBEAN  
ACCEPTED FOR PUBLICATION IN: GEOLOGY

536 MANN, P. + BURKE, K. + MATUMOTO  
NEOTECTONICS OF HISPANIOLA  
ACCEPTED FOR PUBLICATION IN: EARTH AND PLANETARY SCIENCE  
LETTERS

LPI TECHNICAL REPORTS

No activity during this period

APPENDIX V  
NASA-AMES VERTICAL GUN STATUS REPORT

## NASA-Ames Vertical Gun: A Status Report

Peter H. Schultz

LPI Science Coordinator

May, 1984

Introduction:

The NASA-Ames Vertical Gun Range (AVGR) was re-opened in 1979 as a national facility, thereby providing the scientific community ready access to a unique laboratory. The AVGR had established an excellent reputation for revealing fundamental aspects of impact cratering that provided important constraints for planetary processes (e.g., see Gault *et al.*, 1968; Gault, 1970; Oberbeck, 1971; Oberbeck *et al.*, 1974). During the five years since re-opening of the AVGR in the summer of 1979, sixteen separate groups of researchers have focused on twenty-four different programs (Appendix A) resulting in forty abstracts and papers (Appendix B). The following report briefly reviews the current logistics in accessing the AVGR, some of the past and ongoing experimental programs and their relevance, and the future role of this facility in planetary studies.

Accessing the Vertical Gun: The AVGR is operated through contract personnel managed by the Thermophysics Facilities Branch. The Lunar and Planetary Institute interfaces between potential scientific users and the AVGR facility through a Science Coordinator. While Ames personnel provides day-to-day operational guidance, the LPI Science Coordinator provides general scientific counsel for inquiries and potential users. Proposals to use the AVGR are reviewed by mail by the LPI-AVGR Steering Committee, and the results and recommendations from this committee are referred to the Ames Technical Monitor. Such procedures provide processing of requests in a timely and unbiased manner, thereby insuring the standards as a national facility.

The AVGR is available at no direct cost to the scientific user. Several types of users may be provided access to the facility. First, scientists who have successfully proposed a program of research through the Planetary Geology and Geophysics Program (PGGP) are given priority in accessing AVGR time. Although their program may have undergone successful review through the Lunar and Planetary Review Panel (LPRP), a specific experimental series is still reviewed and scheduled through the Steering Committee. Second, scientists may request through PGGP a low-cost mini-grant in order to support exploratory or feasibility studies. Again, their experimental program must be reviewed by the Steering Committee prior to scheduling. Third, qualified scientists without direct NASA support for a specific program of research can use the AVGR following successful review and scheduling by the Steering Committee. These three avenues of access to the AVGR has insured timely access to the laboratory by a variety of users. Because the user is not directly charged for NASA-Ames services, successful scientific programs can be (and have been) performed with no or very minimal additional cost to NASA. This particular avenue of access has accounted for about 70% of the users in the past

Selected Past and Ongoing Experimental Programs: The AVGR facility has provided important new data for understanding impact cratering. These data provide a

physical basis for interpreting planetary processes to complement the observed surface record and finite-element computer codes. The following ongoing and past research programs illustrate the diversity in approaches.

1. Impacts in Viscous Targets (R. Greeley, PI, Arizona State University). Between 1980 and 1982 R. Greeley, J. Fink and D. Gault examined the effect of target viscosity on the formation and collapse of the transient crater. Although the initial experimental series was focused on martian ejecta emplacement, unexpected results led to a new area of research concerned with the formation of central peaks, pits, and rings by oscillatory motions of the collapsing transient crater. Possible applications include cratering on the Galilean satellites where a variety of crustal viscosities can be inferred. The project was funded through the PGGP.
2. Experimental Collision Studies (W.K. Hartmann, PI, Planetary Science Institute). Hartmann and his coworkers (D.R. Davis and S.J. Weidenschilling) have used the facility to examine the fragmentation of rock and aggregate targets by normal and oblique impacts. The distribution of ejecta, the transfer of momentum, and the degree of fragmentation all provide information on the collisional processes of asteroids and ring-particle interactions that can be incorporated in computer models of asteroid evolution. This project was funded through PGGP.
3. Atmospheric Effects on Impact Cratering (P. Schultz, Lunar and Planetary Institute). Although considerable data have been collected for impacts in a vacuum environment, very little work has previously been done on impacts in an atmosphere. This study has concentrated on the dynamic interactions between the growing impact crater and the atmosphere. Impacts in fine-grained anhydrous targets produced ejecta deposits that closely resemble ejecta deposits around much larger martian craters. Theoretical analysis of the controlling variables and observed hydrodynamic phenomena indicate that scaling to martian craters is (to a degree) valid. Unexpected results also have led to important new scaling relations between impact energy and crater dimensions for impacts in an atmosphere with applications for not only Mars, but also Venus and the Earth. Supplemental NASA funding was not solicited; travel support was provided by the LPI as part of staff scientist research.
4. Pelagic Impacts (C. Sonett, University of Arizona). Sonett, working closely with D. Gault, has been investigating the effects of impact cratering in water under vacuum and non-vacuum conditions. Their goal is to understand the origin and propagation of waves by an impact event with the obvious application to the effect of impacts in terrestrial oceans. Unexpected results for impacts under atmospheric pressures have led to a new area of research with important and fundamental implications for understanding the early-time interactions between the projectile bow shocks and water. This research program received a low cost (approx. \$5K) mini-grant in 1981 for an exploratory series of experiments.

5. Impact Vaporization Studies (P. Tsou, Jet Propulsion Laboratory). In a collaborative effort with D. Brownlee and A. Albee, P. Tsou has tested the concepts of collecting hypervelocity material. Although direct applications concern recovering material during a possible comet fly-by mission, experience gained from these experiments may be applied to early-time processes in general. This research was performed through JPL support.
6. Oblique Impact Experiments (H. Zook, Johnson Space Center). In a preliminary series of experiments, Zook examined the high-velocity component of ejecta resulting from a hypervelocity grazing impact. The purpose was to see if and how many of the high-velocity ejecta had the characteristics of hypervelocity impacts. The results may provide new insight for the observed discrepancies between impact-pit data on lunar samples and spacecraft observations of micron to sub-micron size particles. The experimental series did not require a supplemental NASA grant.
7. Multiple-body Impacts (P. Schultz, Lunar and Planetary Institute). Low velocity impacts by  $10^2 - 10^3$  projectiles have been performed by Schultz and Gault in order to examine the cratering efficiency, change in crater morphology, and distribution of projectile material for swarms of impactors. The results have added new information for one aspect of secondary cratering and the production of crater rays. They also have led to the general problem of the effects of projectile density and strength on energy-diameter scaling relations as well as crater morphology.
8. Brittle-Ductile Transition of Impacted Meteorites (T. Matsui, University of Tokyo). Previous studies of the failure of iron meteorites have involved low strain rates. T. Matsui initiated a program to study meteorite failure at the high strain rates produced by impacts. By impacting these samples at temperatures from 100°K to 290°K, he hopes to simulate conditions in the Solar System and gain a better understanding for the evolution of asteroids.

The preceding research programs underscore the variety of perspectives brought to the Ames facility. It also illustrates that a basic aspect of experiments is serendipity where one research objective may lead to new directions. Appendix B documents the resulting publications. The list is dominated by abstracts because most programs involve an iterative approach: an initial experimental series, followed by analysis, followed by a supplemental series of experiments, etc. Full reports from several experimental series are currently in preparation. As shown in Appendix B, results from the AVGR have contributed to a variety of meetings including: Lunar and Planetary Science Conferences, Planetary Geology Principal Investigators Meeting, American Geophysical Union, Multi-ring Basin Conference, International Colloquia on Mars, International Conference on the Venus Environment, The Saturn Conference, and The Snowbird Conference on the Effects of Large-body Impacts on the Earth. In addition, public and scientific awareness of the AVGR Facility has been broadened through exposure on: the cover of EOS; reports in Science; the TV program, "In Search Of"; Encyclopedia Britannica (1983 Year-in-Review: Earth Sciences); Life Magazine; the BBC science TV program "Shooting the Moon"; and the "Scheme of Things", a science series on the Walt Disney cable channel.



Future Role of the AVGR: The Ames Vertical Gun Facility is a unique facility in several respects. First, it provides access to three different launch capabilities: air gun (less than 0.2 km/s); single-stage powder gun (0.5 km/s - 3 km/s); and the two-stage light-gas gun (3 km/s - 8 km/s). Although slightly higher velocities with higher mass are possible with some commercially available gun ranges, the AVGR permits timely access for a greater wide variety of applications. Second, it permits variable launch configurations, including vertical, in a large environmentally controlled chamber. Most guns in use by the defense department are horizontal, and few other facilities have a large impact chamber that permits a variety of in situ conditions resembling planetary environments. Third, it provides relatively low-cost operational support serving a large number of researchers. This aspect cannot be underestimated. Commercial guns reportedly charge up to \$2K/shot for defense department contracts and often are not configured for many experiments of planetary interest. Thus, the AVGR facility provides a unique capability to planetary researchers that cannot be duplicated by other existing facilities without substantially increased cost.

Several experimental programs are anticipated during the next year. First, the availability of very high frame-rate photographs permits examining a variety of very early-time processes, such as the high-velocity jetting phenomenon and the interaction between atmospheric bow shocks and ejecta. This early-time record is important not only for comparisons with theoretical models, but also for revealing unexpected phenomena. Second, cratering efficiency and crater morphology changes with velocity as a result of physical changes in the projectile. A series of experiments is planned to parameterize these changes with broad applications for energy-scaling relations. Third, experiments should permit testing the concept of acoustic fluidization with application to the dynamics of crater collapse and ejecta flow. Fourth, an effort is planned to examine mechanisms for launching unmelted target material at velocities comparable to the velocity of a low-angle impactor.

Longer term availability of the AVGR as a national facility is essential. Past experience has demonstrated that planned research programs with anticipated results represent only one payoff. Unexpected results repeatedly have led to new insights. Additionally, new perspectives offered by analysis of space mission data, terrestrial field work, theoretical models, and focused research efforts will continue to stimulate new experimental programs. Continued access of this facility by planetary researchers would insure that theories and notions could be tested and expanded as the context changes.

APPENDIX A

Research Programs with Ames Vertical Gun Range (1979-1984)

1. Hartmann: Low-velocity Fragmentation Studies (1979).
2. Schmidt/Holsapple: Crater Scaling Studies.
3. Greeley/Gault: Martian Impact Simulations (1979-1980).
4. Fuller: Impact-generated Magnetic Fields (1979).
5. Thomsen: Cratering Flow-fields (1979-1980).
6. Schultz/Gault: Low-velocity Multiple-body Impacts (1979-1980).
7. Ahrens: Impact-generated Vaporization Studies (1979).
8. Austin/Hawke: Miscellaneous Impact Studies (1980).
9. Croft: Impacts into Icy Targets (1980-1981).
10. Gault: Water Impact Studies (1980-1982).
11. Greeley/Fink: Impacts in Bingham Materials (1980).
12. Schultz/Gault: Impacts in an Atmosphere Environment (1981-1984).
13. Sonnet/Gault: Impacts in Water under Non-vacuum Conditions (1981-1984).
14. Greeley/Fink: Effect of Viscosity on Impact Scaling (1981-1982).
15. Davis/Weidenschilling: High-velocity Fragmentation and Momentum transfer Experiments (1981-1984).
16. Tsou: Collection of Impact Products (1982-1984).
17. Ahrens: Collection of Impactors (1982).
18. Zook: Hypervelocity Grazing Impact Studies (1982).
19. Schultz/Gault: Hypervelocity Cluster Impacts (1982-1984).
20. Schmidt: Particle Motion from Impacts (1982).
21. Austin: Ejecta Kinematics (1984).

22. Matsui: Brittle-ductile Transition of Impacted Meteorites (1983-1984).
23. Schultz/Gault: Projectile Deformation and Crater Scaling/Morphology (1983-1984).
24. Polanski/Burnett: Meteorite Signatures in Spacecraft Materials (1984).

APPENDIX B

Publications Resulting from Experiments with NASA-Ames Vertical Gun (1979-1984), arranged alphabetically by author.

1. Austin, M.G. (1984). Impact cratering experiments for ejecta kinematics analysis. Lunar and Planetary Science XV, p. 21-22.
2. Croft, S.K., (1982). Impacts in Ice and Snow: Implications for Crater scaling on Icy Satellites. Lunar and Planetary Science XIII, p. 135-136.
3. Croft, S.K., (1982). Crater Scaling and Morphology on Icy Satellites (abstract), Saturn: Program and Abstract, for Saturn Meeting, May 11-15, Tucson, Arizona, p. 27.
4. Croft, S.K., (1981). Hypervelocity Impact Craters in Icy Media. Lunar and Planetary Science XII, p. 190-192.
5. Davis, D.R. and S.J. Weidenschilling (1982). Catastrophic Disruption and Momentum Transfer in high-speed impacts. Lunar and Planetary Science XIII, 142-143.
6. Fink, J. H. and Greeley, R. (1983). Experimental impacts into viscous fluids: Implications for oscillating peak models of crater formation. Lunar and Planetary Science XIV, p. 193-194.
7. Fink, J. H., R. Greeley, and D.E. Gault (1983). The effect of viscosity on impact cratering of the icy Saturnian satellites. Geophys. Res. Lett. (in press).
8. Fink, J.H., Greeley, R., Gault, D.E. (1982). The effect of crustal viscosity on impact cratering of icy satellites. Reports of Planetary Geology Program - 1982, NASA TM-85127, p. 101-102.
9. Fink, J.H., R. Greeley, and D. E. Gault (1982). The effect of viscosity on the volume and shape of experimental impact craters. Lunar and Planetary Science XIII, 217-218.
10. Fink., J.H., R. Greeley and D.E. Gault (1981). Impact cratering experiments in Bingham materials and the morphology of craters on Mars and Ganymede. Proc. Lunar Planet. Sci. Conf. 12th, 1649-1666.
11. Fink, J. H., R. Greeley, and D.E. Gault (1980). "Fluidized" impact craters in Bingham materials and the distribution of water on Mars. In Proc. Third Collog. on Planetary Water and Polar Processes, p. 64-67. SUNY, Buffalo, N.Y.
12. Fink, J.H., R. Greeley and D.E. Gault (1980). Laboratory simulations of central pit craters. Reports of Planetary Geology, NASA TM-82385, 170-171.
13. Gault, D.E. and C.P. Sonett (1982). Laboratory simulation of pelagic asteroidal impact: atmospheric injection, benthic topography, and the surface wave radiation field. Proceedings of the Conference on Large-Body Impacts (L.T. Silver and P.H. Schultz, ed.). GSA Special Publication 190, p. 69-92.

14. Greeley, R., Fink, J.H., and Gault, D.E. (1982). Experimental insights into the lack of impact craters on Europa. Reports of Planetary Geology Program - 1982, NASA TM-85127, p. 20-21.
15. Greeley, R., J.H. Fink, D.E. Gault and J.E. Guest (1981). Experimental simulation of impact cratering on icy satellites. In The Satellites of Jupiter, D. Morrison, Ed., Univ. Arizona Press.
16. Greeley, R., J.H. Fink, D.E. Gault, D.B. Snyder, J.E. Guest, and P.H. Schultz (1980). Impact cratering in viscous targets: Laboratory experiments. Proc. Lunar Planet. Sci. Conf. 11th, 2075-2097.
17. Greeley, R., J.H. Fink and D.E. Gault (1980). Impact basins: Implications for formation from experiments. Papers presented to the Conference on Multi-ring Basins, 18-20. LPI Contribution 414.
18. Hartmann, W.K. (1983). Energy partitioning in impacts into regolith-like powders. Lunar and Planetary Science XIV, p. 281-282.
19. Hartmann, W.K. (1982). Experimental impacts: Continued study of ejecta velocities from impacts into powdery regoliths. Lunar and Planetary Science XIII, 301.
20. Hartmann, W.K. (1981). Velocity distribution of ejecta from impacts into powdery regoliths: preliminary experimental results. Lunar and Planetary Science XII, 398-400.
21. Hartmann, W.K. (1980). Continued low-velocity impact experiments at Ames Vertical Gun Facility: Miscellaneous Results, Lunar and Planetary Science XI, 404-406.
22. Holsapple, K.A. (1979). Impact cratering experiments with ambient atmospheric pressure. EOS (Trans. Amer. Geophys. Union) 60, 871.
23. Matsui, T. and P.H. Schultz (1984). On the brittle-ductile behavior of iron meteorites: New experimental constraints. Lunar and Planetary Science XV, p. 519-520.
24. Ruhl, S.F. and J.M. Thomsen (1980). Impact jetting in plasticene clay: a computational and experimental comparison. In Lunar and Planetary Science XI, 958-960.
25. Schmidt, R.M. (1980). Meteor crater: energy of formation - implications of centrifuge scaling. Proc. Lunar Planet. Sci. Conf. 11th, 2099-2128.
26. Schmidt, R.M. and Piekutowski (1982). Quarter-space experiments: Particle motion and crater-growth measurements. EOS (Trans. Amer. Geophys. Union), 63, 1020.
27. Schultz, P.H. and Gault, D.E. (1984a). Effects of projectile deformation on cratering efficiency and morphology. Lunar and Planetary Science XV, p.730-731.
28. Schultz, P.H. and Gault, D.E. (1984b). On the formation of contiguous ramparts around martian impact craters. Lunar and Planetary Science XV, p. 732-733.
29. Schultz, P.H. and Gault, D.E. (1983). High-velocity clustered impacts: Experimental results. Lunar and Planetary Science XIV, p. 674-675.

30. Schultz, P.H. (1982). Atmospheric effects on impact cratering efficiency. Lunar and Planetary Science XIII, 694-695.
31. Schultz, P.H. and D.E. Gault (1982). Impact ejecta dynamics in an atmosphere: experimental results. Lunar and Planetary Science XIII, 696-697.
32. Schultz, P.H. and D.E. Gault (1982). Impact ejecta dynamics in an atmosphere: Experimental results and extrapolations. Proceedings of Conference on Large-body Impacts (L.T. Silver and P.H. Schultz, eds.). GSA Special Publication 190, p. 153-174.
33. Schultz, P.H. and D. E. Gault (1981). Ejecta emplacement and atmospheric pressure: laboratory experiments. Third International Conference on Mars, 226-228. LPI Contribution 441.
34. Schultz, P.H., D. E. Gault, and Mendenhall (1980). Multiple-body impacts: implications for secondary impact processes. Lunar and Planetary Science XI, 1006-1007.
35. Schultz, P.H. (1981). Evidence and mechanisms for the non-local contribution to ejecta deposits. In Workshop on Apollo 16, 120-122, O.B. James and F. Horz, Eds. LPI Tech. Rept. 81-01
36. Schultz, P.H. (1981). Impact cratering on Venus. In An International Conference on the Venus Environment (abstracts), p. 6.
37. Thomsen, J.M., M.G. Austin, and P.H. Schultz (1980). The development of the ejecta plume in a laboratory-scale impact cratering event. In Lunar and Planetary Science XI, 1146-1148.
38. Tsou, P., Brownlee, D. and Albee, A. (1984). Experiments on intact capture of hypervelocity particles. Lunar and Planetary Science XV, p. 866-867.
39. Tsou, P., Brownlee, D. and Albee, A. (1983). Sample collection of comet fly-bys. Lunar and Planetary Science XIV, p. 794-795.
40. Zook, H.A., Lange, G., Grün, E., and Fechtig, H. (1984). Lunar primary and secondary microcraters and the micrometeoroid flux. Lunar and Planetary Science XV, p. 965-966.

APPENDIX VI  
C<sup>2</sup>PDA NEWSLETTER



Lunar & Planetary Institute

# NEWSLETTER

Number 2, August, 1984

Kinpong Leung, Editor

*In this issue:* Roger Phillips discusses the various aspects of the Geophysical Data Facility (GDF) and guides the reader through an interactive session with the LPI computer. In a following article, Peter Francis discusses some current research on volcanology at the Image Processing Facility (IPF).

## GEOPHYSICAL DATA FACILITY

### Introduction

The purpose of the Geophysical Data Facility (GDF) is to provide the scientific community with access to a number of large, global geophysical data bases for Earth, Moon, Mars, and Venus. By access we mean the ability to rapidly zoom in on a subset of a global data set, to display this subset in a variety of ways, and to easily model the data.

### Mechanics of Accessing the GDF

The GDF is being designed primarily with the remote user in mind: i.e., we expect that the majority of users will access the system from their home terminals via modem connection. A graphics terminal is needed at the home institution, and at present, the terminal must be able to use DEC REGIS graphics software. Very soon GDF will also be able to work with Tektronics PLOT10 software. It is also possible to select color image output from the GDF program, but the image will be physically produced at the LPI. This can be pre-arranged by phone call, and the images will be mailed to you.

You will want to use the GDF program at 1200 baud because 300 baud will put you to sleep. Although we have recently taken steps to improve the situation, we still find the phone lines into LPI noisier than they should be. Hopefully, this situation will be corrected soon; at present it could take you several tries to pick up the carrier signal, but don't be discouraged. The LPI computer is free (to you), so your expense is going to be phone time. At present, you access the GDF by whatever long distance phone service is available to you. We are concerned that phone costs will become an inhibiting factor in using the GDF; we need feedback from the community on this. Commercial services are available (at a fixed monthly cost to LPI) that could significantly lower phone charges to the user.

Here's what you do to access the GDF:

- (1) Dial up the LPI VAX at 713-486-8214.
- (2) When you obtain the carrier, press RETURN on your keyboard.
- (3) After USERNAME: appears, type GDFLPI & press RETURN
- (4) After PASSWORD: appears, type GDF

You will now be in the GDF program. It is menu driven and self-explanatory. You should be able to use it without any external help. However, deep down inside we don't really believe this is totally true, and we are working on a

users' manual. If you become a serious user of the GDF, you will have your own account on the LPI VAX, and you will access the GDF program through this account. For human help with GDF, you should call Brian Fessler at 713-486-2184.

### Data Sets

The present data sets on the GDF are Earth: Quarter-degree averages of SEASAT altimetry (over ocean) and of topography; Mars: Line-of-sight (LOS) gravity data; Venus: Quarter-degree topography and LOS gravity data. Data sets to be added next are Earth: MAGSAT data and satellite-to-satellite tracking (SST) gravity data.

Of the presently available data sets, the topographic and SEASAT data sets can be displayed as 3-dimensional meshes or images. The orbital gravity data can also be displayed in these modes, after selecting an interpolation option. The gravity data can also be displayed in profile format. At present, the Venus gravity data can be modeled by several functional representations of density distribution. The Mars gravity data will be able to be modeled as soon as we can enter the files of spacecraft state parameters.

### An Example

One of our prime motivations for establishing the GDF was to bring to the scientific community the ability to access and quantitatively deal with orbital gravity data for the terrestrial planets. These are robust data sets that have only been dealt with by a small group of scientists because, we feel, of the difficulty of dealing with the orbital dynamic aspects of the data. The GDF attempts to remove this obstacle so that individuals can very nearly treat this data in the traditional way surface gravity data on Earth has been dealt with. It is natural that the present version of the GDF program is best developed in gravity display and modeling and this is the basis for the example that follows.

Figure 1 shows the screen display from the start of the GDF program through selection of Venus LOS gravity data. After specifying the creation of a new data file, the screen will appear as in Figure 2, showing the various ways of picking a subset of the global data set. The choices made are shown in Figure 3, which isolates a region centered on the Beta Regio area. In Figure 4 we have chosen a display of the global coverage of the selected data set. The ragged appearance at the northern limit is due to the 1000 km altitude cutoff criterion. We will skip the orbital profile data display and go directly to modeling. Figure 5 shows the screen at the start of the modeling run. Here we have chosen to model Beta Regio with a disk conforming to the curvature of the planet and to test the model against the observed LOS data of Orbit 567. The parameters entered for the model are shown at the bottom of



the screen display and at the top of the next screen display (Figure 6). After the output file is named the summary of the model ("CURVED DISK INPUT DATA") is displayed while the model output is being calculated. The results of the modeling, which takes the orbital dynamics into account, are shown in Figure 7 (dotted line) along with the observed LOS gravity data (solid line).

The subject of modeling in the GDF program is a lengthy discussion in itself and will be treated in the next issue of the C<sup>2</sup>PDA Newsletter.

### Try It, You'll Like it (Maybe)

The above discussion is intended to lead you as gently as possible into the mysteries of the GDF program. We encourage you to try it and look forward to your comments when you do so. As you must suspect, the GDF software is in various stages of development and we are certainly in an experimental mode. Nevertheless, some parts of it are working very well and we are confident that you can use the present package to carry out serious research.

```

PLEASE ENTER INSTITUTION YOU ARE AFFILIATED WITH:
LPI

The Geophysical Data Facility has data for the following planets:

Earth
Venus
Mars

To exit this program just type <RETURN>

Which planet do you want to see?: VENUS

The following data types are available for Venus:

Data Type                Abbreviation
-----                -----
Line of Sight Gravity    LOS
Topography                TOPO

Enter abbreviation of desired data type: LOS
  
```

Fig. 1

```

You have the option of constructing a new data file,
or using an already existing one.

What will it be? (OLD or NEW): NEW

PIONEER VENUS LINE OF SIGHT GRAVITY DATA

AVAILABLE DATA SELECTION OPTIONS:

1) SELECT ORBIT NUMBERS                DEFAULT: ALL ORBITS
2) SELECT ALTITUDE LIMIT                DEFAULT: ALL ALTITUDES
3) SELECT LATITUDE - LONGITUDE LIMIT   DEFAULT: ENTIRE SURFACE
4) SEARCH USING DEFINED SELECTION CRITERIA OR DEFAULTS

SEVERAL OPTIONS MAY BE USED SIMULTANEOUSLY.
ENTER OPTION NUMBER:

OPTION:1
  
```

Fig. 2

C.  
OF P...

SEVERAL OPTIONS MAY BE USED SIMULTANEOUSLY.  
 ENTER OPTION NUMBER:

OPTION:1  
 PVO ORBIT NUMBERS RANGE FROM 87 TO 634.  
 SPECIFY SET OR INTERVAL OF ORBIT NUMBERS:(D OR R)  
 1  
 ENTER FIRST AND LAST ORBIT OF INTERVAL:  
 87 634

OPTION:2  
 ENTER MINIMUM AND MAXIMUM ALTITUDE VALUES (KM):  
 0 1800

OPTION:3  
 LONGITUDE RANGES FROM -180.0 WEST TO +180.0 EAST  
 ENTER WEST-MOST AND EAST-MOST LONGITUDE VALUES:  
 -180 -30  
 LATITUDE RANGES FROM -90.0 SOUTH TO +90.0 NORTH  
 ENTER SOUTH-MOST AND NORTH-MOST LATITUDE VALUES:  
 -35 60

OPTION:4

Fig. 3

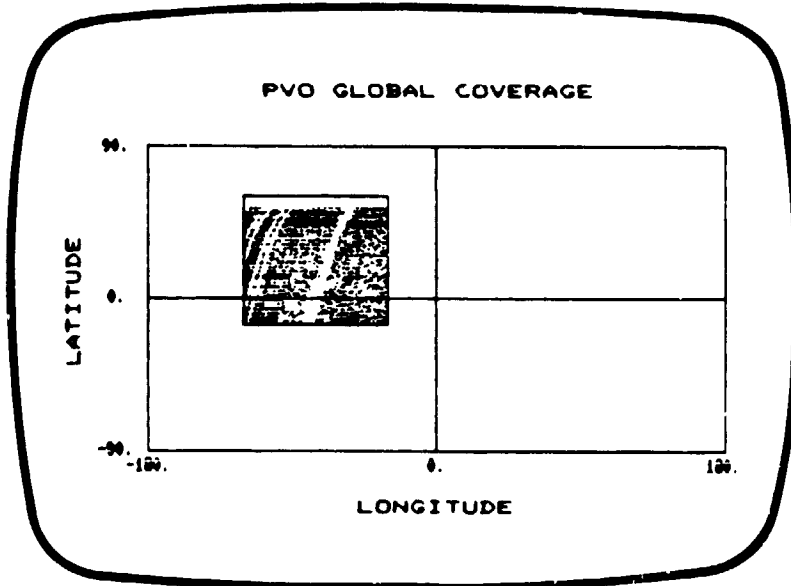


Fig. 4

THE FOLLOWING MODELS ARE AVAILABLE:

- 1) CURVED SURF (UP TO 10)
- 2) FLAT SURF (UP TO 10)
- 3) SMOOGEY (UP TO 10000)
- 4) SPHERICAL HARMONICS (UP TO DEGREE 30)
- 5) TOPOGRAPHY (UP TO 117 x 117)
- 6) QUIT

ENTER NUMBER OF MODEL TO BE USED: 1

CURVED SURF MODELLING OPTIONS:

- 1) USE OLD MODEL (AS IN)
- 2) MODIFY OLD MODEL
- 3) CREATE NEW MODEL
- 4) QUIT

ENTER NUMBER OF OPTION TO BE USED: 1

ENTER NUMBER OF TRAJECTORIES TO BE MODELLED: 1

ENTER PVO ORBIT NUMBER OF TRAJECTORY # 1: 547

ENTER NUMBER OF CURVED SURF TO BE USED: 1

RADIUS OF SURF # 1 (KM) = 2000.0

LATITUDE OF CENTER OF SURF # 1 = 24.00

LONGITUDE OF CENTER OF SURF # 1 = -72.0

DEPTH OF SURF # 1 BELOW SURFACE (KM) = 0.0

NUMBER OF SURF IN SURF # 1 = 1

Fig. 5

DEPARTMENT OF THE ARMY

STARTING WITH OUTER RING  
 SURFACE DENSITY OF DISK # 1, RING # 1 (GM/CM\*\*2) = -1.2805  
 SURFACE DENSITY OF DISK # 1, RING # 2 (GM/CM\*\*2) = -1.2805  
 SURFACE DENSITY OF DISK # 1, RING # 3 (GM/CM\*\*2) = -1.2805  
 SURFACE DENSITY OF DISK # 1, RING # 4 (GM/CM\*\*2) = 4.9805  
 SURFACE DENSITY OF DISK # 1, RING # 5 (GM/CM\*\*2) = 4.2805

ARE THERE ANY ENTRY ERRORS YOU WISH TO CORRECT? (Y OR N): N  
 WOULD YOU LIKE THESE MODEL PARAMETERS SAVED TO A PARAMETER FILE? (Y OR N): Y  
 ENTER NEW MODEL FILENAME: QUADL.DAT

CURVED MME INPUT DATA

DISK #	SURFACE RADIUS	LATITUDE	LONGITUDE	DISTANCE BELOW SURFACE
1	2000.0000	34.0000	-71.0000	0.0000

DENSITIES OF RINGS

RING NO.	DENSITY
1	-120000.00
2	-120000.00
3	-120000.00
4	600000.00
5	420000.00

Fig. 6

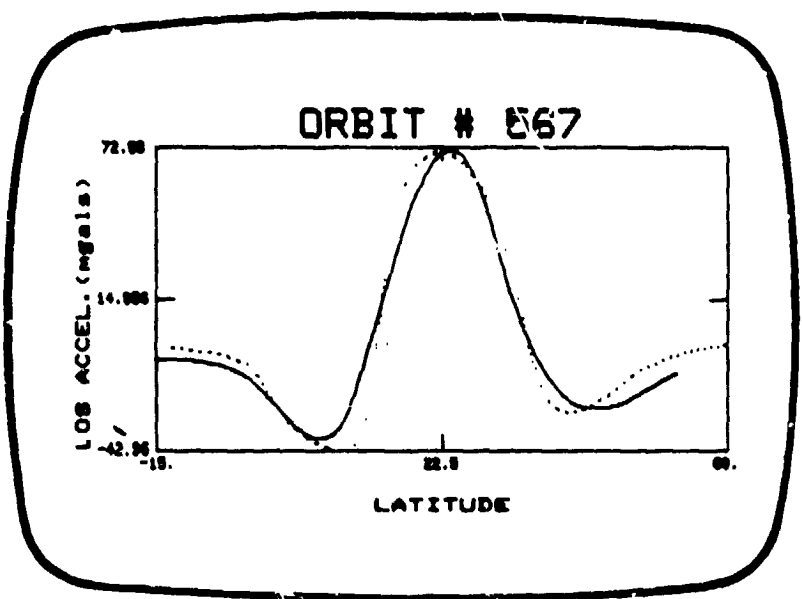


Fig. 7

## IMAGE PROCESSING AND VOLCANOLOGY AT THE LPI

Over the last decade, imagery from LANDSAT satellites has provided an enormous new source of data on terrestrial volcanoes. While a certain amount of useful information can be extracted from black and white hard copy prints of LANDSAT imagery, to obtain the full value of the data contained in the image, digital image processing techniques are essential. At the LPI, a Gould/DeAnza system linked to the Institute's VAX computer is employed. Most of the research is concerned with applications of IP techniques rather than development of new ones.

Three main research themes are being pursued at present. First, identification and interpretation of large volcanic structures. Some classes of volcanic structures known as resurgent calderas are so large, of the order of 30-40 km, that they may be difficult to identify from ground studies, being camouflaged by their own scale. This applies in particular, of course, to remote regions where detailed studies are unavailable, and at present work is concentrated on the high part of the Central Andes, between 14 and 28 deg S, and the Tibetan plateau. Several large calderas between 20 and 2 million years old have been identified in the Andes, and some of them have been investigated subsequently in the field. An important spin-off of the work in the Andes and Tibet is a better appreciation of the relationships between volcanic activity and the regional tectonic setting.

Detailed studies of volcanic areas require knowledge of the age and composition of the rocks concerned, and this forms the second research theme. Work is under way to establish to what extent satellite imagery can be used to discriminate between lavas and pyroclastic flow units of different ages and compositions, and involves correlation of data from known flows in well mapped areas with their multispectral LANDSAT signature. Numerous environmental factors, particularly local climate, affect the radiometric characteristics of the rocks, and a programme of field radiometry of some Andean lavas is helping to place constraints on some of these factors.

Radiometrically, some of the most distinctive types of volcanic rocks are those associated with hydrothermal activity, and these form the third line of research. At the

simplest level, presence of areas of altered rocks in the summit regions of volcanoes in arid areas can be used as a guide to the level of fumarolic activity that is or has been in progress, and has some economic application in prospecting for sulphur. More importantly, many important copper and silver deposits are related to hydrothermal alteration processes taking place late in the evolution of volcanic structures. Work is in progress to characterise the nature of such hydrothermally altered areas, and to identify specific structural sites where alteration is likely to be concentrated. A number of previously unidentified areas have been detected on caldera ring fractures in the Andes, and these studies have been important in elucidating for the first time the setting of some important mineral deposits, notably that of Cerro Rico silver deposit in Bolivia.

In addition to these general themes, image processing is used in a number of special applications. An example which is currently undergoing investigation is the study of the debris avalanche deposits of Socompa volcano, north Chile. This 6000 m high volcano experienced a massive collapse at some point between 10,000 and 500 years ago, somewhat similar to that of Mt. St. Helens in May 1980, but on a much larger scale. About 10 cubic kilometers of the volcanic cone collapsed to form a massive landslide covering some 400 km<sup>2</sup>. The avalanche deposits are amongst the most extensive known on Earth, and contain a number of distinct lithologies. Classification techniques are being employed to discriminate the major lithologies, and to relate each lithology to its original location on the volcanic structure. Since the region is extremely remote and difficult of access, satellite imagery and image processing offer the only means of studying this exceptional deposit.

### ACCESS TO C<sup>2</sup>PDA

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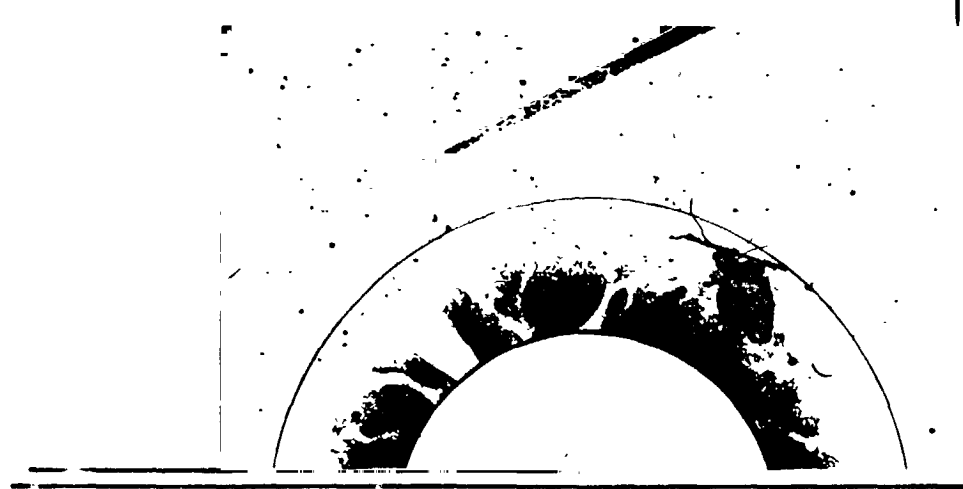
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APPENDIX VII  
NASA'S SESAC REPORT ON  
R&A IN SPACE AND EARTH SCIENCES

43

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**Report of NASA's  
Space and Earth Science  
Advisory Committee  
on  
Research & Analysis  
in the  
Space and Earth Sciences**



**July 1984**

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# **Report of NASA's Space and Earth Science Advisory Committee on Research & Analysis in the Space and Earth Sciences**

**July 1984**

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# Contents

<b>Executive Summary</b> .....	<b>1</b>
<b>Background &amp; Methodology</b> .....	<b>3</b>
<b>Introduction—Science at NASA From a National Perspective</b> .....	<b>5</b>
<b>The Role of the R&amp;A Program</b> .....	<b>7</b>
<b>Program Management</b> .....	<b>9</b>
<b>Critical Issues—Infrastructure and Funding</b> .....	<b>11</b>
<b>A. Infrastructure</b> .....	<b>11</b>
1. Management of Flight Observations and Scientific Data	
2. Advanced Flight Instrumentation	
3. Laboratory and Experimental Equipment	
4. Theory and Predictive Modeling	
<b>B. Funding</b> .....	<b>12</b>
<b>Concluding Remarks</b> .....	<b>15</b>
<b>Acknowledgments</b> .....	<b>15</b>



## **Executive Summary**

This report addresses the role and health of a continuing Research and Analysis Program in NASA, an agency that is dominantly mission oriented. The findings are based on extensive interviews with, and consideration of data compiled by, Office of Space Science and Applications (OSSA) staff, as well as discussions with personnel from NASA centers and university and industry scientists.

### **Conclusion**

Endeavors in Research and Analysis form the foundation for the entire space and earth sciences program because they provide the means of identifying which missions are required and also the means of extracting full scientific results from completed missions. The scientific accomplishments are impressive; current objectives are well-focused and are of scientific significance.

### **Recommendations**

- OSSA must give its Research and Analysis Program a priority commensurate with that of the flight program.
- The management of the R&A Program must remain with scientists at NASA Headquarters, because management of an effective national program requires a broad perspective and the coordination of research at NASA centers, the universities, and in industry.
- OSSA must provide adequate funds for data analysis and interactive data systems as part of each flight program budget. To make this process most effective, OSSA should, in consultation with the scientific community, develop an overall plan for data management and computation that is broad enough to serve the various OSSA scientific endeavors.
- Inadequate funding is the most pressing problem in the R&A Program. In some disciplines 20-30% increases in funding will have significant scientific benefits. In a few cases substantial additional support seems essential. The immediate requirements involve an increase of about \$10 million in each of the Astrophysics, Earth Science and Applications, and Solar System Exploration Divisions, thereby establishing a new base funding level for these activities.

## Background & Methodology

In July 1983, the NASA/University Relations Study Group issued its report, "The Universities and NASA Space Sciences," noting that:

The research and analysis funding provides the research base for the NASA science program both at the universities and at the NASA centers. Over the years there have been substantial changes in the NASA program. The Study Group recommends that a re-examination of the R&A program be made to ensure that the various discipline areas are being properly supported both in the development of new detectors, advanced analysis systems and theoretical research. It is recommended that this study be undertaken by the Space and Earth Science Advisory Committee.

In response to a request by Dr. F. McDonald, NASA Chief Scientist, prior to the formal issuance of this report, the Space and Earth Science Advisory Committee (SESAC) established a working group in May 1983 to examine the health of the Research and Analysis (R&A) Program in the Space and Earth Science disciplines in the Office of Space Science and Applications (OSSA).

A somewhat similar review of R&A had been undertaken almost a decade earlier by the NASA Physical Sciences Committee (PSC; predecessor of the SESAC) and it is appropriate to summarize that committee's conclusions.

The Physical Sciences Committee study recognized that important scientific problems in each scientific discipline were being addressed by the SR&T program, that highly qualified personnel were involved, and that excellent science was being performed. The Report perceived a satisfactory balance among discipline areas and a reasonable balance of effort between NASA centers and universities.

Major recommendations of that report included establishment of a uniform review system for NASA center work and university work (this has been implemented) and a substantial increase in SR&T funding in order to offset the impact of inflation, to encourage an influx of new groups and younger scientists into the program, and to provide continuity of support and refurbishment of laboratories at universities and centers.

Some of the problems identified by the Physical Sciences Committee (e.g., the impact of inflation and the need for laboratory refurbishment) persist to this day, and although the most dire consequences of declining funding by the committee have been averted so far, declining trends that were identified as unfortunate still prevail. As predicted at that time, these trends have created significant strains in the R&A Program.

In the present review, the SESAC working group considered:

1. The goals of the R&A Program and its role in meeting present-day OSSA objectives.
2. Management of the R&A Program by the NASA Headquarters Discipline Chiefs and Program Managers.
3. Funding trends and funding distribution for the period FY 1979-FY 1984. The data base developed for this portion of the study included detailed information on the funding history for each identifiable scientific discipline, a breakdown by category of activity within each discipline (e.g., theory, laboratory and field studies, data analysis, etc.), the allocation of funding to various types of institutions (universities, NASA centers, other government laboratories, and industry) and data on the number of research groups supported.

The Working Group did not explicitly address the basic question: "Is the OSSA supporting high quality science through its R&A Program?" because it considered that this question has been and continues to be answered strongly in the affirmative in scholarly publication, peer review of proposals, and through national and international recognition of the work funded through the R&A program.

The Working Group met four times during the period October 1983-May 1984 for periods ranging from one to three days. Meetings were devoted to a detailed examination of the funding data; three days of meetings with the Discipline Chiefs to discuss the goals of the R&A Program, approaches to program management, accomplishments, trends, issues, and problems; formulation of preliminary conclusions.

preparation of a draft report for consideration by the full Space and Earth Science Advisory Committee which was considered by SESAC at its June meeting. Final revision has incorporated comments from the full committee and this version (which has been approved for adoption on behalf of SESAC by L. Soderblom and L. Lanzerotti, successive SESAC chairmen), represents the views of SESAC itself. J. Alexander, who originally chaired the Working Group, resigned in February 1984 because of other commitments. At that time, D. Papadopoulos joined the Group and K. Burke assumed the duties of Chairperson.



## Introduction—Science at NASA From a National Perspective

In a little more than 25 years, the NASA space science program has produced a number of spectacular and fundamental findings ranging from the initial discovery of the radiation belts surrounding the Earth to the most recent results concerning the distribution of cold material in the Universe. During this relatively brief span of time, samples have been returned from the moon for scientific analysis and unmanned space probes have explored the solar system from Mercury out past the orbit of Neptune. Measurements obtained from space helped characterize the sun as a variable star whose magnetic field stretches throughout the solar system—steady streams and intense bursts of atomic particles blow outward from the sun, colliding with the atmospheres of the Earth and other planets. Space observatories produced a new view of the Universe revealing the existence of entirely new classes of celestial objects, such as black holes and the x-ray luminous gas in clusters of galaxies. Major steps have been taken in studying the Earth as a planet, using the vantage point of space to provide a truly global perspective of processes taking place in the atmosphere, in the oceans, and on land.

This history of accomplishment has been characterized by the emergence of new scientific fields—areas of scientific inquiry that did not exist prior to the space age. At the present time, exciting new results continue to appear in all the areas of the program. Continued advances in technology in “older” space science disciplines still offer the prospect of major future advances while new scientific opportunities have emerged. Even the most mature areas of the program are still youthful in the scientific sense, with challenging questions still presenting major opportunities for important research.

Today, NASA must contend with both opportunity and challenge: the opportunity to move in new directions and the challenge of maintaining momentum in developed fields while establishing new ones. In this study, we examine the status of one element of the Space Science Program—Research and Analysis—which is central to the NASA mission, to meeting both opportunity and challenge, and to assuring the existence of a continuing flow of ideas, capabilities, scientific results, and people into the Space Science Program. All these are required for the continued health and vitality of NASA’s scientific enterprise.

In considering the NASA science program, it must be realized that the Agency has been given the responsibility for managing and fostering programs of national significance. The importance of the R&A program within NASA can be viewed from two perspectives: as directly supporting NASA’s immediate scientific goals, and as supporting the basic science that is necessary for achieving long-term success in the programs in the space and earth sciences for which NASA is responsible.

NASA has a distinctive role as a manager of national programs in that it must integrate contributions from three diverse communities: the universities, the NASA centers, and industry. The efficacy of the total effort depends strongly on maintaining appropriate balances between these components, taking advantages of the special strengths of each, and stimulating each of them to contribute in an optimum way to the total endeavor.

It is crucial that the NASA management be cognizant of the unique and complementary contribution of each of these three components. The university community provides both a strong capability for carrying out fundamental research and, through the educational functions associated with research, the mechanisms for educating the scientists and engineers on whom future successes in space and earth science depend. Much of the NASA sponsored research involving graduate students and postdoctoral researchers at universities is carried out within the Research and Analysis Program. Therefore, in addition to being a key source of ideas, technology, and techniques, the program is also a fountainhead for scientific and technical talent for the country. The NASA centers, in addition to their role in basic research, provide special talents for research and engineering associated with the development of mission concepts and the integration of new technology into mission design and development, and may be particularly well suited for the calibration, reduction and archiving of mission data. Industry, with its special talents for system design and spacecraft manufacture, is responsible for building spacecraft and instruments that will meet mission objectives.

NASA’s challenge in managing national programs is thus essentially one of integrating its own expertise with the skills and knowledge available outside NASA. Of special significance is the role thus thrust on NASA of ensuring the long-term strength of its partners. NASA must, both in its own interests and in the interests of

the nation, support and nurture the elements of the academic and industrial communities that contribute to its programs. This requires that NASA's managers must be aware of a special need and responsibility to foster innovation and imaginative approaches. The R&A Program is, as we shall argue in the next section, the core of the OSSA program in the space and earth sciences because it provides both the means of identifying the most appropriate missions and of ensuring that scientific results are fully realized. It is also the means by which the nation supports and encourages the generation of knowledge that makes possible advances in national programs in the space and earth sciences.

Thus we reach the main theme of this report:

**OSSA must give its Research and Analysis Program a priority in funding and attention commensurate with that of flight programs. The endeavors in R&A are the foundation for the entire Space and Earth Science Program. The success of OSSA in contributing to the NASA mission has been and will be determined by the successes of the R&A Program.**

# The Role of the Research & Analysis Program

The Research and Analysis Program is the foundation for NASA's activities in space and earth science. The NASA flight missions do not stand alone. They are essential tools used to address broad and important scientific problems. However, while the space missions are the often dazzlingly visible aspects of the OSSA program, they are useful only in so far as they contribute to the continuing effort to understand our planet and our universe. It cannot be emphasized too strongly that the quality of NASA's scientific program and the return that the country receives from its investment in space missions, directly depends upon the effectiveness, the health, and the vitality of the Research and Analysis Program.

The achievement of the OSSA goals requires success in four separate endeavors:

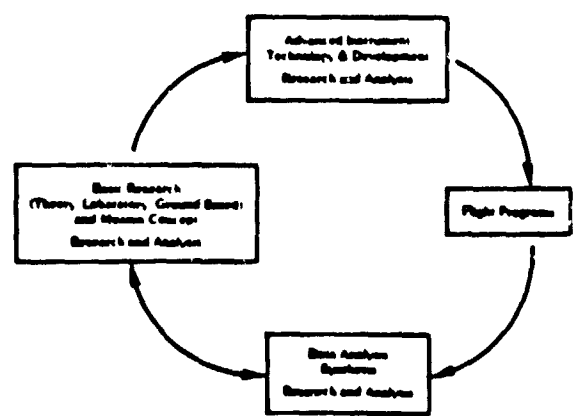
**Basic Research and Formulation of Mission Concepts.** Basic research includes theoretical work and modeling that provide the scientific framework for the interpretation of data, as well as for developing hypotheses that permit the synthesis of results from varied missions and definition of objectives for new missions. Laboratory, field and ground-based studies that provide crucial supplementary and complementary information for analysis of mission data also form part of basic research. The formulation of scientific questions, the clarification of scientific issues, and the realization that scientific opportunities are available, are all part of the process of developing concepts for effective and meaningful missions. While some of the required basic research is performed without direct OSSA sponsorship, the agency must participate actively in the effort to use data from space missions to pose deeper and more profound scientific questions and, especially, in efforts to express these questions in forms amenable to further testing in space.

**Instrument and Technology Development.** The development of sensors, instruments, and observational capabilities within the OSSA R&A Program responds to two driving forces: the need to answer new scientific questions and the need to use new capabilities made possible by technological advances. This part of the OSSA effort is the component that provides the tools for implementing the next generation of space missions.

**Flight Programs.** The missions are the means by which OSSA contributes to progress in the space and earth sciences; they are not themselves an objective.

**Data Analysis, Synthesis, and Interpretation.** The benefits from space missions are first realized when the observations of the spacecraft are converted into scientific data. It is essential to ensure that the maximum possible benefit is obtained from the mission data, for expanding knowledge is the reason for flying the mission. The data from a well-designed mission will presumably answer or clarify the scientific issues that motivated the mission. The data will also usually lead to new questions and new issues and will suggest new avenues of basic research. Thus a cycle continues, with the space missions providing the link through which theory, experiment, and observation combine to reveal the nature of our surroundings. The interactions in this cycle are illustrated in Figure 1.

Figure 1



From these considerations we conclude that the research and analysis program supports a broad range of essential activities that are at the very core of NASA's abilities to reach its goals. The value of NASA's scientific activities to the nation is dependent on the breadth and strength of the Research and Analysis Program.

# Program Management

## A. The Role of NASA Headquarters and Its Discipline Scientists

We noted earlier that NASA's R&A Program is of national scope, involving the integration of contributions from diverse elements. For this reason it must be guided by highly qualified individuals who have a broad perspective in relevant scientific disciplines. These people must be capable of drawing upon the strengths of the various potential participants in the program and developing the coherent research programs essential for meeting NASA's long-term objectives.

We find that the quality of research management at NASA Headquarters is impressive. The discipline chiefs and program managers are generally knowledgeable, experienced, and in possession of a strong sense of the direction in which the programs for which they are responsible must move.

We find that NASA Headquarters has a crucial role to play in structuring truly national programs and in ensuring that only the best work is supported regardless of institutional considerations. The individual discipline chiefs are the heart of the program and it is vital that knowledgeable scientists who can interact strongly with the outside community in structuring and directing research programs continue to play a strong role at NASA Headquarters. There tends to be a direct correlation between the strength, expertise, and professional experience of the Program management staff and the quality of a particular R&A Program. We conclude that the management of R&A Programs must remain at NASA Headquarters in order to ensure the broadest possible involvement of the scientific community.

Neither the R&A Program nor the flight programs stand alone. Both are integral and indivisible elements in NASA's program in space and earth science. Missions are planned on the basis of new scientific insights or on the basis of new technological developments. Conversely, technology programs are frequently constructed to ensure that new missions are ready to be started. Mission definition and execution require iterations between what is scientifically desirable and what is technically possible. It is crucial that program planning, mission planning and execution, and management of the R&A Program be done in concert. They are not separate elements that can be pursued independently of each other. One of the greatest strengths of NASA's scientific program has been the strong links, through the NASA Headquarters discipline chiefs, between the research and mission activities. The future quality of NASA's program depends, in a fundamental way, on the preservation of such links.

## B. The Role of Peer Review

One of the principal responsibilities of the Headquarters discipline chiefs is to ensure that proposed research is impartially reviewed and selected on the basis of its scientific quality and potential for contribution to the overall program. The 1976 Physical Sciences Committee review of the R&A Program explicitly recommended that a uniform review system be applied to all work both outside and inside NASA, and that recommendation has now been implemented across the board. Peer review is a major element of the process of selecting recipients of R&A funding in all disciplines. This practice constitutes one of the basic strengths of the management of the program, and it is a major factor in contributing to the quality of the program. R&A managers also pay close attention to science policy recommendations from panels formed by the National Academy of Sciences and from similar advisory groups. Many program managers also use Management Operations Working Groups to provide more specific guidance on programmatic issues, and these groups appear to have been very helpful in assessing priorities in programs where funding constraints or changes in research directions have led to changes in the constitution of the R&A Program in a given discipline.

We recommend that NASA continue to utilize a uniform peer review process to evaluate research projects proposed under the R&A Program. We also recommend that where they are not being used now, the use of Management Operations Working Groups should be encouraged as a valuable management tool.



### C. Use of Multiyear Funding

Declining real funding in many areas and fierce competition, both in numbers proposing and in scientific calibre of proposal content, have resulted in increasing pressure on R&A Programs. If investigators are required to compete annually, the fraction of time spent in generating paper work increases considerably with the result that NASA is getting diminishing performance and scientific return from its investment. We are pleased to observe that since this problem was identified by the PSC, there has been a noticeable trend toward multiyear funding that we recommend should continue.

### D. Breadth of Participation

In most areas of the R&A Program there is a balance in participation between universities, field centers, and other laboratories (both government and industry) that appears to be satisfactory.

The older space science disciplines such as astronomy, planetary exploration, and space plasma physics have consistently structured programs having major involvement by university researchers. This pattern was established early in the history of NASA as a matter of conscious policy in recognition of the unique role that universities play in scientific research in the United States.

In other areas, particularly the elements of the earth science program that originated in the former Office of Space and Terrestrial Applications, the fraction of university participation is considerably lower. We note that over the past several years there has been a conscious attempt on the part of the program managers to broaden the base of participation and increase the fraction of university involvement. We applaud this trend. It is our observation that there seems to be a direct correlation between the quality of a program and the degree of university involvement. There appear to be a few discipline areas, such as Land Processes, where particular attention needs to be paid to increasing the breadth of university participation.

### E. Managing Innovation

As has been discussed at length, the R&A Program contributes in many ways to the Space and Earth Science Program. In particular, it is the principal source of support for the development of new technology and new ideas. Innovation is a spontaneous process and cannot be planned or delegated. The best the Agency can do is provide the appropriate climate in which it can bloom. Possible approaches to providing such a climate include reserving a small portion of R&A funds to support serious high risk research ventures. Such efforts should be for a limited time to enable initial exploration of challenging ideas, development of novel instruments and fostering interdisciplinary research. The current OSSA Innovative Research Program is an important step in this direction and could be supplemented by similar efforts in the individual research disciplines.

In some areas of the Program, it is clear that new approaches to research are emerging. We will return to this topic later, noting here only that the development of such new research styles places a particular responsibility on both managers and research scientists to recognize and foster both innovative ideas and non-traditional approaches to carrying out research.

# Critical Issues—Infrastructure and Funding

Successful implementation of the flight programs and ensuring the maximum scientific return for the nation from its investment in those flight programs requires a strong and dynamic infrastructure and adequate funding support.

## A. Infrastructure

We have identified four critical issues concerning infrastructure.

### 1. *Management of Flight Observations and Scientific Data*

To obtain the maximum possible benefit from space observations requires that new emphases be placed on the management and processing of flight observations, on the archiving of scientific data, and on providing quick, easy access to the data bases. Costs of adequate data management, although not negligible, are small relative to the costs of spacecraft and operating space missions.

Two factors mandate a new approach to data management in the OSSA structure:

1. Increasingly sophisticated instruments and the drive toward imagery are accelerating data rates and the total data production from a mission.
2. Advancing communications and computational power make it possible for researchers to utilize larger amounts of data, to examine it interactively, and to summarize it or incorporate it in more sophisticated computer models. It is possible to use data from space missions more effectively than is presently being done.

We conclude that the management of data and data bases, the provision of adequate computational and communication power, and the provision of access to data from flight missions constitute a generic problem and a challenge that OSSA must meet.

We consider that this is an essential issue: the investment in flight missions is too large not to obtain the maximum benefit from the data they produce. **Creative and effective management of scientific data must be given a high priority within OSSA. OSSA should, in consultation with the scientific community with which it collaborates, develop an overall plan for data management, computation, and communications that is broad enough to serve the various OSSA scientific endeavors.**

### 2. *Advanced Flight Instrumentation*

The success of future space missions is critically dependent upon the availability of state-of-the-art instrumentation and technology. Many years are required for the development of such instrumentation. If OSSA mission planning is not to be seriously compromised, the needs of the future must be dealt with now. We are concerned that because of the funding restrictions of recent years, inadequate attention has been paid to the development of new technology and new instrumentation. These areas are so crucial to NASA's future that they must be singled out for special emphasis.

### 3. *Laboratory and Experimental Equipment*

It has been recognized in many national forums that laboratory and experimental equipment acquired by researchers throughout the scientific community in the United States during the early 1960's and '70's has fallen into disrepair, become all but impossible to maintain, and been made obsolete by dramatic technological advances. Unfortunately, it has commonly been impossible to replace this equipment because declining R&A budgets have precluded expenditures for all but the most important elements of every research task. This has usually meant that available funds have largely been used for the retaining of critical personnel. We are now training the next generation of scientists and engineers with antiquated equipment and expecting critical experiments to be carried out with inadequate instrumentation. Many European and Japanese laboratories are equipped with instrumentation far superior to our own. It is important to the country's long-term technological well-being and to NASA's future in particular that this situation in universities be remedied. This will require an infusion of funds dedicated to the renovation and replacement of obsolete and inoperable equipment over a period of a few years as well as continuing funding so that this

problem does not recur and become a crisis again in the future. This issue is a general problem nationally. The recent NASA/university study singled out the issue of adequacy of laboratory instrumentation and cited other reports that have also addressed this issue. We concur that this is a crucial issue requiring particular attention.

#### 4. Theory and Predictive Modeling

In several areas of the program, a new style of research is emerging involving relatively large critical mass groups either at a single institution or a consortium of institutions. We believe that such team efforts offer the possibility of establishing much closer quantitative links between mission planning, data sets and theoretical modelling than has heretofore been possible. In addition, with their diversified expertise, such groups have been shown to provide an environment conducive to critical debate and innovation. The relatively new Solar-Terrestrial Theory Program (STTP), which concentrates its support on about a dozen groups, funded at an average of \$200K/year, can be considered as a very successful example of this approach. Use of consortia could prove highly successful in numerous other fields as well. A program for astrophysical theory, for example, might enhance the scientific benefits from the astrophysics missions that have flown or are now under development. While project or single investigator research must still occupy a central position in the R&A Program, major advances in the understanding of many physical processes in space and the increase in power and sophistication of computational techniques require increasing emphasis on interdisciplinary research accompanied by extensive computer modeling on advanced main frame computers. The R&A Program must be flexible enough to accommodate and encourage this type of effort as part of a broad spectrum of research activities. Interdisciplinary collaborations and activities such as small workshops that foster new ideas and cross fertilization must also be encouraged. As noted earlier, the development of such non-traditional approaches to research places new responsibilities on scientists and research managers to recognize and support such work.

#### B. Funding

Figure 2 shows the level of R&A funding for the fiscal years FY 1962-1984. Although in the aggregate the level appears to be relatively constant, the fraction devoted to space science areas, as contrasted to the areas that used to be part of the applications program, has suffered a major net loss. The situation becomes even more striking when funding trends in individual discipline areas are examined on a case-by-case basis. To give a typical example, R&A buying power in astronomy and astrophysics has decreased 50% compared to 1979. Comparable decreases are noted in other areas, such as solar system exploration and space plasma physics. Furthermore, the increase in the annual appropriation of the applications R&A Program is deceptive. Here the research and analysis base is primarily carrying a disproportionately large burden of advanced development and capital investment while waiting for flight opportunities.

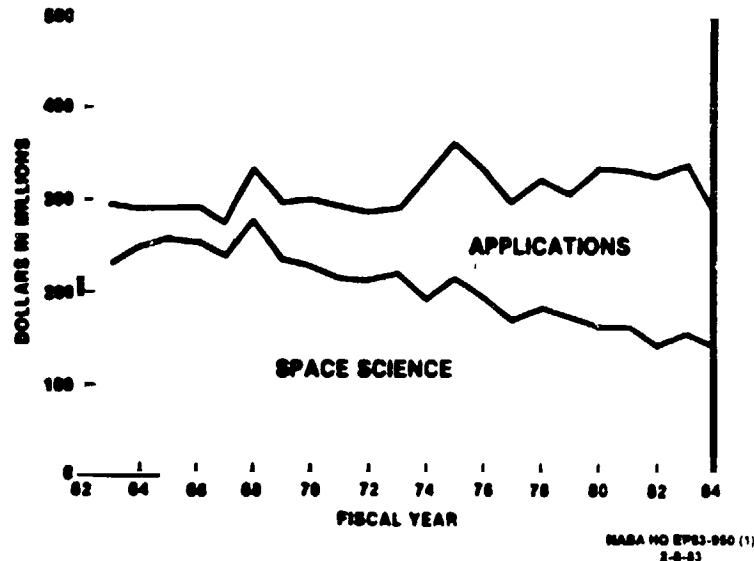
Many of these trends were already noted in the 1976 PSC report. Unfortunately, in several areas of the program the trends have continued since that time and, as predicted, serious strains have developed. The success of NASA's scientific enterprise clearly depends upon there being an appropriate balance between the flight missions and activities undertaken in the Research and Analysis Program. It appears to us that undesirable imbalances have, in fact, developed. Furthermore, because of the close relationship between the R&A Program and the missions, the existence and execution of missions in an orderly fashion has historically helped to stabilize the level of funding going into the scientific community. Unfortunately, the current erratic changes in flight opportunities and inadequate MO & DA support have seriously destabilized the situation and placed increasing demands on the R&A Program.

In particular, based on our interviews with the Division Directors and Discipline Chiefs and on our careful analysis of the funding data for the past six years, we conclude that inadequate funding in some (but not all) of the disciplines is the most pressing problem in the R&A Program with the following consequences:

- the inability to support the number of instrument and detector development efforts necessary to permit competition among alternative approaches in a generic area,
- the inability to upgrade or replace aging laboratory equipment,
- the inability to support adequate data analysis projects for highly successful flight missions such as Voyager and Pioneer,

OFFICE OF SPACE SCIENCE AND APPLICATIONS  
**RESEARCH AND ANALYSIS ANNUAL APPROPRIATIONS**  
 (1982 CONSTANT YEAR DOLLARS)

Figure 2. The aggregate dollar value for space science and what was formerly called Applications appears fairly steady from this figure, but space science activities are shown to have suffered a major loss. Moreover (as explained in the text) funds for Applications include advanced development and capital investment money as well as R&A funds, making the situation worse than it appears.



- the inability to extend advanced study and development efforts to a broad range of problems with the consequent neglect of areas that will need attention in the future,
- the inability to fund important proposals rated "excellent" in the peer review process, as well as high risk, high pay-off ventures,
- the inability to support development of ideas for Space Shuttle and Explorer satellite investigations,
- the inability to develop state-of-the-art theoretical and computational efforts,
- the inability to provide appropriate ATD resources for future missions.

One of the most important consequences of all of these pressures has been to inhibit the potential for innovation. A lack of flexibility has developed that inhibits the undertaking of programs in new areas of research or the undertaking of high risk research programs and an emphasis (whether conscious or unconscious) is being placed on conservative or risk-free undertakings both in theoretical and experimental areas. Deliberate steps must be taken to reverse this trend.

A broad consequence of the trends described in this section is that although a few programs appear to be adequately funded and thriving (such as some programs in the earth sciences, of which upper atmosphere research is an example), there are others (such as solar system exploration and climate research) that, with a 20% to 30% increase in R&A funding, could make substantial advances. It should be emphasized that these are areas where relatively modest changes in funding could have substantial beneficial consequences. In a small minority of programs (of which the Land Processes Program within the earth sciences is the most notable) there is a situation in which a modest increase is unlikely to be sufficient to make much difference and substantial additional support coupled with more coherent management seems essential. Support in Land Processes, a field in which both new instruments and new observational opportunities are becoming possible, is likely to produce a major step forward if adequate funding is provided.

Additional dollars could be used in many effective ways and we here provide some specific examples. This list is not to be read as either comprehensive or exhaustive.

An augmentation of \$10M in solar system exploration R&A in FY86 would, for example, not only permit some laboratory instrument upgrading and a return to earlier levels of core science support, but would also permit allocation of funds to enhanced Halley observations and support for data reduction of International

Halley Watch and Giotto Program material. There could also be support of more extensive U.S. participation in foreign missions. Support could be made available for continuing the Mars Data Analysis Program and for Voyager Uranus data analysis. A start could be made on a Planetary Data System Program permitting easy access for many scientists to the treasury of planetary data that has been accumulated from past missions.

Augmented funding in the Earth Sciences would permit undertaking important new activities directed towards fully utilizing microwave and Landsat Thematic Mapper data to study a variety of problems in geology, climatology and global ecology and to initiate a number of interdisciplinary studies dealing with understanding the Earth as a coupled system. Examples of the latter include studies of Land-Biosphere-Atmosphere interactions, air-sea interactions and ice sheet-ocean-climate interactions. Additional work could also be undertaken to develop new instruments to study key chemical constituents within the troposphere and the transfer of such constituents between the stratosphere and the troposphere, as well as to study in the laboratory the rates of chemical reactions occurring at gas-solid or gas-liquid interfaces which play a vital role in controlling the regional and global distribution of many atmospheric species.

A \$10M augmentation to the Astrophysics Program would permit the initiation of a theory program (such as that referred to elsewhere in the report) and significantly greater effort in infra-red, ultraviolet, x-ray and gamma-ray instrumentation. New instruments for solar observations as well as heavy nuclide cosmic ray instrumentation and a new balloon-borne infra-red telescope could also be introduced.

NASA must have the ability to meet new needs by changing the emphasis within a division through redistribution of available funding among laboratory research, theory, instrument development, data analysis and advanced technology development. A stable R&A budget is required to make this possible. However, a stable budget does not mean a static program. Rather it provides a flexible environment that permits planning over several years. Without the ability to plan, it is impossible to use resources to their best advantage. **Planning and flexibility require budget stability.**

## Concluding Remarks

The accomplishments of NASA's Space and Earth Sciences Program depend in a fundamental way on the strength of the Research and Analysis Program. Research and Analysis is, in a real sense, the foundation for the total program, giving it stability and direction and blending the results of the past with the preparations for the future. If present declining support is not halted, this foundation is at risk of crumbling in key places. NASA must act to halt the decline.

In its recent *Study of the Mission of NASA*, the NASA Advisory Council recommended that: "Adequate and stable levels of funding for ground-based, laboratory and theoretical research, a key part of NASA's scientific program, be provided independently of the fluctuating needs for spacecraft and instrument construction."

We concur with that recommendation and have shown why responding to it is essential for NASA's continuing success in the space and earth sciences.

The National Aeronautics and Space Act of 1958 charged NASA with contributing to "... the expansion of human knowledge of... the atmosphere and space," with "preservation of the role of the United States as a leader in space science and technology..." and with "the most effective utilization of the scientific and engineering resources of the United States..."

The success of the Research and Analysis Program is imperative if NASA is to meet its own objectives. It needs attention and it needs support.

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