701-140

FY'73 RESEARCH AND TECHNOLOGY OPERATING PLANS SUBMITTED TO NASA-OSS BY THE JET PROPULSION LABORATORY SCIENCE OFFICE

15 April 1972

Donald G. Rea
Assistant Laboratory Director
for Science

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

INDEX

Page	NASA Code	Title	(NASA Contact)	Work Unit	RTOP
1	185-47-71-	ATMOSPHERIC EXP. DEV.	(R. F. Fellows)		147
5	01-55	Atmospheric Exp. Development		100	
6	05-55	Atmospheric Dynamics		47	
7	185-47-72-	THEORETICAL PL. ATMOS. STUDIES	(R. F. Fellows)		372
25	01-55	Photochem Pl. Atmos.		50	
26	02-55	Pl. Atmos. Theoretical Study		117	
27	03-55	MW Spectral Studies		64	
28	04-55	Volatile Evolution		91	
29	05-55	Electron Scattering		50	
30	185-47-72-	ADDENDUM	(R. F. Fellows)		52
35	10-55	Ion Chemistry Pl. Atmos.		52	
36	185-50-71-	PLANETOLOGY STUDIES	(S. E. Dwornik)		130
45	05-55	Pl. Frost Study		30	
46	08-55	X-Ray Diffraction/Fluorescence		50	
47	14-55	X-Ray Fluorescence Analysis		50	
48	185-50-71-	ADDENDUM-1	(S. E. Dwornik)		150
53	XX-55	Silicon Camera Development		150	
54	185-50-71-	ADDENDUM-2	(S. E. Dwornik)		40
58	YY-55	Mars, Radar Profiling & Sounding Study		20	
59	ZZ-55	Venus, Radar Profiling & Sounding Study		20	
60	188-36-55-	MAGNETOSPHERIC PHYSICS	(E. R. Schmerling)		150
67	01-55	Adv. Mag. Engineering		75	
68	01-55	Adv. Mag. Science		50	
69	01-55	Theoretical Space Physics		25	
70	188-41-52-	RADIO ASTRONOMY	(N. G. Roman)		107
76	04-55	Interstellar MW Spectr. Engineering		37	
77	05-55	Interstellar MW Spectr. Lab.		48	
78	12-55	Interstellar MW Spectr. Observations		15	
79	09-55	Pulsar Rotation Constancy		7	
80	188-41-54-	RELATIVITY & CELESTIAL MECH.	(N. G. Roman)		25
82	04-55	Tech. Review of ESRO Studies		25	
83	188-41-54-	ADDENDUM	(N. G. Roman)		81
88	07-55	Low-g Super Fluid He		81	

Page	NASA Code	Title	(NASA Contact)	Work Unit	RTOP
89	188-41-55-	INFRARED ASTRONOMY	(N. G. Roman)		20
94	01-55	Hi-Res. IR Stellar Astr.		20	
95	188-46-53-	X/GAMMA-RAY ASTRONOMY	(A. G. Opp)		150
100	01-55	X/Gamma Ray Sc.		150	
101	188-46-53-	ADDENDUM	(A. G. Opp)		300
106	XX-55	Instr. Study for Shuttle		300	
107	192-55-63-	LIFE DETECTION	(R. S. Young)		608
116	20-55	Metab. & Photosynth		78	
117	21-55	Geo. Chem. Bio Molecules		74	
118	25-55	Reaction Mech. in Thermal Decomp.		87	
119	26-55	Volatile Der. Organic Comp.		73	
120	27-55	Bio Sphere Recycling		82	
121	30-55	Analytical Tech. in MS		57	
122	35-55	Adv. Tech. in Organic Anal.		89	
123	36-55	Kerogens of Harsh Env. Soils		68	
124	192-55-64-	BIOLOGICAL Adaptations	(R. S. Young)		120
130	01-55	Desert Microflora		59	
131	03-55	Microbiology		61	
132	192-55-65-	BIO INSTRUMENTATION	(R. S. Young)		205
137	35-55	Bio Instrumentation		205	
138	195-42-55-	GEOLOGY & MINERALOGY	(R. P. Bryson)		310
143	01-55	Geology & Mineralogy		187	
144	01-55	Gamma/X-Ray Sp.		35	
145	01-55	MW Surface Properties		35	
146	01-55	Magnetic Resonance Studies		18	
147	XX-55	Arecibo Data Reduction		35	
148	195-42-57-	PARTICLE TRACK COSMO CHRON.	(R. P. Bryson)		25
153	01-55	Fission Track Geo Chron.		25	
154	196-41-71-	GROUND-BASED OPTICAL ASTR.	(W. E. Brunk)		270
160	01-55	Optical Astronomy		270	
161	196-41-72-	GROUND-BASED IR ASTR.	(W. E. Brunk)		226
167	01-55	IR Astronomy		226	
168	196-41-72-	ADDENDUM	(W. E. Brunk)		23
172	05-55	Far IR Astronomy		23	
173	196-41-73-	RADIO & RADAR PLANETARY STDY.	(W. E. Brunk)		417
180	01-55	Radio Astronomy		185	
181	02-55	DSIF Radar Astr.		75	
182	03-55	MW Radiometer Dev.		135	
183	04-55	DSIF Radar Astr. Sc. Spt.		22	

Page	NASA Code	Title	(NASA Contact)	Work Unit	RTOP
184	196-41-74-	INFRARED SPECTROSCOPY	(W. E. Brunk)		97
189	01-55	Spectra Synthetic Atmos.		97	
190	383-09-51-	PRECISION LUNAR EPHEMERIS	(R. P. Bryson)		150
196	01-55	Prec. Lunar Ephemeric		125	
197	05-55	Stellar Occultation by Moon		25	
198	383-09-55-	INTERPRETATION APOLLO RESULTS	(R. P. Bryson)		100
202	01-55	Interp. Apollo Results		50	
203	03-55	Lunar Science Studies		50	
204	384-50-71-	PLANETOLOGY DATA ANALYSIS	(S. E. Dwornik)		40
207	01-55	Mars Photogeology Interpret.		40	
208	384-50-71-	ADDENDUM 1	(S. E. Dwornik)		183
212	WW-55	Mars Regolith		16	
213	XX-55	IPL Processing Spt.		63	
214	YY-55	MM'71 Information System		55	
215	ZZ-55	Mars Gravity Analysis		49	
216	384-50-71-	ADDENDUM 2	(S. E. Dwornik)		45
221	AA-55	Computer Cartographics		45	
223	385-36-00-	MAGNETOSPHERIC PHYSICS D/A	(E. R. Schmerling)		150
229	01-55	Magnetometer D/A		100	
230	03-55	Solar Wind D/A		50	
231	385-41-XX-	GENERAL RELATIVITY DATA ANALYSIS	(N. G. Roman)		60
236	YY-55	Gen. Rel. D/A		60	
237	975-50-01-	SPACE SHUTTLE INSTR. STUDY	(W. O. Armstrong)		54
242	01-55	Shuttle Instr. Study		54	

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		41	185-47-71

5. TITLE

ATMOSPHERIC EXPERIMENT DEVELOPMENT

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

N/A

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The purpose of this work is to define in detail the key investigations to be conducted in studying the atmospheres of the planets. In FY'73 special emphasis will be placed on Jupiter and Saturn, although the results will have relevance to other cloudy or hazy planets (including Venus and Earth). Principal objectives are the definition and recommendation of techniques and instrumental concepts to be developed for both space-flight and supporting Earth-based investigations. Theoretical and laboratory investigations of crucial features of new concepts are also to be undertaken and error analyses performed. These include (i) new methods in radiative transfer theory for cloudy atmospheres (ii) inversion and interpretation of radiometric (broad-band) and spectroscopic measurements (iii) definition of relationships between practical instrument parameters and feasibility of objectives (iv) spectroscopic properties of atmospheric gases and cloud constituents under Jovian conditions and at long wavelengths.

Preliminary studies of techniques for the investigation of the outermost regions of the atmospheres of Jupiter and Venus from orbiters are to be initiated.

A new program of studies in atmospheric dynamics is proposed in support of the above.

13. KEYWORDS

Planetary Atmospheres, remote sensing, spectroscopic experiments

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rao ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. JUSTIFICATION

Spectroscopic and radiometric measurements contain recoverable information relevant to the fundamental science objectives laid out for the study of the atmospheres of the planets. Experiments using properly designed instruments (i.e. optimized with respect to wavelength coverage, spectral resolution, spatial coverage, spatial resolution and radiometric accuracy, subject to the necessary practical constraints) are capable of returning basic data on the composition, thermal structure, radiation balance and dynamics and meteorology of the planets, provided numerical methods for the interpretation of data have also been developed. This work defines the observational conditions and associated instrumental performance criteria needed for the development of the rationale for science payloads of future planetary missions.

15. TECHNICAL PLAN

A. Objective

The overall objective is to develop the rationale and requirements of spectroscopic and radiometric experiments for the exploration of planetary atmospheres from future flyby or orbital missions. Two aspects of this work are of special interest at the present time.

1. Experimental concepts and instrumentation for the exploration of Jupiter and Saturn. Specific objectives are (i) measurement of vertical temperature profiles (ii) determination of bulk composition (iii) radiation balance studies (iv) thermal mapping for studies of dynamics and meteorology (v) physical, microphysical and chemical properties of clouds.

2. Experimental concepts and instrumentation for measurements of the temperature structure of the atmospheres of Venus and Mars at very high levels. The science objectives here are to study the physical structure of the ionospheres of these planets and their interaction with the interplanetary medium, and to investigate radiative non-equilibrium processes and cooling rates in atmospheres other than Earth.

A further, long-term objective is the development of a systematic program of theoretical planetary meteorology to provide the basic science input to relevant planetary tasks.

B. Technical Approach

Numerical studies are to be continued for the improvement of tentative instrument designs and the refinement of computational techniques for the interpretation of data. These will include the analysis of new laboratory data on the spectral properties of gases under Jupiter-like conditions and performance studies of prototype instrumentation designed to meet requirements specified by earlier results from the Task. Radiative transfer studies will continue

B. Technical Approach (Cont'd)

to be addressed to the problem of recovery of basic parameters from atmospheres which are cloudy or scattering. Numerical cloud modelling procedures have been defined for this purpose, and mathematical inversion methods are under development for the reconstruction of cloudy atmospheres from spectral radiance measurements. The use of a range of atmospheric models, designed to bracket the present understanding of conditions on each planet, allows error analyses to be performed and performance limitations to be established. New methods in radiative transfer theory are under study on a continuing basis for the improvement of the accuracy and/or efficiency and/or scope of the numerical studies. Theoretical studies of planetary dynamics and meteorology are carried out in order to relate important physical processes (e.g. the mechanisms of cloud formation and the nature of the driving forces for general circulation) to the observable quantities (e.g. temperature structure and opacity profiles).

For Jupiter, Venus and Mars specifically, advanced techniques which have been developed for earth satellite experiments are to be studied with a view to proposing versions for the investigation of the highest parts of the atmospheres of these planets. Numerical studies will be instigated to establish whether and to what degree the objectives outlined above can be achieved by feasible hardware.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

Meetings and Symposia Papers

Farmer, C. B., "The Inference of Temperature from the Infrared Spectra of Planets," presented at the American Institute of Physics Fifth Symposium, Washington, D. C., June 21-24, 1971. Conference Proceedings published by AIP.

Farmer, C. B., "The Infrared Investigations on the Outer Planets Grand Tour," presented at the American Astronautical Society meeting, Seattle, Washington, June 28-30, 1971. Conference Proceedings published by AAS.

Taylor, F. W. and Hunt, G. E., "The Infrared Spectrum of Jupiter and Radiative Properties of the Clouds," presented at American Astronomical Society Division of Planetary Sciences Meeting, Kailua-Kona, Hawaii, March 20-24, 1972.

Journal Articles

Taylor, F. W., "Temperature Sounding Experiments for the Jovian Planets," J. Atmos. Sci., in press.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	185-47-71	ATMOSPHERIC EXPERIMENT DEVELOPMENT	4 OF 4

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL	2.0	3.2	3.5		
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	2.0	3.2	3.5		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS	60				
IN-HOUSE SUPPORT	100	147	160		
TOTAL FUNDS	160	147	160		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT
953284	01-01-72	North American Rockwell Science Center	60

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	601-47110-0-8250	N/A	185-47-71-01-55

5. TITLE
ATMOSPHERIC EXPERIMENT DEVELOPMENT (N)

6. RESPONSIBLE NASA ORGANIZATION
NAME: JET PROPULSION LABORATORY, California Institute of Technology
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103
RESPONSIBLE INDIVIDUAL: Farmer, C.B
TELEPHONE: 213 - 354 - 2039

7. CONTRACTOR (IF APPLICABLE)
NAME: N/A
ADDRESS
PRINCIPAL INVESTIGATOR
TELEPHONE

CONTRACT NO.
CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	100	60
CURRENT FY 73 (c)	100	
NEXT FY 74 (c)	110	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 80-0-20-0-0

The purpose of this work is to define in detail the key investigations to be conducted in studying the atmospheres of the planets. In FY'73 special emphasis will be placed on Jupiter and Saturn, although the results will have relevance to other cloudy or hazy planets (including Venus and Earth). Principal objectives are the definition and recommendation of techniques and instrumental concepts to be developed for both space-flight and supporting Earth-based investigations. Theoretical and laboratory investigations of crucial features of new concepts are also to be undertaken and error analyses performed. These include (i) new methods in radiative transfer theory for cloudy atmospheres, (ii) inversion and interpretation of radiometric (broad-band) and spectroscopic measurements, (iii) definition of relationships between practical instrument parameters and feasibility of objectives, (iv) spectroscopic properties of atmospheric gases and cloud constituents under Jovian conditions and at long wavelengths.

Preliminary studies of techniques for the investigation of the outermost regions of the atmospheres of Jupiter and Venus from orbiters are to be initiated.

10. JUSTIFICATION (WHY)

Spectroscopic and radiometric measurements contain recoverable information relevant to the fundamental science objectives laid out for the study of the atmospheres of the planets. Experiments using properly designed instruments (i.e. optimized with respect to wavelength coverage, spectral resolution, spatial coverage, spatial resolution and radiometric accuracy, subject to the necessary practical constraints) are capable of returning basic data on the composition, thermal structure, radiation balance and dynamics and meteorology of the planets, provided numerical methods for the interpretation of data have also been developed. This work defines the observational conditions and associated instrumental performance criteria needed for the development of the rationale for science payloads of future planetary missions.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Accurate computational routines for the radiative transfer properties of hydrogen, ammonia and methane at low temperatures and high pressures have been developed. These have been used to define remote sensing experiments for the determination of atmospheric temperature profile and bulk composition (hydrogen to helium ratio and ammonia and methane abundances) on Jupiter. Error analyses have been performed for a range of planetary conditions. The increased constraints on instrument performance required to perform these investigations at Saturn have been established. A different approach calling for radical instrument design is needed for Uranus and Neptune: the requirements and theoretical performance have been detailed. Methods for the interpretation of infrared spectra by direct radiative transfer theory using laboratory measurements of cloud materials have been evolved using ground-based spectra: preliminary conclusions about the structure of the Jovian clouds were obtained from the low resolution spectra of Gillett et al. and the Jovian H:D ratio was determined from the high-resolution spectrum of Beer et al.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	185-47-71-05-55

5. TITLE

ATMOSPHERIC DYNAMICS

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Farmer, C. B.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 -	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	47	
NEXT FY 74 (c)	50	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 80-0-20-0-0

Studies of atmospheric dynamics are proposed in order to identify those aspects of the motions which characterize the atmospheric structure and which are therefore accessible to remote sensing measurements. Fluid dynamical studies of individual planets will indicate the critical factors controlling the circulation regimes and global meteorology so that experimental criteria for the study of these phenomena can be defined. Close cooperation with dynamicists at the University of Southern California is intended for the development of basic theory and supporting laboratory work. Principal emphasis would be placed on the development of observational techniques from spacecraft which would provide information bearing on comparative studies of the atmospheric dynamics of the outer planets. Some attention will also be paid to the study of the dynamics of the Venus atmosphere from spacecraft.

10. JUSTIFICATION (WHY)

The investigation of the circulation and dynamics of their atmospheres is a principal science objective in the exploration of the planets. This part of the Task will define specific measurements and observational sequences for science payloads on forthcoming missions in such a way that the information returned is optimized with respect to these objectives.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

7

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41	185-47-72

5. TITLE

THEORETICAL STUDIES - PLANETARY ATMOSPHERES

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

N/A

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

A broad program of experimental and theoretical studies related to planetary atmospheres will be conducted, with the following objectives:

1. Understanding the properties and determination of the parameters of planetary atmospheres.
2. Application of laboratory experimental data to understanding and interpretation of spectral features of complex planetary atmospheres.
3. Applying these findings towards design of ground based and spacecraft experiments.
4. Interpretation of above data as well as other observations to aid in the evolution of valid planetary atmospheric models.

This program contributes to NASA planetary missions both in its direct research relevance to planetary atmospheric science and in the maintenance within JPL of a staff of specialists who may evaluate and define scientific objectives and experiments for planetary flight projects.

The studies to be conducted in FY'73 pertain to:

A. Photochemistry of planetary atmospheres.
B. Theoretical studies, planetary atmospheric models and radiative transport theory.
C. Microwave spectral studies of planetary atmospheres.
D. Volatile evolution.
E. Electron ionization and collisions in planetary atmospheres.

13. KEYWORDS

Photochemistry, planetary atmospheres, radiative transfer, microwave spectroscopy, electron collision.

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald P. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

The details of our knowledge of the planets is based in a large part on the information gathered from direct and remote studies of their atmospheres. In order to improve our understanding of the structure, composition, physical behavior and evolution of their atmospheres, more refined methods must be developed for the interpretation of observational data and for the observational techniques themselves. To this end a broad program of theoretical studies in appropriate areas of atmospheric science must be pursued in support of the complementary observational and space experiment program.

A. Photochemistry of Planetary Atmospheres

Planetary probes, such as the Mariner series, have returned data on atmospheric chemical composition. The chemical composition holds many clues to the evolution of the planet. At present, this data is inadequately understood due to gaps in our comprehension of thermochemical and photochemical reaction processes. Detailed atmospheric chemical balance thus remains a mystery. Our methods for studying reactions of atomic oxygen and CO_2 photochemistry and recombination processes are particularly applicable to the solution of these problems.

B. Theoretical Studies, Planetary Atmospheric Models and Radiative Transport Theory

The interpretation of observed planetary spectra in order to determine the composition, structure and thermal properties and profiles and thereby establish the physical parameters that define the atmospheres of the planets is the fundamental problem of atmospheric physics. In order to understand and interpret the experimental data and to aid in the proposal of future ground based and spacecraft experiments, a broad theoretical program covering the theory of radiative transfer, development of atmospheric models and detailed spectroscopic analysis of the component particles is required.

Recently, we have made advances in the extraction of analytic solutions to specific cases of multiple scattering. These advances can be applied to the problem of spectral line formation, the determination of molecular parameters and problems of radiative transfer in planetary atmospheres. We have also shown that a unique solution can be obtained for the vertical temperature profile of a nonscattering atmosphere from measurements of its outgoing radiance. The method, which involves the relaxation approach to the inverse solution of the steady state radiative transfer equations, has the capability of being extended to include scattering terms, effects of partial cloudiness, surface elevations, etc., and to obtain compositional profiles. A realistic inhomogeneous model of the lower Venusian atmosphere in which all processes of radiative transfer by cloud particles and gases are incorporated in order to understand the formation of pressure broadened absorption lines has also been developed. This model can be extended to the Jovian atmosphere. The application of these and other theoretical techniques can enable us to shed some light on the fundamental problem of atmospheric physics noted above.

C. Microwave Spectral Studies of Planetary Atmospheres

In addition to the known molecular constituents in complex planetary atmospheres, there are a number of other species or radicals which are expected to be present. These can be predicted from consideration of photolytic action and ion-molecule reactions in the upper atmosphere or from the simple thermal equilibrium chemistry of the bulk atmosphere.

Because spectral linewidths are very small at the lower pressures found in the upper atmosphere, complex molecular species may best be detected in microwave wavelengths with ground based observations. Those species present below the visible or near infrared cloud layers will lose their sharp spectral lines and will be more difficult to detect in a simple unique way. Fortunately, each of the more prominent molecules has a characteristic behavior as a function of wavelength. Thus some information can be obtained about the abundance of such molecules, in spite of the pressure broadening and radiative filling which occurs.

In recent years radio astronomers have attempted to detect water vapor in the lower Venusian atmosphere and to observe the temperature inversion in the upper Jovian atmosphere. The experience gained from such attempts has shown that a systematic planetary microwave spectroscopy observational program must be coupled with and guided by a supporting theoretical radiative transfer computational program, which requires absorption coefficient data and an atmospheric model for its solution. The observability of different molecular species present in planetary atmospheres will depend on the minimum detectable difference in brightness temperature between the line center frequencies and frequencies several line widths distant from the line center. In many cases, laboratory measurements are also required to determine the absorption line frequencies and transition strengths needed in the above computations.

Inadequate fragmentary and frequently inaccurate spectral line data are available for many of the predicted planetary atmospheric molecular species. In almost all cases, with the partial exception of ammonia, little or no experimental data are available for spectral line intensities and line shape for either low or high pressures for either pure gases or gaseous mixtures. Because of conflicting published results, even the ammonia data reliability can be questioned. In addition, almost none of the published ammonia data is directly applicable to the planetary atmospheric case and rather tenuous extrapolations must be made.

As a consequence, it is difficult or impossible to select the "correct" microwave transitions which would be the most favorable for detecting these species. In the past, the lack of suitable theoretical and experimental programs devoted to these problems has been a major shortcoming in planetary radio astronomy.

D. Volatile Evolution

To understand the origin and the history of a planet's surface volatiles, three lines of investigation are essential: (1) the elemental composition of the "source" function (juvenile volatiles) must be determined, as distinct from the gross composition of volcanic effusions, which are dominated by recycled volatiles. To this end we are investigating the composition of gas released by vacuum fusion of primary igneous rocks. (2) the temporal history of interior degassing (the "transfer" function) must be understood. This is the purpose of theoretical studies which attempt to explain differences in Xe isotopic composition between (e.g.) the lithosphere and the atmosphere. This is also the purpose of experimental studies attempting to determine the isotopic composition of lithospheric rare gas. (3) the fate ("sink" function)

of volatiles once they are supplied to a planetary atmosphere - their mean residence times, mode of renewal, possible recycling, etc. - must also be understood. For this reason, studies of the adsorbed gas and ambient pore gas in sediments have been undertaken.

The above studies are augmented by theoretical and experimental studies of the pre-planetary history of volatiles in an attempt to understand causes of possible differences in bulk planetary volatile inventories. The main objects of interest are carbonaceous chondritic meteorites, their mode of origin in the solar system and differences between the volatile content (and its composition) of these objects, normal chondrites and the earth.

E. Electron Ionization and Collisions in Planetary Atmospheres

The collisions of primary, secondary and photo electrons with the constituent gases of the planetary atmospheres cause a large variety of reactions (excitation, ionization, electron capture, momentum transfer, elastic and super-elastic collisions, etc.). In order to understand and predict planetary atmospheric behavior, one needs to know the probability for the occurrence of these processes. Most of the electron impact cross sections are not known or are unreliable. This is especially so for the intermediate electron energy range (a few eV to a few hundred eV kinetic energy), where most of the cross sections have their maximum value. The study of electron-molecule collisions also yields spectroscopic information, some of which is not available from optical spectroscopy because of the forbidden selection rules.

We have the capabilities to determine electron-impact cross sections and use them for the interpretation of planetary atmospheric behavior (aurora, airglow, energy degradation of high energy electrons, etc.). Measurements of CO and CO_2 cross sections are needed for the understanding of Martian and Venusian atmospheres and the He and H_2 cross sections and their utilization in model calculations will help in the planning and interpretation of spectroscopic observations of Jupiter.

15. OPERATING PLAN

A. Objectives

1. Photochemistry of Planetary Atmospheres

The primary objective of the photochemical effort will be to explain why the equilibrium photodissociation of CO_2 in the Martian atmosphere is lower than would be predicted on the basis of our present knowledge of CO_2 photochemistry. Particular attention will be given to mechanisms of CO oxidation, effects of trace water concentrations and factors such as surface effects in order to determine the applicability of laboratory rate data to the planetary atmospheres.

2. Theoretical Studies, Planetary Atmospheric Models and Radiative Transport Theory

The broad objective is to establish the physical parameters, such as temperature, structure, composition and absorption altitude profiles, surface elevations, cloud cover, ..., that define the atmospheres of the planets.

The developments in the theory of radiative transfer provide a theoretical basis on which the optical properties and spectral characteristics of the planets for both brightness and polarization, which are formed in a scattering and absorbing medium, can be explained. Developments of new inverse solutions will establish methods for determining compositional profiles along with temperature profiles for active gases in an atmosphere from measurements of its outgoing radiance. Extension of the method to include scattering terms and effects of partial cloudiness will provide aid in the proper design of remote sensing experiments for unknown planetary atmospheres at all wavelengths. The realistic inhomogeneous model proposed for the Venusian lower atmosphere will be extended to the Jovian atmosphere.

Continue the mathematical characterization of optical components and instruments by detailed understanding of polarization effects to lead to new designs to help optimize operation of Fourier interferometers, beam splitters for interferometric spectrophotometers and to suggest techniques for improving spectral resolution of interferograms.

Develop spectroscopic theory to enable us to analyze the quantum number assignments and the higher level bands of NH_3 which are needed for the atmospheric parameters of Jupiter and Saturn. Also needed for the atmospheric parameters of the outer planets is a detailed theoretical understanding of H_2 (the major component of the Jovian atmosphere) in its ground and low lying excited singlet and triplet states, its quadrupole rotation-vibration spectrum, collision-induced dipole transitions and HD which, although it exhibits a rotational and rotation-vibration spectrum due to the presence of a small permanent dipole moment has not yet been detected due to the supposedly small abundance of D.

3. Microwave Spectral Studies of Planetary Atmospheres

Laboratory microwave spectroscopic methods and techniques will be used to determine microwave and radio spectral features and molecular radiation characteristics of complex planetary atmospheres, including the earth. Microwave spectral frequencies and intensities will be measured for important planetary atmospheric constituents. These laboratory results, along with other available data, will be used to predict and interpret the composition and structure of the planetary atmospheres and to provide the required background for proposed planetary observations.

This effort will support both classical and radio astronomical observations and spaceflight studies by providing the relevant laboratory microwave spectroscopic information required for the planning of experiments and the interpretation of the results.

4. Volatile Evolution

a. A computer program is being devised which will predict relative concentrations of all radiogenic nuclides (e.g., Ar^{40}, excess fission Xe^{136}, excess radiogenic Xe^{129}, etc.) in both the earth's interior and atmosphere as a function of time, planetary formation interval, the decay constants and the choice of transfer or degassing function (and the degassing constant). This will allow for model evaluation by fitting to observable ratios.

b. Mass spectrometric analysis of ambient rock pore gas and the adsorbed phase in shales will be conducted. Initial studies are emphasizing the rare gases, allowing the ambient phase and the adsorbed phase to be sharply distinguished. Stepwise heating (including room temperature desorption) and vacuum grinding will be utilized. For control purposes, both shales and commercial silica gel (in adsorption equilibrium with the atmosphere) will be subjected to the desorption studies.

c. Mass spectrometric analysis of gas released by vacuum fusion of rocks in the Table Mt. solar furnace are being conducted to determine the composition of juvenile gas released by melting of primary igneous rocks. This procedure offers the potential of minimizing "wall effects" (gas-wall interactions) which normally alter the composition of rock gas released in other procedures. Serious contamination problems resulting from the inability to properly bake out the large fusion chamber have arisen. Current work is aimed at eliminating these problems so that advantage may be taken of the unique aspects of the method of gas release.

d. Spectral reflectance studies of a large number of carbonaceous chondrite meteorites have been undertaken with a view to comparing these (and also spectra of other low albedo cosmically important objects, such as iron meteorites) with earth-based spectra of low albedo solar system objects.

5. Electron Ionization and Collisions in Planetary Atmospheres

Nearly monoenergetic electrons of a few to a few hundred eV kinetic energy are scattered from gaseous molecular targets. The energy and angular distribution of the scattered electrons are determined. From these measurements, the cross sections for the different electron-molecule collision processes and the energy level scheme of the mutual target molecule and the negative ion molecule are obtained. The measurements require a high degree of technological sophistication which has been developed during the past few years. Continuous semi-automatic operation of the instruments and computer aid in data handling and interpretation is necessary for reasonable expediency.

An instrument (noted Apparatus E in the milestone schedule) will be designed and built to extend the measurements to very low impact energies.

B. Technical Approach

1. Photochemistry of Planetary Atmospheres

Photochemical and non-photochemical mechanisms of CO oxidation will be studied, including the effects of trace water concentrations on the conversion of CO and CO_2. Emphasis will be placed on the temperature dependence at low temperatures, in view of the low temperature of much of the Martian atmosphere. The absorption spectrum of CO_2 at wavelengths near 2000Å will be studied in order to determine with greater certainty which wavelengths of solar radiation penetrate to the Martian surface.

2. Theoretical Studies, Planetary Atmospheric Models and Radiative Transport Theory

Work on the derivation and application of analytic solutions to problems of radiative transfer in planetary atmospheres for specific cases of atmospheric composition and type of scattering will be continued. Tables of scattering functions for conservative and non-conservative cases, which have been computed, will be used and extended to help develop the theory of the formation of spectral lines and of intensity and polarization in a scattering atmosphere. Work will be continued on the relaxation method of inverse solution of the steady state radiative transfer equations for the determination of unique temperature profile for a non-scattering atmosphere. New inverse problems will be formulated for the determination of compositional profiles and the methods extended to include scattering terms and effects such as partial cloudiness. Models developed for pressure broadened absorption lines in the Venusian lower atmosphere will be refined and extended to the Jovian atmosphere.

A theoretical analysis of quantum assignments for higher level bands in NH_3, based on laboratory spectral observations, will be undertaken. Spectroscopic properties of the ground state and the B state of H_2, HD and D_2 will be generated and compared against theoretical calculations. These calculations will include corrections for nuclear motion (partial breakdown of Born-Oppenheimer approximation and isotopic effects), non-adiabatic effects and relativistic and radiative effects.

3. Microwave Spectral Studies of Planetary Atmospheres

A flexible new precision microwave spectrometer will be used to study the appropriate molecular species. The results will be used in radiative transfer calculations to determine how their effects will be manifested in the observed planetary spectra.

A computer program has been written to solve the radiative transfer equation for a plane parallel atmosphere in which there is only one microwave absorber in the presence of a foreign gas. This program, which employs the complete low and high pressure line shape has been specifically applied to NH_3 in the atmospheres of Jupiter and Saturn.

This microwave radiative transfer program will be extended to include multi-component mixtures of microwave absorbing gases in the presence of one or more foreign gases (H_2, He). The program will be extended later to include linear polyatomic molecules, normal symmetric rotor molecules and asymmetric rotor molecules.

4. Volatile Evolution

Differences between the elemental and isotopic composition of lithospheric rare gas and that of the atmosphere will be determined and these differences interpreted in terms of a model for the temporal history of earth degassing. Recycling and atmosphere-interior gas exchange will be studied by examining the composition of the adsorbed and ambient pore gas composition in sediments. The composition of the component of truly juvenile interior gas will be determined and distinguished from the recycled component of volatiles in surface effusions.

5. Electron Ionization and Collisions in Planetary Atmospheres

The objective of this program is to measure cross sections for processes that can occur as the result of the collision of electrons with molecules and atoms. A complete set of cross sections for all important atmospheric species (He, H_2, N_2, O_2, CO, NO, H_2O, CO_2, N_2O, NH_3, CH_4) will be computed and will be made available to researchers in atmospheric and planetary physics. Special emphasis will be placed on establishing the energy level diagram of CO and CO_2 and on determining all electron impact cross sections for these molecules. Model calculations will be carried out with the utilization of the measured cross sections to interpret and predict atmospheric observations and behavior. Aurora, airglow and energy degradation processes of high energy electrons will be studied. The capabilities of electron impact spectroscopy will be exploited for detecting metastable states of molecules and optically forbidden electronic and vibrational excitations. Cross section measurements will also be extended to the important very-low energy range.

Long-range objectives include simultaneous observation of electrons, ions and/or photons which are produced in electron collisions and the direct determination of accurate absolute cross sections.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

Meetings and Symposia Papers

DeMore, W. B. and Mosesman, M, "Photolysis of CO_2 at 1849 Å," presented at the Fifth Arizona Conference on Planetary Atmospheres, Tucson, Arizona, 1971.

DeMore, W. B., "Pressure Dependence of the O + CO Reaction and the B_2 State of CO_2," presented at the Tenth Informal Conference on Photochemistry, Stillwater, Oklahoma, 1972.

Chahine, M. T., "Recent Developments in Inversion by Method of Relaxation," presented at the Ames Meeting of Mathematical Inversion Techniques, 1971.

Hunt, G. E., "Interpretation of Absorption Lines Formed in Venus Atmosphere," presented at the AGU Meeting, Planetology Section, Washington, D. C., 1971.

Hunt, G. E. and Margolis, J. S., "On the Validity of the Dicke Approximation for Computing Collision Narrowed Profiles of Quadrupole Lines in Hydrogen Atmospheres," presented at the American Astronomical Society Division of Planetary Sciences Meeting, Kailua-Kona, Hawaii, 1972.

Margolis, J. S. and Hunt, G. E., "On the Level Formation of the Hydrogen Quadrupole Lines on Jupiter," presented at the American Astronomical Society Division of Planetary Sciences Meeting, Kailua-Kona, Hawaii, 1972.

Hunt, G. E., "Spectroscopic Evidence for the Structure of the Visible Jovian Clouds from Observations of Methane and Hydrogen Quadrupole Lines," presented at the American Astronomical Society Division of Planetary Sciences Meeting, Kailua-Kona, Hawaii, 1972.

Taylor, F. W. and Hunt, G. E., "The Infrared Spectrum of Jupiter and Radiative Properties of the Clouds," presented at the American Astronomical Society Division of Planetary Sciences, Kailua-Kona, Hawaii, 1972.

Schorn, R. A. J., and Hunt, G. E., "Spectroscopic Observations of Venus at Superior Conjunction," presented at the American Astronomical Society Division of Planetary Sciences, Kailua-Kona, Hawaii, 1972.

Trajmar, S., Williams, W. and Cartwright, D. C., "Excitation of Electronic States of CO by Electron Impact," presented at the VII International Conference on Physics of Electronic and Atomic Collisions, Amsterdam, Holland, 1971.

Cartwright, D. C., Trajmar, S., Williams, W. and Huestis, D., "Observation of 'Parity Unfavored' Transitions in Electron-Molecule Collisions," presented at the VII International Conference on Physics of Electronic and Atomic Collisions, Amsterdam, Holland, 1971.

Trajmar, S., Williams, W., Truhlar, D. G. and Cartwright, D. C., "Vibrational Excitation of Diatomic Molecules by Electrons in the 10 to 100 eV Energy Range," presented at the VII International Conference on Physics of Electronic and Atomic Collisions, Amsterdam, Holland, 1971.

Trajmar, S., Williams, W., Kupperman, A. and Cartwright, D. C., "Differential and Integral Cross Sections for Electron-Impact Excitation of O_2," presented at the VII International Conference on Physics of Electronic and Atomic Collisions, Amsterdam, Holland, 1971.

Cartwright, D. C., Trajmar, S. and Williams, W., "Excitation and Dissociation of O_2 in Auroras," presented at the XV General Assembly of International Union of Geodesy and Geophysics, Moscow, USSR, 1971.

Cartwright, D. C., Williams, W. and Trajmar, S., "Emission Spectrum of N_2 Excited Under Auroral Conditions," presented at the XV General Assembly of International Union of Geodesy and Geophysics, Moscow, USSR, 1971.

Trajmar, S., "Electron Impact Spectroscopy," presented at the Molecular Structure and Spectroscopy Symposium, Ohio State University, Columbus, Ohio, 1972.

Cartwright, D. C., Hunt, W., Williams, W and Trajmar, S., "Low-Lying Rydberg States in O_2 by Electron Impact Spectroscopy," presented at the Molecular Structure and Spectroscopy Symposium, Ohio State University, Columbus, Ohio, 1972.

Winter, N., Goddard, W. and Trajmar, S., "Theoretical Description of Valence Excited States of CO," presented at the Molecular Structure and Spectroscopy Symposium, Ohio State University, Columbus, Ohio, 1972.

Gulkis, S. and Poynter, R. L., "Thermal Radio Emission from Jupiter and Saturn," presented at the Lunar Science Institute Conference on Physics of the Earth and Planetary Interiors, Houston, Texas, 1972.

Poynter, R. L. and Gulkis, S., "Thermal Radio Emission from Jupiter and Saturn," presented at the American Astronomical Society Division of Planetary Sciences, Kailua-Kona, Hawaii, 1972.

Gulkis, S., and Poynter, R., "Saturn, Interpretation of Its Microwave Spectrum," presented at the 136th Meeting of the American Astronomical Society, San Juan, Puerto Rico, 1971.

Journal Articles

DeMore, W. B. and Mosesman, M., "Photolysis of CO_2 at 1849 Å," J. Atmos. Phys. 28, 842, 1971.

Chahine, M. T., "Inverse Problems in Radiative Transfer: Determination of Atmospheric Parameters," J. Atmos. Sci., 1971.

Fymat, A. L. and Abhyankar, K. D., "Effect of Absorption on Scattering by Planetary Atmospheres," J. Geophys. Res. 76, 732, 1971.

Abhyankar, K. D. and Fymat, A. L., "Tables of Auxiliary Functions for Conservative Rayleigh Phase Matrix in Semi-Infinite Atmospheres," Astrophys. J., Supp. Ser., #195, 1971.

Fymat, A. L., "Jones' Matrix Representation of Optical Instruments. I. Beam Splitters," Applied Optics 10, 2499, 1971.

Fymat, A. L., "Jones' Matrix Representation of Optical Instruments. II. Fourier Interferometers," Applied Optics 10, 2711, 1971.

Fymat, A. L., "Polarization Effects in Fourier Spectroscopy. I. Coherency Matrix Representation," Applied Optics, in press.

Hunt, G. E. and Schorn, R. A., "Height Variations of Venusian Clouds," Nature Phys. Sci. 233, 39, 1971.

Hunt, G. E., "Formation of Spectral Lines in Planetary Atmospheres. I. Theory for Cloudy Atmospheres; Application to Venus," J. Quant. Spect. Rad. Trans. 11, 1971.

Hunt, G. E., "Formation of Spectral Lines in Planetary Atmospheres. II. Spectroscopic Evidence for the Structure of the Venus Clouds," J. Quant. Spect. Rad. Trans. 11, 1971.

Hunt, G. E., "Formation of Spectral Lines in Planetary Atmospheres. III. Use of Analytic Scattering Diagrams," J. Quant. Spect. Rad. Trans. 12, 1972.

Trajmar, S., Williams, W. and Kupperman, A., "Detection and Identification of Triplet States of H_2O by Electron Impact," J. Chem. Phys. 54, 2274, 1971.

Cartwright, D. C., Trajmar, S. and Williams, W., "Vibrational Population of A and B States of N_2 in Normal Auroras," J. Geophys. Res. 76, 8368, 1971.

Trajmar, S., Cartwright, D. C. and Williams, W., "Differential and Integral Cross Sections for Electron Impact Excitation of a and b States of O_2," Phys. Rev. A4, 1482, 1971.

Trajmar, S., Williams, W. and Kupperman, A., "Angular Dependence of Electron Impact Excitation Cross Sections of O_2," J. Chem. Phys., 1972, in press.

Rice, J. K., Truhlar, D., Cartwright, D. C. and Trajmar, S., "Effect of Charge Polarization on Inelastic Scattering Cross Section for Excitation of 2^1S State of He," Phys. Rev. A5, 762, 1972.

Cartwright, D. C., Trajmar, S. and Williams, W., "Excitation of O_2 in Aurora," Ann. de Geophys., 1972, in press.

Trajmar, S., Williams, W. and Kupperman, A., "Electron Impact Excitation of H_2O", J. Chem. Phys., 1972, in press.

Truhlar, D. G., Rice, J. K., Trajmar, S. and Cartwright, D. C., "Importance of Polarization for Electron Scattering in Intermediate Energy Region," Chem. Phys. Lett. 9, 299, 1971.

Cartwright, D. C., Trajmar, S., Williams, W. and Huestis, D., "Selection Rules for 'Parity Unfavored' Transitions in Electron Molecule Collisions," Phys. Rev. Lett. 27, 704, 1971.

Goddard, W. A., Huestis, D., Cartwright, D. C. and Trajmar, S., "Group Theoretical Selection Rules for Electron Impact Spectroscopy," Chem. Phys. Lett. 11, 329, 1971.

Gulkis, S. and Poynter, R., "Thermal Radio Emission from Jupiter and Saturn," Proc. of Conf. on Physics of Earth and Planetary Interiors, North Holland Publ. Co., North Holland, Amsterdam, 1972.

Fanale, F. P. and Cannon, W. A., "Origin of Planetary Primordial Rare Gas: The Possible Role of Adsorption," Geochim. et Cosmochim. Acta, 36, 319, 1972.

Fanale, F. P., "A Case for Catastrophic Early Degassing of the Earth," Chem. Geology, 8, 79, 1971.

Fanale, F. P., "History of Martian Volatiles: Implications for Organic Synthesis," Icarus, 15, 279, 1971.

Fanale, F. P. and Cannon, W. A., "Physical Adsorption of Rare Gas on Terrigenous Sediments," Earth and Planetary Sci. Lett. 11, #5, 1971.

Fanale, F. P. and Cannon, W. A., "Adsorption on the Martian Regolith," Nature 230, #5295, 502, 1971.

Taylor, F. W., "Methods and Approximations for the Computation of Transmission Profiles in the O_4 Band of Methane in the Atmosphere of Jupiter," J. Quant. Spec. Rad. Trans., in press.

Young, L. G., "Comments on: Accurate Formula for Gaseous Transmittance in the Infrared," Appl. Optics, 11, 202-203, 1972.

Young, L. D. G., "Calculation of the Partition Function for $^{14}N_2{}^{16}O$," J. Quant. Spec. Rad. Trans., 11, 1265-1270, 1971.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-47-72-01-55	Photochemistry of Planetary Atmospheres		13 OF 18

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY QUARTER 1	2	3	4	FY QUARTER 1	2	3	4
Measure Extinction Coefficient of CO_2					▽																							
Complete O + CO Rate Measurements								▽																				
Investigate Temperature Dependence of O + CO Reaction													▽															

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▽ ▭ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▭ ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

jpl → **RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE**

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-47-72-02-55	Theoretical Studies, Planetary Atmospheric Models & Radiative Transport Theory		14 of 18

MAJOR MILESTONES	PRIOR FY ___ QUARTER 1	2	3	4	CURRENT FY _____ MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY _____ QUARTER 1	2	3	4	FY _____ QUARTER 1	2	3	4	FY _____ QUARTER 1	2	3	4
1. Develop New Inverse Problems in RTE to determine compositional profiles--no scattering										△																		
--with scattering included																△												
2. Tables of Scattering Functions completed																												
3. Extend derivation of analytic solns of RTE problems to specific cases of composition and scattering.							△																					
4. Assess importance of polarization in mathematical characterization of Fourier Interferometers.														△														
5. Extend model for pressure broadened absorption lines to Jovian Atmosphere										△																		
6. Comparison of Experimental and Theoretical Results on constants of H_2, HD, D_2 in X & B states.												△																

NOTES 7. First stage in quantum assignment of NH_3 bands △

LEGEND (EXAMPLES) ▽ - SCHEDULED COMPLETION DATE; ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1); ▼ - ACTUAL COMPLETION DATE; ▽—▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END; ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE); ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

jpl → **RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE**

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-47-72-03-55	Microwave Spectral Studies of Planetary Atmospheres		15 OF 18

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY QUARTER 1	2	3	4	FY QUARTER 1	2	3	4
1. Modify disc temperature calculations to include He										△																		
2. Modify disc temperature calculations to include IR lines of NH_3														△														
3. Complete analysis of NH_3 - $000^01'$ excited vibrational state microwave lines (within available frequency range)																△												

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▭ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-47-72-04-55	Volatile Evolution		16 OF 18

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY QUARTER 1	2	3	4	FY QUARTER 1	2	3	4
1. Radiogenic Rare Gas Transfer Problem									△																			
2. Atmosphere-sediment interaction problem								△																				
3. Atmosphere-sediment interaction problem																△												
4. Rock-gas analysis										△																		
5. "Pre-accretion" volatile history problem						△																						
(see notes below)																												

NOTES

1. "Universal" computer program applied to reasonable parameters for earth; transfer functions evaluated on ability to match data for lithosphere and atmosphere.
2. Spectrometer operating optimumly—ability to sum individual ion counter and output is digitized. Background and sensitivity sufficient for problem
3. Several shale and gel samples run. Rare gas elemental and isotopic composition measured with sufficient accuracy; Differences from atmospheric values interpreted in terms of atmosphere-interior interactions.
4. Satisfactory analysis of rock-gas composition with demonstrable absence (hopefully) of "wall-effects" obtained.
5. All carbonaceous chondrites and other low-albedo objects run. Spectral interpretation re solar system observations.

LEGEND (EXAMPLES)

- SCHEDULED COMPLETION DATE
- 1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-47-72-05-55	Electron Ionization & Cullisions in Planetary Atmospheres		17 OF 18

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY ____ QUARTER 1	2	3	4	FY ____ QUARTER 1	2	3	4
e - N_2, e - O_2 Measurements	▼																											
Put Apparatus B into operation	—	—	▼																									
e - He Measurements	—	—	—	▽																								
e - CO, CO_2, NO, H_2 Measurements											—	—	—	—	—	▽												
Design and Build Apparatus E														—	—	▽												

NOTES

Apparatus B - Molecular - Beam/Electron-Beam instrument with capability of electron, photon and ion detection.

Apparatus E - Very-low-energy electron impact spectrometer.

LEGEND (EXAMPLES)

- ▽ - SCHEDULED COMPLETION DATE
- ▽(1) - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▽ ▭ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	185-47-72	THEORETICAL STUDIES - PLANETARY ATMOSPHERES	18 OF 18

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL					
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	5.2	7.9	8.8		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	280	372	443		
TOTAL FUNDS	280	372	443		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	601-47210-0-8280	N/A	185-47-72-01-55

5. TITLE

PHOTOCHEMISTRY OF PLANETARY ATMOSPHERES (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: DeMore, W. B.

TELEPHONE: 213 - 354 - 2436

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS:

PRINCIPAL INVESTIGATOR:

TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	50	
CURRENT FY 73 (c)	50	
NEXT FY 74 (c)	65	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-0-0-70-20

The primary objective will be to explain why the equilibrium photodissociation of CO_2 in the Martian atmosphere is lower than would be predicted on the basis of our present knowledge of CO_2 photochemistry.

Photochemical and nonphotochemical mechanisms of CO oxidation will be studied, including the effect of trace water concentrations on the conversion of CO to CO_2. Factors such as surface effects will be investigated in order to determine the applicability of laboratory rate data to planetary conditions.

10. JUSTIFICATION (WHY)

Planetary probes, such as the Mariner series, have returned data on atmospheric chemical composition. At present this data, and therefore detailed atmospheric chemical balance, is inadequately understood due to gaps in our comprehension of thermochemical and photochemical reaction processes. Our methods for studying reactions of atomic oxygen and CO_2 photochemistry and recombination processes are particularly applicable to the solution of these problems.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

The rate of the $O + CO \rightarrow CO_2$ reaction has been measured at pressures from 1 to 40 atmospheres. The results have been shown to be independent of surface effects. The observed pressure dependence is more complex than previously believed because of the intervention of a new reaction path which is unimportant at low pressures but increasingly more significant at higher pressures.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	601-47220-0-8250	N/A	185-47-72-02-55

5. TITLE

THEORETICAL STUDIES, PLANETARY ATMOSPHERIC MODELS & RADIATIVE TRANSPORT THEORY (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Geller, M.

TELEPHONE: 213 - 354 - 2593

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS:

PRINCIPAL INVESTIGATOR:

TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	100	
CURRENT FY 73 (c)	117	
NEXT FY 74 (c)	137	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 100-0-0-0-0

The broad objective is to establish the physical parameters that define the atmosphere of the planets.

Developments in the theory and application of analytic solutions to problems of radiative transfer in planetary atmospheres for specific cases of atmospheric composition and scattering will be pursued. The relaxation method of inverse solution to steady state full RTE for determination of unique temperature profile in a nonscattering atmosphere and extensions to include scattering terms and techniques for obtaining compositional profiles will be investigated further. A model developed for pressure broadened absorption lines in Venusian lower atmosphere will be refined and extended to the Jovian atmosphere.

Theoretical analysis of quantum assignments for high level bands of NH_3 needed for determination of atmospheric parameters of Jupiter and Saturn will be initiated based on laboratory spectral data. Detailed theoretical and comparative experimental analysis of H_2 (the major component of the Jovian atmosphere), HD and D_2 in the ground and low lying excited states will be undertaken to ascertain atmospheric parameters of the outer planets.

10. JUSTIFICATION (WHY)

The interpretation of observed planetary spectra in order to determine the composition, structure and thermal properties and profiles and thereby establish the physical parameters that define the atmosphere of the planets is the fundamental problem of atmospheric physics. In order to understand and interpret the experimental data and to aid in the proposal of future ground based and spacecraft experiments, a broad theoretical program covering the theory of radiative transfer, development of atmospheric models and detailed spectroscopic analysis of the component particles is required.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A comprehensive model for the formation of pressure broadened absorption lines in the lower Venusian atmosphere in which all processes of radiative transfer are accurately incorporated has been completed and published in a series of articles. The relaxation method for the inverse solution to the full RTE leading to unique vertical temperature profile for nonscattering atmosphere has been published. Extensive tables of scattering functions for nonconservative Rayleigh phase matrix appropriate for semi-infinite atmospheres have been published. The first two in a series of papers pertaining to the mathematical characterization of optical components and instruments which may lead to new designs and optimization in interferometry have been published. A paper in press demonstrates that for an atmosphere of plane parallel or spherical geometry, a gradient flux relation exists that provides the absorption altitude profile and that is independent of scattering or state of polarization.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	601-47230-0-8250	N/A	185-47-72-03-55

5. TITLE
MICROWAVE SPECTRAL STUDIES OF PLANETARY ATMOSPHERES

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)	CONTRACT NO.
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A	CONTRACT START DATE
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS	
RESPONSIBLE INDIVIDUAL: Poynter, R.	PRINCIPAL INVESTIGATOR	
TELEPHONE: 213 - 354 - 2437	TELEPHONE	

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	50	
CURRENT FY 73(c)	64	
NEXT FY 74(c)	80	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-10-40-40-0

Laboratory microwave spectroscopic methods and techniques will be used to determine microwave and radio spectral features and molecular radiation characteristics of complex planetary atmospheres including the earth. Microwave spectral frequencies and intensities will be measured for important planetary atmospheric constituents. These laboratory results, along with other available data, will be used to predict and interpret the composition and structure of the planetary atmospheres and to provide the required background for proposed planetary observations.

A flexible new precision microwave spectrometer will be used to study the appropriate molecular species. The results will be used in radiative transfer calculations to determine how their effects will be manifested in the observed planetary spectra.

10. JUSTIFICATION (WHY)

Inadequate, fragmentary, and frequently inaccurate spectral line data are available for many of the predicted planetary atmospheric molecular species. In almost all cases, with the partial exception of ammonia, little or no experimental data are available for spectral line intensities and line shapes for either low or high pressures for either pure gases of gaseous mixtures. In addition, almost none of the published ammonia data is directly applicable to the planetary atmospheric case and rather tenuous extrapolations must be made.

As a consequence, it is difficult or impossible to select the "correct" microwave transitions which would present the most favorable vehicles for detecting these species. The lack of a suitable theoretical and experimental program devoted to these problems has been a major shortcoming in planetary radio astronomy.

11. Main Achievements (Significant Progress)

(1) Deep atmospheric models have been constructed for Jupiter and Saturn. These models employ the real gas compressibilities and specific heat capacities, and where possible, match other models for the upper atmospheric regions. (2) The radiative transfer program has been applied to compute radio spectra for both Jupiter and Saturn for wavelengths from 0.8 cm to 60.0 cm. (3) Nineteen inversion transitions between inversion split rotational energy levels in the microwave spectrum of ammonia have been observed and assigned.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	601-47240-0-8260	N/A	185-47-72

5. TITLE

VOLATILE EVOLUTION (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Fraser P. Fanale	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 6741	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	49	
CURRENT FY 73(c)	91	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 50-0-0-50-0

Theoretical calculations pertaining to the temporal history of earth degassing will be performed using model simulation of growth of excess fission Xe and radiogenic Xe^{129} relative to Ar^{40} and shielded Xe nuclides in the lithosphere as well as the transfer of all these nuclides to the atmosphere. An attempt will be made to explain differences between lithospheric and atmospheric rare gas isotopic composition using reasonable models for the temporal history of earth degassing. Possible values of the formation interval of the earth and other geochemical quantities are simultaneously obtained. Room temperature desorption, stepwise heating and vacuum grinding are used to release adsorbed and pore gas from earth sedimentary materials. Released gas is chemically cleaned up by Ti getters and rare gas saved for mass spectrometric analysis. The static Reynolds MS is being improved for this use. Table Mt. solar furnace vacuum fission studies of mafic rock gas composition are continuing, using mass spectrometric analysis at JPL.

10. JUSTIFICATION (WHY)

From theoretical calculations it is possible to deduce the time dependence of earth degassing and simultaneously pin down the formation interval (nucleosynthesis-gas retention) for earth material. Compositional analysis of gas(especially rare gas) released on vacuum grinding or low temperature heating of terrestrial sediments will be the key to distinguishing and evaluating contributions from adsorbed atmospheric gas, trapped atmospheric gas, adsorbed ambient rock gas and ambient rock pore gas. This will elucidate the poorly understood physical equilibrium between planetary atmospheres and soils. Rock gas analysis will be much more indicative of true juvenile contributions of volatiles to earth volcanic gas and the expected composition of possible martian or lunar volcanic emanations. The solar furnace minimizes wall effects.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A theoretical and experimental study of the relationship between solar rare gas composition and that of the "planetary primordial" component, as found (for example) in carbonaceous chondrites and the earth's atmosphere, was completed and has been published in Geochim. et Cosmochim. Acta, March 1972 ("Origin of Planetary Primordial Rare Gas - The Possible Role of Adsorption"). In the last year four other articles reporting on theoretical and experimental studies funded under the task and related to the origin and chemical evolution of earth and martian surface volatiles have also been published in Earth and Planetary Science Letters, Nature, Icarus, and Chemical Geology.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	601-47250-0-8280	N/A	185-47-72-05-55

5. TITLE

ELECTRON IONIZATION AND COLLISIONS IN PLANETARY ATMOSPHERES (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Trajmar, S.

TELEPHONE: 213 - 354 - 2145

7. CONTRACTOR (IF APPLICABLE)

NAME

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	30	
CURRENT FY 73 (c)	50	
NEXT FY 74 (c)	65	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-5-40-45-0

Electron-molecule (atom) collision processes which are important in atmospheric and planetary physics are studied. Cross sections for these processes are measured, energy levels of the molecules (many of them not observable by means of optical spectroscopy) are determined, and the nature of interactions between electrons and molecules is studied.

The measured cross sections are utilized for interpreting and aiding atmospheric and planetary observations (aurora, airglow, energy degradation processes of high-energy electrons, etc.). Electron-impact spectrometers constructed in previous years and being constructed presently will be utilized to carry out the measurements, and the rate equation method will be used to carry out model calculations with the measured data. Special effort will be made to predict atmospheric properties of Jupiter that could be utilized in future outer planet missions, to understand the electron impact processes involving CO and CO_2, and in measuring cross sections in the important very-low energy range by means of an instrument which will be designed and built.

10. JUSTIFICATION (WHY)

The collisions of primary, secondary and photo electrons with the constituent gases of the planetary atmospheres cause a large variety of reactions. In order to understand and predict planetary atmospheric behavior, one needs to know the probability for the occurrence of these processes. Most of the electron impact cross sections are not known or are unreliable. This is especially so for the intermediate electron energy range (a few eV to a few hundred eV kinetic energy), where most of the cross sections have their maximum value.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

We have carried out pioneering work in the field of electron-impact cross section measurements and have made several important discoveries. Our results are widely quoted and utilized by other researchers. Six papers have been presented at international conferences and nine papers have been published as journal articles during the past year.

ADDENDUM

30

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		10,41	185-47-72 Addendum

5. TITLE
THEORETICAL STUDY, PLANETARY ATMOSPHERES

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002200,012700

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The objective of this work is to study the ion chemistry of planetary atmospheres: to determine the ionization rates by photon and electron impact, to identify the ions produced, to identify the reactions which occur between ions and neutrals in the atmosphere, to measure the rates for ion-molecule reactions, and to study ion loss by ion-electron recombination. The technique which will be used in these studies is ion-cyclotron magnetic resonance (ICR). The ICR instrument is a relatively new concept in mass spectrometry featuring an open ion source geometry with long ion trapping times and remote ion sensing. A magnetically confined swarm of ions is formed over a large volume in a crossed field ion trap and allowed to react with the neutrals present in the gas. Ions are mass analyzed in situ as a function of time, using an rf oscillator detector. At short times the initial products of primary ionization are obtained, while at longer times the changes in ion distribution are readily followed to obtain ion-molecule reaction rates. Through a technique of rf "double resonance" it is possible to directly identify individual ion-molecule reactions occurring concurrently with a number of other reactions which might otherwise obscure unique identification. With this one instrument, the kinds of processes which can be studied include: photoionization and electron impact ionization, Penning and associative ionization, elastic scattering of ions and electrons, inelastic scattering of electrons, ion-molecule reactions, electron attachment, photodetachment of electrons, and photodissociation of ions. It is hoped that information on ion-electron recombination can be obtained after modification of existing equipment. The ICR technique is applicable for the study of almost all known processes in planetary ionospheres, and quantitative information can be readily obtained which has heretofore been extremely difficult or impossible to acquire.

13. KEYWORDS
Planetary atmospheres, ionisphere, ionization reactions

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. Justification

A fair amount of information on ion-molecule reactions and ion-molecule reaction rates has been obtained for ionospheric reactions using mainly flowing afterglow and conventional mass spectrometric techniques. Although satisfactory data has been obtained for ionospheric reactions in the atmospheres of the earth, Mars, and Venus, these methods are not readily applicable to more complex systems such as the Jovian atmosphere. This restriction arises because it is not possible using flowing afterglows and conventional mass spectrometric techniques to uniquely identify the precursor ions for ionic reactions. Thus, only simple systems where few reactions occur, such as rare gases, atoms, and diatomics, can be readily studied with conventional systems. Also, branching ratios cannot be accurately determined using flowing afterglows, and the high pressures required by the flowing afterglow method preclude the study of excited ions formed in the primary ionization process.

The ICR spectrometer neatly complements the more conventional techniques for studying ion-molecule reactions and alleviates most of the restrictions of other methods. The ICR technique is a low pressure method which comes closest to simulating on a small scale the actual conditions in planetary ionospheres; the open source geometry, ion trapping, and remote sensing features allow this unique capability. The ICR spectrometer is capable of identifying individual ion-molecule reactions in complex systems, and branching ratios and rates are readily obtained. The number of ionization processes which can be studied and the quantity of data which can be obtained with this single instrument make it ideal for the laboratory study of atmospheric ionization phenomena.

The ICR technique is the only method capable of a complete study of the ion chemistry of the atmospheres of the Jovian planets because of the complexity of the molecules involved and the number of possible reactions. Very few experimental studies have been conducted of ionization phenomena in the atmospheres of the Jovian planets. Discharges in mixtures of H_2, He, CH_4, NH_3, and H_2O are extremely complex and little is known of the ion chemistry of these systems. Preliminary work in the ICR laboratory at JPL has gone far in unraveling the ion chemistry in irradiated mixtures of H_2, He, CH_4, NH_3, H_2O, and H_2S. Although several simple models of the ionosphere of Jupiter have been published by Hunten, Rasool, Trafton and others, these models are based on old and incomplete laboratory measurements.

In order for the construction of more detailed models of the ionospheres of the Jovian planets, extensive examination of the ion chemistry of these atmospheres is required. These data are not only necessary for a better understanding of Jovian atmospheric phenomena, but are also required for entry probe studies.

15. Operating Plan

A. Objectives

The main objective of this work is to examine in detail the ion chemistry of the Jovian planets. The long-range goal is to obtain a complete list of the ionization processes and ion-molecule reactions which occur in mixtures of H_2, He, CH_4, NH_3, H_2O, H_2S, Ne, and the rare gases, to obtain the rates for these processes, and to examine ion-electron recombination in these systems. During the next fiscal year, rates will be obtained for the major ion-molecule reactions occurring in most of the binary mixtures of

these gases, such as H_2-He, H_2-CH_4, He-CH_4, and CH_4-NH_3. Also, the ICR spectrometer will be modified for an attempt at studying ion-electron recombinations.

B. Technical Approach

The ICR spectrometer will be set up for the study of ion-molecule reactions in planetary atmospheres. The spectrometer is presently in operation and the only modification required is to rig the electronics for the study of ion density as a function of time using the trapped ion mode of operation. Most required ancillary equipment and supplies are available. The only major modification will be to set up the spectrometer for ion-electron recombinations, which will require the design and construction of a low energy crossed electron beam. Work would initially concentrate on ion-molecule reactions and could begin immediately.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-47-72	THEORETICAL STUDY, PLANETARY ATMOSPHERES		4 OF 5

MAJOR MILESTONES	PRIOR FY___ QUARTER 1	2	3	4	CURRENT FY '73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY '74 QUARTER 1	2	3	4	FY___ QUARTER 1	2	3	4	FY___ QUARTER 1	2	3	4
Ion-molecule reactions in CH_4-NH_3, CH_4-H_2S, CH_4-H_2O mixtures																												
Ion-molecule reactions in H_2-He, H_2-CH_4, H_2-NH_3, H_2-H_2O mixtures																												
Ion-molecule reactions in He-CH_4, He-NH_3, He-H_2O mixtures																												
Modification for the study of ion-electron recombination																												

NOTES

Work on ion-molecule reactions can proceed concurrently with spectrometer modifications for ion-electron recombination studies.

LEGEND (EXAMPLES)

- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	185-47-72	THEORETICAL STUDY, PLANETARY ATMOSPHERES	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
DIRECT PROFESSIONAL	0	1.0	1.0		
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	0	1.0	1.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	0	52.0	58.0		
TOTAL FUNDS	0	52.0	58.0		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72			185-47-72-10-55

5. TITLE

ION CHEMISTRY OF PLANETARY ATMOSPHERES (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)	
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A	CONTRACT NO.
ADDRESS: 4800 Oak Grove Dr / Pasadena, Calif. 91103	ADDRESS	CONTRACT START DATE
RESPONSIBLE INDIVIDUAL: Huntress, W.T.	PRINCIPAL INVESTIGATOR	
TELEPHONE: 213 - 354 - 2439	TELEPHONE	

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72	0	
CURRENT FY '73 (n)	52	
NEXT FY '74 (c)	58	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The ion cyclotron magnetic resonance (ICR) technique will be used to examine the ion chemistry of the Jovian atmosphere. Ion-molecule reactions occurring in the atmosphere will be identified and the rates for these reactions will be determined. An attempt will also be made to determine ion-electron recombination rates by a suitable modification of the ICR apparatus. To study ion-molecule reactions, the ICR spectrometer will be reconfigured to allow the study of ion density as a function of time in a weakly-ionized, magnetically confined plasma using radio frequency double resonance to identify individual ion-molecule reactions. The gas mixtures which will be studied include H_2-He, H_2-CH_4, H_2-NH_3, H_2-H_2O, He-CH_4, He-NH_3, He-H_2O, CH_4-NH_3, CH_4-H_2O, and CH_4-H_2S.

10-0-20-50-20

10. JUSTIFICATION (WHY) Very few experimental studies have been made of the ion chemistry of the Jovian planets. This is because the molecules involved are complex, the number of molecules involved is large, and current methods for the study of ion-molecule reactions are for the most part restricted to simple systems. The ICR spectrometer is uniquely capable for the study of ionization phenomena in complex systems. Previous models of the Jovian ionosphere are based on incomplete and inaccurate laboratory data. More detailed models are required not only for a basic understanding of Jovian atmospheric phenomena, but also for atmospheric entry probe studies. New models require more laboratory data, data which can be easily obtained, and in some cases can only be obtained, by the study proposed in this RTOP.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

36

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41	185-50-71

5. TITLE
PLANETOLOGY STUDIES

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
006800, 007100, 011000, 015300

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 -3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

This program is devoted to the development of experimental techniques, instrumental configuration and methods of data analysis for the in situ measurement of planetary surface composition.

A. X-Ray Diffraction/Fluorescence

The objective of this task is to develop a flight-configured engineering model of a combined X-ray fluorescence spectrometer and diffractometer for use in determining the elemental and mineralogical content of planetary materials. The instrument will be miniaturized and capable of ruggedization.

B. X-Ray Fluorescence Analysis of Planetary Surfaces Using Solid-State Detectors

The main objective of this program is to develop a solid-state X-ray detector system of high resolution that can be flown on instrumented spacecraft missions for the chemical analysis of planetary surfaces. Solid-state detectors offer a great improvement in resolution relative to gas-filled proportional counters. Likely applications of a flyable solid-state X-ray detector include: (1) use in an X-ray mode of an alpha-scattering instrument for chemical analysis of the Martian surface, and (2) use in a combined X-ray diffraction/spectroscopy experiment for Martian surface analysis.

C. Planetary Frost and Ice Studies

A program will be carried out to investigate the optical properties of frosts, ices and ice silicate mixtures of suspected relevance to the atmospheres and surfaces of the outer planets. Spectral measurements will be made in the laboratory as well as the field.

13. KEYWORDS X-ray diffraction, mineralogy, X-ray fluorescence, X-ray detectors, planetology, frost and ice

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald P. Rice ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. JUSTIFICATION

A. X-Ray Diffraction/Fluorescence

As Apollo sample studies are demonstrating, a determination of the mineralogy and elemental composition of lunar and planetary surface material is fundamental for an understanding of the origin and evolution of these bodies and comparison with the earth's own history. The combined X-ray diffractometer/spectrometer is being designed to perform such an in situ analysis from a planetary lander.

B. X-Ray Fluorescence Analysis of Planetary Surfaces Using Solid-State Detectors

One of the most fundamental things that can be learned about the surface of a planet is its chemical composition. The value of such information to the scientific community has been demonstrated by the interest shown in the Surveyor and Apollo analyses of lunar surface material.

The proposed work can lead to the development of chemical-analysis experiments that can be flown on Mars-lander missions and on fly-by or orbiting spacecraft missions to atmosphere-free planetary bodies. Potential experiments which could take advantage of the high resolution of the solid-state X-ray detectors include: (1) a combined alpha-scattering/X-ray experiment for chemical analysis of the Martian surface. The first application of these detectors to the analysis of rocks using alpha-particle excitation was in the NASA-sponsored JPL development of an X-ray mode for use with the University of Chicago alpha-scattering instrument for Martian surface analysis; (2) a combined X-ray diffraction/spectroscopy experiment for Martian surface analysis; (3) a scanning electron microanalyzer for a Mars lander mission which would combine the imaging features of a scanning electron microscope with the chemical analysis capabilities of an X-ray microprobe; (4) an X-ray fluorescence experiment, per se, using either X-ray tube or radioisotope excitation for Martian surface analysis; and (5) an experiment for remote analysis of atmosphere-free solar system bodies (Mercury, planetary satellites, asteroids) on fly-by or orbiting missions.

C. Planetary Frost and Ice Studies

Bulk compositions of solar system objects are of obvious importance for theories of origin of the planets and satellites. Bulk density has always served as a guideline for determining bulk composition of the terrestrial planets; the conventional interpretation has been that density variations are related to (1) volatile content, and (2) variations in (principally) Fe/Si ratio. A boundary condition on bulk composition is the composition and distribution of surface material. Spectroscopic observations in the UV, visible and infrared provide a means of determining geometrical surface properties and some definite compositional information. These are fundamentally "fingerprint" techniques, successful interpretation of either telescopic or spacecraft observations require a thorough, careful laboratory study of expected surface materials and their optical properties. The optical constants of important solids such as methane and ammonia ice will also be essential for scattering calculations. Such calculations will be involved with a host of questions on determining compositions, structures and temperature distributions in atmospheres of the major planets by spectroscopic techniques.

15. OPERATING PLAN

A. X-Ray Diffraction/Fluorescence

1. Objectives

The objective of this program is to develop an in situ method of identifying the compositional properties of planetary surface material, using an X-ray diffractometer combined with an X-ray fluorescence instrument. For FY'73 several tasks are defined: (1) determine minimum sample preparation required to give acceptable results, (2) test and evaluate a working model of a position sensitive X-ray detection system and compare this model with the existing scanning proportional counter system, (3) test and evaluate a Si(Li) X-ray detector system with the breadboard using a Cr target X-ray tube as the source and using the same sample for elemental analysis as used for mineralogical analysis, and (4) conduct design studies relative to the configuration of an engineering model.

2. Technical Approach

Diffraction will be accomplished by means of a modified Seeman-Bohlin geometry with the source placed on the focal circle, fluorescence by electronic pulse height discrimination of characteristic X-rays emitted from the same sample used for diffraction. Tests to date show that a sealed X-ray tube with a chromium target is more suitable for the X-ray source than an intense radioisotope source. Utilization of a fixed position detector will be studied and tested as an alternative to the use of one or more moving proportional counters. Primary attention will be given to direct deployment as the preferred method of sample presentation. Fabrication of the engineering model will be subsequent to an evaluation of these design studies.

The program will be carried out in the following manner:

1. A series of tests will be conducted to determine the sensitivity of diffraction results to soil particle size distribution, density, and bearing strength. Furthermore, the effect of bearing strength changing with depth will be investigated. These tests should indicate if an impression in the soil due to instrument weight alone will be sufficient preparation of the sample.

2. A detailed evaluation will be made to compare a single, fixed, curved, position-sensitive proportional counter and a set of moving proportional counters. This is expected to include laboratory testing of both designs. R. A. Semmler of ITTRI is developing the position sensitive counter, and it is expected that ITTRI will supply a counter for breadboard testing.

3. Under the companion program of study, a Si(Li) detector will be tested to determine its usefulness as an alternative to a proportional counter-single filter array for elemental analysis. The resolution of this detector will be measured as a function of temperature to determine its usefulness under ambient Martian and lunar conditions in the absence of active cooling. Elemental detection efficiency will be measured with the diffractometer breadboard.

4. A feasibility study will be made concerning the development of an extremely lightweight, miniature X-ray tube operated in the 1 watt range that can be used to replace the present 13 oz. 25 watt tubes.

5. The optimum data handling system will be defined.

6. At the conclusion of Items 1 through 5, a set of functional specifications will be drawn up, preliminary to fabrication of an engineering model.

7. Knowledge of the diffractometer's analytic capability will be extended by measurements on representative mineralogical systems. A resident research associate (RRA) is being sought to undertake the bulk of this effort.

B. X-Ray Fluorescence Analysis of Planetary Surfaces Using Solid-State Detectors

1. Objectives

The long-range goal of this work is to perform chemical analyses of planetary surfaces using instruments which incorporate solid-state X-ray detectors. The goals for the current budget year are to demonstrate that intrinsic germanium detectors have sufficient resolution for the proposed experiments, that they can be efficiently cooled using small Joule-Thompson gas expansion systems, and that they have advantages over other types of detectors in the areas of room-temperature storage and survival of heat sterilization.

2. Technical Approach

Earlier NASA-sponsored research at JPL has demonstrated the scientific advantages of adding a solid-state X-ray detector to an alpha-scattering instrument. The technical approach for the current budget year is to perform laboratory studies that (1) will expand the application of the technique to include other potential experiments, and (2) will focus more on demonstrating the technical feasibility of building a flyable instrument. Laboratory measurements of characteristic X-rays from standard rock samples will be made using X-ray tube, radioisotope, and electron excitation. Studies of the properties and performance of the new intrinsic germanium detectors will be made to demonstrate their superiority over lithium-drifted detectors in the areas of room-temperature storage and heat sterilization. The requirement for cooling (to achieve optimum resolution) will be investigated. A preliminary evaluation of cooling techniques indicates that an open-cycle Joule-Thompson cryostat that can be activated after several months and be operated for many hours would weigh less than one pound. An intrinsic germanium detector will be operated with a Joule-Thompson gas expansion system to determine the effect of microphonics on detector resolution and to establish the efficiency of the system in maintaining the detector at the required operating temperatures.

C. Planetary Frost and Ice Studies

1. Objectives

The eventual objectives of this program are to make laboratory measurements of the optical properties of ices such as H_2O, CO_2, NH_3, and CH_4 which are expected in the atmospheres of the outer planets and on the surfaces of the satellites. In order to develop scattering models for the clouds of the outer planets required to reduce ground based as well as spacecraft data, the complex indices of refraction must be known over a large range of wavelengths. Presently these are not well known. For instance, the optical constants for water ice below 0.9μm are poorly known and only appear in the literature as a reference to unpublished data (Dunkle and Bevans, 1954). Photometric measurements of the satellites of the outer planets from ground based techniques yield results that are not directly interpretable based on the present spectral reflectivity for ices and frosts last measured by Krinov in 1947.

2. Technical Approach

A systematic study of the visible and IR reflection and transmission spectra of the relevant ices and frost surfaces will be made in the laboratory. From these data optical constants can be derived by several methods. We plan to use least

square techniques and a classical oscillator model fit. The programs will be checked by applying them to quartz for which the optical constants are already known. The difficult technical problem to overcome is the growing of reproducible, clear ice samples for measurement. An existing vacuum chamber will be adapted for this purpose. In the case of frost surface photometric function, measurements will be made in the field in addition to the laboratory measurements using a portable field reflectance spectrometer in the 0.4-2.5μ range.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

E. J. Franzgrote, "Use of a Solid-State Detector for the Analysis of X-Ray Excited in Silicate Rocks by Alpha-Particle Bombardment," Advances in X-Ray Analysis, Vol. 15, Plenum Press (1972).

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-50-71	X-Ray Diffraction/Fluorescence		6 OF 9

MAJOR MILESTONES	PRIOR FY___ QUARTER 1	2	3	4	CURRENT FY_____ MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY_____ QUARTER 1	2	3	4	FY_____ QUARTER 1	2	3	4	FY_____ QUARTER 1	2	3	4
Sensitivity to sample characteristics																												
Multi-component diffraction tests																												
Tests with position sensitive counter																												
Fluorescence with X-ray tube and solid state detectors																												
Design studies																												
Engineering model design																												

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-50-71	X-RAY FLUORESCENCE ANALYSIS OF PLANETARY SURFACES USING SOLID-STATE DETECTORS		7 OF 9

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY '73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY '74 QUARTER 1	2	3	4	FY '75 QUARTER 1	2	3	4	FY '76 QUARTER 1	2	3	4
Report on rock analysis using X-ray excitation								▽																				
Incorporation of Ge detector in J-T cooler										▽																		
Report on heat sterilizability of Ge detectors												▽																
Tests of J-T cooling of Ge detector												[	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Integration tests with alpha-scattering, X-ray diffraction, and grazing incidence telescope instrumentation																	—	—	—	—	—	—	—	—	—	—	→	

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- [ ] - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ [- - -] - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- [ ] ▽ [- - -] - SCHEDULED COMPLETION DELAYED (REVISION 1)

72

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	185-50-71	PLANETARY FROST AND ICE STUDIES		8 OF 9

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	NEXT FY QUARTER 1	2	3	4
Write data interpretation programs						▽														
Check out using quartz							▽													
Design and fabricate ice chamber										▽										
Field photometric studies													▽							
Preliminary spectra and optical constants																▽				

NOTES

LEGEND (EXAMPLES)
▽ - SCHEDULED COMPLETION DATE
▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
▼ - ACTUAL COMPLETION DATE
▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEUDLE)
▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	185-50-71	PLANETOLOGY STUDIES	9 OF 9

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY 75	FY
DIRECT PROFESSIONAL	0.1	1.6	2.6	2.7	
DIRECT SUPPORT	0.2	1.0	1.0	1.0	
TOTAL DIRECT MAN YEARS	0.3	2.6	3.6	3.8	

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY 75	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	8	130	205	240	
TOTAL FUNDS	8	130	205	240	

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

45

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	185-50-71-05-55

5. TITLE

PLANETARY FROST AND ICE STUDIES (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Goetz, A. F. H.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 3254	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	30	
NEXT FY 74	50	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 20-0-0-80-0

A program will be carried out to investigate theoretically and experimentally the optical properties of frosts, ices and ice silicate mixtures of suspected relevance to the atmospheres and surfaces of the outer planets. Spectral measurements will be made in the laboratory as well as in the field. Field measurements may be particularly important for obtaining photometric function measurements of "natural" frost surfaces and frost silicate mixtures. Such measurements will be carried out using the 0.4-2.5μ on field spectrometer now being constructed for rock reflectance work.

10. JUSTIFICATION (WHY)

Bulk compositions of solar system objects are of obvious importance for theories of origin of the planets and satellites. Bulk density has always served as a guideline for determining bulk composition of the terrestrial planets; the conventional interpretation has been that density variations are related to (1) volatile content, and (2) variations in (principally) Fe/Si ratio. A boundary condition on bulk composition is the composition and distribution of surface material. Spectroscopic observations in the UV, visible and infrared provide a means of determining geometrical surface properties and some definite compositional information. These are fundamentally "fingerprint" techniques; successful interpretation of either telescopic or spacecraft observations requires a thorough, careful laboratory study of expected surface materials and their optical properties. The optical constants of important solids such as methane and ammonia ice will also be essential for scattering calculations. Such calculations will be involved with a host of questions on determining compositions, structures and temperature distributions in atmospheres of the major planets by spectroscopic techniques.

Photometric measurements of the satellites of the outer planets from ground based techniques yield results that are not directly interpretable based on the present spectral reflectivity for ices last measured by Krinov in 1947. Theoretical studies cannot proceed without more data on the optical constants of various ices expected in the outer solar system. For instance, the optical constants for water ice below 0.9μm are very poorly known and only appear in the literature as a reference to unpublished data (Dunkle and Bevans, 1954).

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	601-57180-0-8280	N/A	185-50-71-08-55

5. TITLE
X-Ray Diffraction/Fluorescence (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Metzger, A. E.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 4017	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	8	
CURRENT FY 73 (c)	50	
NEXT FY 74 (c)	105	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-70-0-20-0

The objective of this task is to develop a flight-configured engineering model of a combined X-ray fluorescence spectrometer and diffractometer for use in determining the elemental and mineralogical content of planetary materials. The instrument will be miniaturized, capable of ruggedization, and with performance characteristics approaching those of laboratory units. Simplicity of design will be emphasized. Diffraction will be accomplished by means of a modified Seeman-Bohlin geometry with the source placed on the focal circle. Tests to date show that a sealed X-ray tube with a chromium target is more suitable for the X-ray source than an intense radioisotope source. Utilization of a fixed position detector will be studied and tested as an alternative to the use of one or more moving proportional counters. The response characteristics of representative mineralogical systems will be determined. A high resolution lithium-drifted solid state detector will be tested and evaluated as the sensor used for the elemental analysis phase of the program. Primary attention will be given to direct deployment as the preferred method of sample presentation. Fabrication of the engineering model will be subsequent to an evaluation of these design studies.

10. Justification

As Apollo sample studies are demonstrating, a determination of the mineralogy and elemental composition of lunar and planetary surface material is fundamental for an understanding of the origin and evolution of these bodies and for a comparison with the terrestrial case. The combined X-ray diffractometer/spectrometer is being designed to perform such an in-situ analysis from a planetary lander or lunar surface vehicle.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A breadboard system with a single scanning proportional counter has been thoroughly tested with both Cu and Cr target X-ray tubes. An Fe^{55} radioisotope has been tested with the breadboard and compared with the X-ray tubes. Several advanced concept fixed, position sensitive detectors have been studied and one has been chosen as most promising. Arrangements are being made to obtain and test a curved position sensitive proportional counter designed for the breadboard. A sample delivery system has been built and tested. A Si(Li) detector for use in the elemental analysis is now being tested. Stepping mode scan and continuous drive scan have been tested and compared. Preliminary designs for a flight configured model are now underway. The optics of the breadboard diffractometer have proven to be nearly as good as that on a standard laboratory diffractometer. Tests to determine the quality of response with direct deployment onto a sample surface are in progress.

47

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	185-50-71-14-55

5. TITLE

X-Ray Fluorescence Analysis of Planetary Surfaces Using Solid-State Detectors (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Metzger, A. E.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 4017	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72	—	
CURRENT FY 73 (n)	50	
NEXT FY 74 (c)	50	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-70-0-20-0

The main objective of this program is to develop a solid-state X-ray detector system of high resolution that can be flown on instrumented spacecraft missions for the chemical analysis of planetary surfaces. This work should be pursued because of the great improvement in resolution (relative to gas-filled proportional counters) offered by the solid-state detectors. The approach that is being taken is to perform laboratory studies of the recently-developed intrinsic germanium detectors because of their potential for surviving both long-term room temperature storage and heat sterilization at 135°C.

10. JUSTIFICATION (WHY)

One of the most fundamental things that can be learned about the surface of a planet is its chemical composition. This information bears directly on the origin and evolution of the planet. The proposed work can lead to the development of chemical-analysis experiments that can be flown on Mars-lander missions and on certain fly-by or orbiting spacecraft missions.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Although this is a new task, related NASA-sponsored work at JPL has demonstrated the advantages of adding a solid-state X-ray detector to an alpha-scattering instrument for a Mars lander.

48

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		29, 41	185-50-71 Addendum 1

5. TITLE
Planetology Studies

6. RELATED SUBPROGRAMS (IF APPLICABLE)
115-24-06

7. RELATED RTOP'S (IF APPLICABLE)
115-24-06, 185-68-52

8. CONSOLIDATION OF RTOP NO'S.

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
016400, 011900

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 1973

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

Future exploration with imaging instruments will be extended to include the outer planets of the solar system and their satellites. To explore these bodies the imaging instruments will be required to have lifetimes ranging from 4 to 10 years. The instruments must also measure natural phenomena over a broader spectral range with greater sensitivity and better photometric stability than is achievable with current instruments. The proposed effort will be accomplished in two parts. The first will be the fabrication of a breadboard which will be used to aid in developing the specifications and requirements for a flight unit. The second part will consist of the detailed design, fabrication, and evaluation of a camera developed for spaceflight application.

The breadboard camera will be designed to provide preliminary information necessary in developing the specifications and requirements for a flight camera using a silicon vidicon sensor. Once fabricated the breadboard camera will be evaluated and specifications for the flight camera will be revised as necessary based on the data obtained. The evaluation of the breadboard camera will include, in addition to laboratory testing, imaging of astronomical bodies at astronomical observatories.

In developing the flight camera, the primary approach will be to develop a suitable mounting for the sensor that will provide for operation at low temperatures (about -40°C) and will survive a launch environment. The design of a camera package will be developed to the degree required to house supporting electronic circuitry required to support the silicon vidicon. Once assembled a detailed evaluation of the silicon camera's performance at expected operating temperatures will be made which will include sensitivity, resolution, residual image characteristics, noise performance, and spectral response.

13. KEYWORDS
Television, Scientific Instrument

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald P. Rose ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. JUSTIFICATION

Silicon vidicons, although relatively new, show great promise for both ground and spacecraft based observation of planets and satellites. The scope of this effort will be to develop a silicon vidicon camera suitable for flight applications. The camera will be designed to have lifetime, sensitivity, and spectral characteristics consistent with those which would be required to explore the outer planets of the solar system.

While silicon vidicons offer many advantages, relatively little is known about their capabilities as a scientific measuring device. A breadboard silicon vidicon camera will be fabricated to provide the preliminary information required to design and fabricate a camera which would be capable of operating in a space environment. It is expected that this phase of the effort will provide data on such sensor properties as photometric stability, dark current stability, dark current temperature dependence, blooming, and image distortion.

The development of a flight silicon vidicon camera, as planned in this effort, will be directed toward slow-scan operation. A limiting factor in using silicon vidicons at slow-scan rates is the amount of dark current that is inherent in the sensors. The dark current can be reduced to an acceptable level for 20 second to 40 second scan times by cooling the sensor to about -40°C. This effort will result in the design of a camerahead which provides a mounting for the sensor that will allow survival of Mariner-type launch environments and will provide a flight operating temperature of about -40°C at the sensor. Upon completion of the design, the camerahead will be integrated into a suitably modified set of Mariner television electronics and the performance of the camera will be evaluated. As with data from the breadboard camera described above, performance data on this camera will be obtained to determine what capabilities might be expected of a silicon vidicon camera on a space mission. Upon completion of this task, it is expected that the feasibility of a silicon vidicon slow-scan camera will have been demonstrated and the uncertainties in development costs for future applications will be significantly reduced.

15. OPERATING PLAN

A. Objectives: The objective of this effort will be to design and build a breadboard silicon vidicon camera by January of 1973 and to design, build, and evaluate a flight type silicon vidicon camera by July of 1973. The breadboard camera will provide engineering data required for the design of the flight camera. The evaluation of the breadboard will be accomplished in part in a laboratory environment and in part at astronomical observatories.

The objective of the flight camera design will be to demonstrate the feasibility of using a silicon vidicon in a slow-scan mode for space flight applications. This will require design of a sensor mounting structure that is capable of surviving launch vibration environments and will provide for cooling of the sensor to about -40°C. Once completed, an extensive evaluation of the performance of the camerahead, used in conjunction with Mariner-type television electronics, will be performed as the last major objective of this task.

B. Technical Approach: The basic approach for both phases will be to take maximum advantage of current technology, and to concentrate the effort in areas

where current technology is not consistent with the needs of the task. The design of the breadboard camera will be similar to a system currently being employed by Dr. J. A. Wesphal (CIT) and Dr. T. B. McCord (MIT). Spatial resolution and photometric stability will be given greatest attention during the breadboard definition and design phases. The fabrication of the camera will be done at JPL using both JPL and contract manpower.

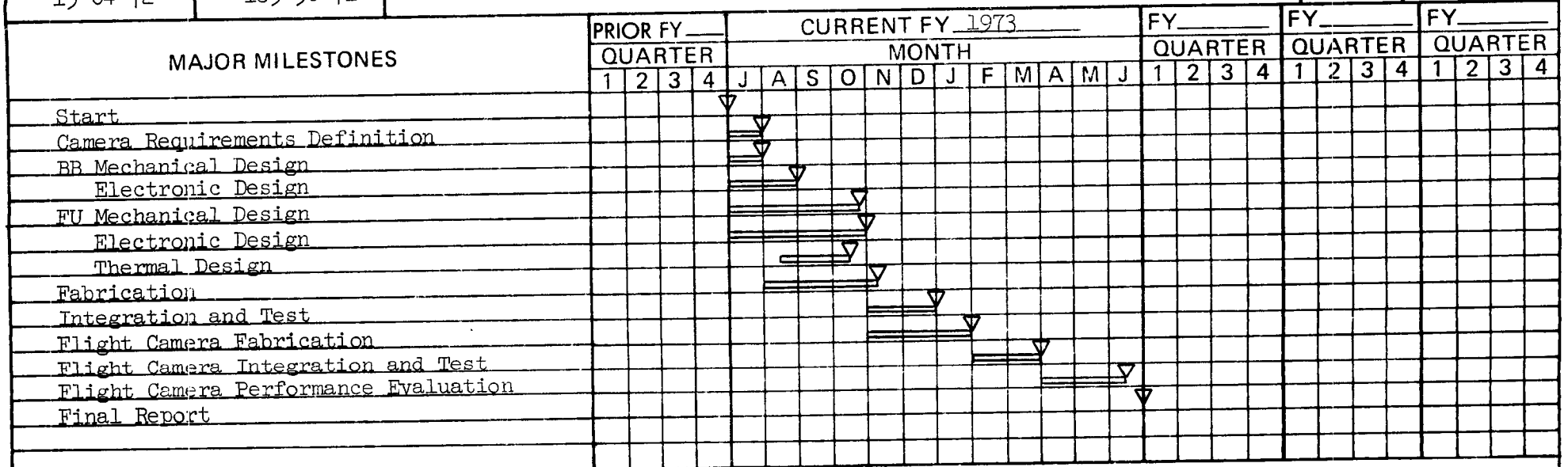
The flight camera will be approached using a system design philosophy. Requirements for the camera will be developed and reviewed. The design will consider thermal, structural, electrical, and optical constraints, and will be reviewed as it develops. Upon completion of design, the camerahead will be fabricated and integrated into existing Mariner television electronics. Upon completion of integration, a detailed evaluation of the cameras performance will be made.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	Addendum-1 185-50-71	Planetology Studies		4 OF 5



NOTES

BB - Breadboard Camera

FU - Flight Unit Camera

LEGEND (EXAMPLES)

- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION COMPARED TO PRIOR SCHEDULE
- SCHEDULED COMPLETION DELAYED (REVISION 1)

5

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	Addendum 185-50-71	Planetology Studies	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 1973	FY	FY	FY
DIRECT PROFESSIONAL		1.0			
DIRECT SUPPORT		0.0			
TOTAL DIRECT MAN YEARS		1.0			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 1973	FY	FY	FY
R & D CONTRACTS		0			
IN-HOUSE SUPPORT		150			
TOTAL FUNDS		150			

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY 1973	FY	FY	FY
TOTAL MAN YEARS		2.4			

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	Addendum-1 185-50-71-XX-55

5. TITLE
Silicon Camera Development

6. RESPONSIBLE NASA ORGANIZATION
NAME
JET PROPULSION LABORATORY
California Institute of Technology
ADDRESS
4800 Oak Grove Dr / Pasadena, Calif. 91103
RESPONSIBLE INDIVIDUAL Simmons, Larry L.
TELEPHONE 213 - 354 - 6336

7. CONTRACTOR (IF APPLICABLE)
NAME N/A
ADDRESS
PRINCIPAL INVESTIGATOR
TELEPHONE

CONTRACT NO.
CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 1973	150	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

The objective of this work unit is to develop a silicon vidicon camera for space flight applications. The objective is to be accomplished by building a breadboard camera to aid in defining the capabilities of a silicon vidicon used in a slow-scan mode, and to establish the requirements that will be the basis for the flight camera design. The flight camera design will focus on mounting the vidicon in such a manner that it can be cooled to about -40°C (required for slow-scan operation), and will survive a spacecraft launch environment. The electronics to support the vidicon will be as similar as possible to the MM'71 Television electronics, and will be obtained by using the MM'71 prototype modified as necessary. Once operating, an extensive evaluation of the flight type silicon camera will be performed.

10. JUSTIFICATION (WHY)

Silicon vidicons have at least three potential advantages over current selenium vidicons when used in a slow-scan mode as is necessary for imaging instruments used in planetary exploration. They have greater sensitivity, which will be advantageous either by reducing the systems optical weight or by being more compatible with exploration of more distant bodies such as Uranus and Neptune. They have broader spectral response which will extend long wavelength capabilities from about 670nm to about 1000nm and allow investigations of such phenomena as methane absorption. Finally, they possess the potential for the long lifetimes which would be required for outer planets exploration. It is expected that completion of this task will significantly decrease the uncertainties in development costs for future applications of a silicon vidicon camera.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

54

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		27, 29, 41	Addendum 2 185-50-71

5. TITLE
Radar Planetology (N)

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
015900, 002000

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The purpose of this task is to study the use of linear coherent radar techniques for exploring the planetary surfaces.

The objectives are to:

(1) Study the use of coherent radar for profiling and sounding the surface of Mars from a Viking follow-on orbiter.

(2) Study the use of coherent radar for profiling, sounding and imaging Venus from a spinning spacecraft.

13. KEYWORDS
Planetary Surfaces, Sounding, Radar, Remote Sensor

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. Justification

For Mars, the radar can be used to determine the planetary profile, the general shape and the depth of dust or sand layers. A detailed study of this type of radar operation has been performed by JPL for the Apollo Lunar Sounder (S-209, Apollo 17). This software could be used for a study of a Viking follow-on mission.

For Venus, the radar is the only known method for acquiring information about the surface geology. Two out of the three Lunar Sounder radars are omnidirectional and could operate from a spinning spacecraft. Missions planned to Venus in the late 70s are currently considering spinning spacecraft. A large fraction of the work done for Apollo could be applied to the design of a radar with low weight, power and data rate. Imaging the surface from a spinning spacecraft is possible and should also be given serious study.

15. Operating Plan

A. Objectives

For Mars, study the type and extent of geomorphology that can be determined from radar profile and sounding data or a combination of radar and photograph data. Determine those radar parameters that are related to the most significant geological information and the radar/geological tradeoffs.

For Venus, determine those radar measurements that would provide unequivocal geological information about a surface where no a priori information exists. Determine the radar design that is compatible with the geological requirements and the spacecraft characteristics.

B. Technical Approach

The technical approach is to use the software and coherent radar techniques developed for the Apollo Lunar Sounder Experiment, S-209, to determine the radar designs and the basic characteristics of the data thus acquired. This information will be used by geologists to ascertain the data interpretation problems. The radar designs would then be redone as necessary to optimize the geological information returned.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15-04-72	Addendum 2 185-50-71	Radar Planetology	A	3 OF 4

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	NEXT FY 74 QUARTER 1	2	3	4
Initiate Study					▽															
Geomorphology Meeting									▽											
Complete Study														▽						
Submit Report																▽				

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽(1) - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▽ - ACTUAL COMPLETION DATE
- ▽——▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEUDLE)
- ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

56

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15-04-72	Addendum 2 185-50-71	Radar Planetology	4 OF 4

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
DIRECT PROFESSIONAL		.5			
DIRECT SUPPORT		.5			
TOTAL DIRECT MAN YEARS		1.0			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT		40K			
TOTAL FUNDS		$40K			

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72		N/A	Addendum 2 185-50-71-YY-55

5. TITLE
Mars, Radar Profiling and Sounding Study (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME JET PROPULSION LABORATORY California Institute of Technology	NAME N/A
ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL Brown, W. E., Jr.	PRINCIPAL INVESTIGATOR
TELEPHONE 213 - 354 - 2110	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	20	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 80-00-00-10-10

Radar system parameters and tradeoffs will be determined for a Mars orbiting experiment. The basic techniques used to design the Lunar Sounder Experiment (Apollo 17) will be applied. Existing system design software will be used. Geomorphology requirements on the radar will be included in the radar design iterations. A science rationale for the use of profile and sounding information about the Martian surface will be developed.

10. JUSTIFICATION (WHY)

Surface profile information, particularly on a circum-Martian basis is important in the study of surface geology. A measure of the dust layer thickness and its variation from month to month is also significant in the understanding of the surface of Mars. Knowledge of the dust layer could also aid in locating areas where the probability of finding life forms would be the highest.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Although no work has been done on this particular work unit, a great deal of software and knowledge pertaining to these types of systems has been acquired in the design of the Lunar Sounder Experiment (Brown, P.I.; Phillips, Co I, Team Leader).

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72		N/A	Addendum 2 185-50-71-ZZ-55

5. TITLE
Venus, Radar Profiling, Sounding and Imaging (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME JET PROPULSION LABORATORY California Institute of Technology	NAME
ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Brown, W. E., Jr.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 2110	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	20	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 80-00-00-10-10

Acquiring Venus profile information from a spinning spacecraft that is orbiting Venus is the subject of this study. Techniques similar to those developed for the Lunar Sounder (Apollo 17) will be employed. Since profiling and sounding require similar techniques, both will be included in the study, although it is not known whether or not the surface electrical properties are conducive to sounding.

10. JUSTIFICATION (WHY)

The surface of Venus is largely an unknown. The surface geomorphology and the interaction between the lithosphere and atmosphere are unique and are of considerable interest to the planetologist. The study is related to spinning spacecraft because there are tentative plans to orbit Venus with a spinning spacecraft late in the 70s.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A number of studies of Venus orbiting imaging radars have been performed under Planetology and advanced mission auspices. The results are favorable, but no emphasis has been placed upon the study of light weight low power omnidirectional radars.

60

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41,45,47	188-36-55

5. TITLE

MAGNETOSPHERIC PHYSICS

6. RELATED SUBPROGRAMS (IF APPLICABLE)

385-50

7. RELATED RTOP'S (IF APPLICABLE)

N/A

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002100,005500,013000,002100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

Advanced Magnetometer: The major objective is to develop the vector helium magnetometer for use on space missions where extremely weak interplanetary or interstellar fields are to be measured and where intense planetary fields may also be encountered. Tests and experiments will be carried out to understand the underlying principles of operation and to develop improved components, a more optimum design and new or more optimum modes of operation.

Spectral Analysis: It is of major interest to examine the power spectral density of the solar wind at frequencies up to and beyond the proton gyro-frequency. Workers in the field of radio scintillation have interpreted their data to indicate the existence of an anomalously high number of electron density fluctuations or "blobs" of scale size 100-200 km. This claim has been disputed. Because of the high data acquisition rate of OGO-5, it is now possible to extend the power spectrum to frequencies correesponding to a scale size of less than 100 km. Hopefully this will shed light on the question of "blobs." Even if blobs are not found, the high frequency spectrum is of intrinsic interest to determine the behavior of solar wind phenomena in the neighborhood of the proton gyro-frequency.

13. KEYWORDS Spectrum, scintillation, proton gyro-frequency, solar wind, magnetometer, optical pumping

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Daniel S. Ree ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. Justification

Deep space missions to the outer planets and beyond will undoubtedly include magnetic field measurements. A magnetometer will provide basic information about (1) intrinsic planetary magnetic fields, (2) the nature of the magnetized solar wind in the outer solar system, (3) the interaction of the solar wind with the planets, (4) the extent and shape of the heliosphere, and (5) the galactic magnetic field. Both the interplanetary magnetic field at great distances and the galactic field are expected to be extremely weak, far below the magnitude of the interplanetary field at 1 AU. It is not evident that existing low field spacecraft magnetometers are sensitive enough and stable enough to fulfill the above scientific objectives. The additional requirements of an extended dynamic range to accommodate the possibility of large planetary fields and an extremely long life also tax the capabilities of existing magnetometers. A magnetometer must be developed now for these missions which is extremely sensitive and very stable, which can measure large magnetic fields and which requires a minimum amount of weight and power. Other major requirements of these missions are an extremely long equipment lifetime and the ability to withstand a hostile environment. The ability of magnetometer components to meet such requirements must be evaluated.

A power spectrum is a graphical presentation of the relative importance of frequencies present in solar wind variations. These frequencies are contributed by a variety of phenomena: waves, discontinuities, sector structure. etc. Although the spectrum does not distinguish between the contributing phenomena, it often provides the first clue as to their existence. For example, a study of the power spectrum in 1966 led to the prediction of Alfvén waves in the solar wind.

Much work has now been done in finding and interpreting the low frequency spectrum of the solar wind. Until now the high frequency spectrum could not be obtained because of the low data sampling rate of previous satellites. The OGO-5 Faraday cup is, however, about three orders of magnitude faster than previous plasma instruments. This permits the spectrum of the ion flux to be obtained in the neighborhood of the ion gyro-frequency.

15. Technical Plan

A. Objectives

Advanced Magnetometer

1) To develop the vector helium magnetometer

   a) To improve the sensitivity

   b) To measure and improve the long term stability

   c) To improve the reliability and lifetime

   d) To reduce the power required, especially in high field operation

2) To improve the low field test facility so that the advanced magnetometer may be evaluated adequately.

3) To identify the factors affecting the lifetime of a magnetometer intended for missions of long duration and to investigate the survivability of those components which are most critical.

4) To refine the criteria procedures used to screen helium magnetometer sensor components.

Theoretical Space Plasma Physics

The immediate objective is the calculation and interpretation of high frequency power density spectra of the ion flux in the solar wind. After these spectra are understood, cross-spectra between flux, velocity, density, and magnetic field will be investigated. Eventually we hope to make inter-spacecraft comparisons to study the solar radial gradient of fluctuations (OGO-5 vs. Pioneer 9) and the wave modes excited by the interaction of the solar wind with the moon (OGO-5 vs. Apollo 12 ALSEP and Apollo 12 vs. Apollo 15 ALSEP).

B. Technical Approach

Advanced Magnetometer

The effort will be carried on at JPL by Laboratory personnel, with emphasis placed upon redesign, testing, and evaluation of the sensor. Evaluation of the individual sensor components (lamp, cell, polarizer, IR detector) will continue. Experiments will be performed to develop a physical understanding of how the magnetometer operates.

The helium magnetometer will be analyzed to determine which components are most likely to limit its lifetime. JPL will continue to contact manufacturers to obtain the most recent information on component reliability and to become familiar with any activities they are undertaking or are planning in order to improve the lifetime of their parts. Critical components will be procured or fabricated and subjected to appropriate testing such as accelerated life tests.

Theoretical Space Plasma Physics

Although in principle the spectrum is merely the Fourier transform of the autocorrelation function, in practice it is difficult to achieve a meaningful spectrum. Finite record length, choice of lag window, and aliasing are a few of the considerations which must be weighed carefully if useful results are to be obtained. There is an added difficulty: the pattern of spacing of the OGO-5 flux data does not lend itself readily to spectral analysis. Therefore, at the highest acquisition rate, the spectra of 60 groups of 19 equally spaced data points are averaged to obtain the high frequency tail of the spectral distribution. In the mid-frequency range there are 4 groups of 258 points, while the low-frequency end is determined by 96 equally spaced points. (Other patterns of equally spaced or near-equally spaced points may be used in subsequent analyses.) Thus 1 spectrum is comprised of 3 overlapping curves, sloping generally as $f^{-1.5}$. Care must be taken in interpretation at each end of the 3 segments, as aliasing and instability are most evident in these regions. For these reasons, spectra of simple mathematical models of the solar wind, with and without blobs, are used to gain familiarity with the techniques and a degree of confidence in the results.

16. Review and Reporting

Written narrative reports will be preapred and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. Publication

T. W. J. Unti, G. Atkinson, C.-S. Wu, and M. Neugebauer, "Dissipation Mechanisms in a Pair of Solar Wind Discontinuities," J. Geophys. Res. (to be published).

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	188-36-55	Magnetospheric Physics: Advanced Magnetometer Engineering		5 OF 7

MAJOR MILESTONES	PRIOR FY ___ QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4
1. Sensor component life tests																												
2. Sensor configuration study																												
3. Breadboard sensor evaluation																												
4. Sensor component study																												
5. Advanced system study																												
6. High field study																												

NOTES

LEGEND (EXAMPLES) ▽ - SCHEDULED COMPLETION DATE
▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
▼ - ACTUAL COMPLETION DATE
▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

69

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	188-36-55	Magnetospheric Physics: Theoretical Space Plasma Physics		6 OF 7

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY 75 QUARTER 1	2	3	4	FY 76 QUARTER 1	2	3	4
AGU presentation, Washington, D. C.				▽																								
Preliminary linear spectra (for publication in JGR)											▽																	
Complete density spectra														▽														
Cross spectra (flux, density, velocity, field)																			▽									

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	188-36-55	MAGNETOSPHERIC PHYSICS	7 OF 7

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
DIRECT PROFESSIONAL	2.0	2.0	1.0		
DIRECT SUPPORT	2.0	2.0	1.0		
TOTAL DIRECT MAN YEARS	4.0	4.0	2.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	168	150	70		
TOTAL FUNDS	168	150	70		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY '72	FY '73	FY '74	FY	FY
TOTAL MAN YEARS			1.0		

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	603-35110-0-8230	N/A	188-36-55-01-55

5. TITLE

MAGNETOSPHERIC PHYSICS: ADVANCED MAGNETOMETER ENGINEERING

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Smith, E. J.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 2248	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72 (c)	85	
CURRENT FY '73 (c)	75	
NEXT FY '74 (c)	35	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 0-85-0-0-15

A vector helium magnetometer is being developed for future missions. The parameters of the sensor components are under study to improve the instrument's sensitivity and long-term stability. Sensor components are evaluated for long life reliability as well as susceptibility to radiation damage. The advanced magnetometer program consists of the following: (1) Determination of the optimum pressure, volume and rf power for the lamp and cell; (2) the minimization of the low field offset by modifying the sensor configuration (housing design, optic design, component layout, etc.); (3) development of a very reliable rf supply consistent with frequency and power stability; (4) continuation of the sensor components long life studies and evaluation of the radiation test results.

10. JUSTIFICATION (WHY)

Based on our previous studies, the design of an improved version vector helium magnetometer can be achieved. However, these problem areas still require further detailed studies: (1) accurate determination of lamp and cell pressure; (2) system stability with variation in rf power; and (3) evaluation of sensor in as close to space environment as possible.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

(1) Several lamps and cells were fabricated and filled at various pressures. With slight modifications in the pressures, the sensitivity of the VHM was increased significantly. Leak rate studies showed the pressures to be feasible for long space flights. The rf power to the lamps and cells was adjusted to maximize the signal-to-noise ratio of the sensor. (2) Several housing materials were fabricated and tested. Gold plated plastic was found to be the best rf shield while minimizing thermoelectric offsets and maintaining a strong housing. (3) Long life studies on the polarizer continued with no adverse effects apparent after 18 months at an elevated temperature. Radiation tests were conducted. No optical component, as presently used in the sensor, was significantly damaged by electron, proton, neutron, or gamma bombardment. The complete sensor operated in a proton environment with no increase in noise. (4) A dual rf supply was designed and breadboarded and is presently being used for SRT sensor evaluation. (5) A large area silicon IR detector was evaluated. The detector increased the sensitivity of the sensor and simplified the optics; unfortunately, the silicon detector acts as a particle detector and becomes very noisy in a radiation environment.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	603-35111-0-8280	N/A	188-36-55-01-55

5. TITLE

MAGNETOSPHERIC PHYSICS: ADVANCED MAGNETOMETER SCIENCE (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Smith, E. J.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 2248	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72 (c)	55	
CURRENT FY '73 (c)	50	
NEXT FY '74 (c)	35	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 20-50-5-10-15

The vector helium magnetometer is being developed for use on future space missions. The magnetometer sensitivity, stability and reliability are being improved. The primary emphasis is placed on experimental evaluation of the sensor and its components. Key experimental studies are required to understand better the optical pumping and gaseous discharge phenomena occurring in the sensor. The work is being carried out jointly by personnel in the Physics and Space Instruments Sections. Physics Section personnel carry out the scientific evaluation of the sensor and design, conduct, and interpret experiments in support of the instrument development.

10. JUSTIFICATION (WHY)

Future magnetometer experiments in deep space will impose very stringent scientific and engineering requirements. A magnetometer must be developed now which is extremely sensitive, very stable, yet capable of measuring large magnetic fields, and highly reliable. Based on previous studies, the major areas still to be investigated are: (1) the offset and the changes contributed by the sensor components, including their alignment; (2) the optical pumping efficiency and ways to increase it; (3) the configuration of an advanced sensor and tradeoffs between performance, reliability, ease of manufacture, etc.; and (4) the magnetic and thermal-electric effects associated with the sensor housing.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

(1) Magnetic Test Facility. The cryogenic flux tank procured on a subcontract was delivered, tested and accepted. It meets stringent specifications and provides an extremely quiet environment in which to test magnetometers. (2) Offset Stability. (a) The quantitative dependence of offset stability on basic design parameters such as sweep field frequency and amplitude, rf power delivered to the lamp and cell was determined. The changes in offset are relatively insensitive to variations in such parameters. (b) Theoretical studies revealed several possible sources of offset and offset unstability: an asymmetric discharge with subsequent changes in the asymmetry and the scattering of pumping light off the optical axis. (3) Sensitivity. (a) The responsivity and detectivity were measured of two IR detectors, the PbS detector now in use and a newly developed large area Si detector. Use of the Si detector reduces the magnetometer noise by a factor of 2. (b) The sensitivity of the present magnetometer can be increased by reducing the lamp pressure and by increasing the length of the absorption cell by modest amounts.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	603-35310-0-8280	N/A	188-36-55-01-55

5. TITLE

Theoretical Space Plasma Physics (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Unti, Theodore J.

TELEPHONE: 213 - 354 - 6259

7. CONTRACTOR (IF APPLICABLE)

NAME

CONTRACT NO.

CONTRACT START DATE

ADDRESS

PRINCIPAL INVESTIGATOR: N/A

TELEPHONE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	28	
CURRENT FY 73 (c)	25	
NEXT FY 74 (c)	30	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

Spectral Analysis: It is of major interest to examine the power spectral density of the solar wind at frequencies up to and beyond the proton gyro-frequency. Workers in the field of radio scintillation have interpreted their data to indicate the existence of an anomolously high number of electron density fluctuations or "blobs" of scale size 100-200 km. This claim has been disputed. Because of the high data acquisition rate of OGO-5, it is now possible to extend the power spectrum to frequencies corresponding to a scale size of less than 100 km. Hopefully this will shed light on the question of "blobs." Even if blobs are not found, the high frequency spectrum is of intrinsic interest to determine the behavior of solar wind phenomena in the neighborhood of the proton gyro-frequency.

10. JUSTIFICATION (WHY)

A power spectrum is a graphical presentation of the relative importance of frequencies present in solar wind variations. These frequencies are contributed by a variety of phenomena: waves, discontinuities, sector structure, etc. Although the spectrum does not distinguish between the contributing phenomena, it often provides the first clue as to their existence. For example, a study of the power spectrum in 1966 led to the prediction of Alfvén waves in the solar wind.

Much work has now been done in finding and interpreting the low frequency spectrum of the solar wind. Until now the high frequency spectrum could not be obtained because of the low data sampling rate of previous satellites. The OGO-5 Faraday cup is, however, about three orders of magnitude faster than previous plasma instruments. This permits the spectrum of the ion flux to be obtained in the neighborhood of the ion gyro-frequency.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Computer programs have been developed to select, reduce and prepare segments of the OGO-5 data suitable for spectral analysis. Several spectra have been obtained. A simple mathematical model has been devised, which simulates the spectra of the solar wind with and without "blobs"; this is used as a guide to the interpretation of the actual solar wind spectra. A presentation of the preliminary results was given at the Fall meeting of the AGU in San Francisco, December 1971.

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 '72		N/A	188-41-52

5. TITLE
Radio Astronomy

6. RELATED SUBPROGRAMS (IF APPLICABLE)
125-21/150-22/188-46/196-41

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002000/002100/003900

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

This RTOP uses the unique facilities of NASA's Deep Space Instrumentation Facility (DSIF) to find microwave spectral lines of interstellar atoms and molecules at X-band (8GHz) and K-Band (15 GHz), regions in which NASA's receiving capabilities are the best in the world. Concurrently, a laboratory microwave spectroscopy program is carried out in order to interpret the results of the observation program as to the molecular species, abundances within the source, and the doppler shift of the source itself. DSIF equipment to be used includes the 64m Goldstone antenna; K-Band and X-Band wideband low noise feeds, masers, and receivers; a wideband digital correlator spectrum analyzer; calibrated noise sources; and programmable local oscillators. This DSIF equipment either already exists or is being developed for programs supported by the Office of Tracking and Data Acquisition (OTDA); thus, this RTOP does not pay for such equipment. The spectrometer system to be used in the laboratory investigations includes a Stark Modulation Spectrometer and associated programmable digital data handling and control equipment.

Fundamental questions in stellar and galactic evolution to be answered by interstellar microwave spectroscopy include the galactic molecular and isotope distribution and the isotopic abundance ratios; the velocity distribution of interstellar material; and the causes of anomalous interstellar molecular spectral line intensities. Of particular interest is the location and abundance of complex interstellar molecules, because the mechanism that allows the creation and retention of such molecules is presently unknown.

13. KEYWORDS
INTERSTELLAR MOLECULES: ISOTOPE ABUNDANCE: SPECTRUM ANALYZER; K-BAND

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Daniel L Rose ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. Justification

Since the initial 1963 observation of the OH radical in interstellar space twenty interstellar molecules have been detected by microwave astronomy. The list includes the molecules:

CN, OH, H_2O, CO, H_2CO, HCN, CS, SiO, OCS, CH_3OH, CH_3HCO, HC_3N, $HCOOH$, $HNCO$, CH_3C_2H, NH_3, CH_3CN, NH_2HCO

The observational data obtained from these molecules is potentially very rich in information about present and past conditions in the interstellar medium. This is particularly so because of the greater microwave penetration of the dense interstellar dust clouds and because the microwave spectral lines represent a sampling of molecular species which can exist at very low temperatures. We are thus presented with a totally different view of the interstellar medium than has been obtained from prior optical astronomy studies. To extract the wealth of information contained in these radio observations requires a complementary set of programs designed to (1) map the spatial distribution of known spectral lines, (2) search for spectral lines from molecules not yet detected, and (3) determine the laboratory physical, chemical, and spectral properties for both the reported and likely new molecules.

15. Operating Plan

A. Objectives:

The objectives of this research program are the discovery, location, mapping, and interpretation of microwave absorption and emission lines arising from atomic and molecular transitions. The laboratory microwave spectroscopy program will obtain data on transition frequencies, intensities, and quantum assignments for interstellar molecules. [In conjunction with other physical and chemical information, these laboratory data will be used to assist in the planning of observing programs and in the interpretation of the astronomical data.] In addition, the laboratory program will study the various energy transfer mechanisms which apply to molecules in the interstellar medium. The initial phase (FY-'73) of the laboratory program will concentrate upon obtaining data for the molecules NH_3, H_2CO, and $HCOOH$. Depending upon the experimental difficulties which may be encountered, the actual number of molecules studied may be more or less than those listed. If time permits, energy transfer mechanisms between energy levels will be examined for selected molecules from the above group.

B. Technical Approach

The search for interstellar microwave lines will be carried out using the DSIF facilities; in particular the 64m antenna will be used with existing X-Band & K-band radiometers. Spatial regions to be investigated will be confined to those areas which are known to be astrophysically interesting, and, in particular, to those areas in which specific interesting spectral lines have already been found. Since the DSIF system is up to two orders of magnitude more sensitive than other radio receiving systems at these frequencies, the system is ideally suited for studying weak lines and for searching for known lines not yet observed in the interstellar medium.

While many molecules have been observed in the interstellar medium, good laboratory frequency measurements are available for only H_2O and a few of the ammonia, formaldehyde, HCN, and OH lines. Frequency measurements of only fair accuracy have been reported for the remainder of the observed interstellar molecules, HCN, H_2CO, HCOOH, HC_3N, etc. Because the available laboratory microwave spectral frequencies for these molecules are of relatively low accuracy (±0.05 to 1.0 MHz), the vast majority of this work will have to be remeasured to obtain accuracies of ±0.003 MHz or better so that gas cloud Doppler velocities can be properly determined.

With the exception of a few NH_3 lines and the H_2O line, virtually no measurements of spectral line intensities have been either performed or reported for the molecular species mentioned above. Calculated intensities have been quoted in a few cases, but these values have never been compared to experimental results, which are difficult to obtain. As a consequence, accurate experimental line intensities will also have to be measured for both the presently observed interstellar molecules and for other predicted or potentially interesting molecules where such information is now absent.

In addition, numerous unidentified spectral lines have been reported in laboratory studies of some of the above molecules; a critical appraisal of these lines is needed.

The laboratory program will study the presently observed interstellar species first. Other simple molecules are also to be expected and will be studied. A partial list of such molecules is as follows:

$H_2N\text{-}NH_2$	(hydrazine)
$H_2N\text{-}CN$	(cyanamide)
CH_3NH_2	(methyl amine)
CH_3SH	(methyl mercaptan)
HSCH	(thioisocyanic acid), etc.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. In addition, oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	188-41-52	Radio Astronomy		5 OF 6

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY 75 QUARTER 1	2	3	4	FY 76 QUARTER 1	2	3	4
K-band radiometer completed		▼																										
Interface spectrum analyzer to receiver			▼																									
Start K-band system calibration test			▽																									
Astronomical observations																												
Upgrade local oscillator system								▽																				
Obtain and install spectrometer				▽																								
Calibrate spectrometer system					▽																							
Lab measurements of sample gases																												
Data analysis and interpretation of data																												
Upgrade laboratory spectrometer																												

NOTES

LEGEND (EXAMPLES): ▽ - SCHEDULED COMPLETION DATE; ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1); ▼ - ACTUAL COMPLETION DATE; ▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END; ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE); ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 '72	188-41-52	Radio Astronomy	6 OF 6

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
DIRECT PROFESSIONAL	1.9	2.0	2.2		
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	1.9	2.0	2.2		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	92	107	140		
TOTAL FUNDS	92	107	140		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 '72	603-45210-0-3330	N/A	188-41-52-04-55

5. TITLE

INTERSTELLAR MICROWAVE SPECTROSCOPY/ENGINEERING SUPPORT (0)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Sato, T.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 5715	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY(n) '72	35	3
CURRENT FY(c) '73	37	
NEXT FY(c) '74	48	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-10-10-60-10

This work is in support of the Interstellar Microwave Spectroscopy/Observations Task. The objectives are to provide engineering support for the operation and maintenance of the low noise K-band and X-band radiometer systems used in the Interstellar Microwaves Spectroscopy Observational Program. The search for interstellar microwave lines is being carried out using the DSIF facilities, and in particular the 64m Goldstone antenna.

During FY '73, the specific objectives are (1) to continue the upkeep of the X-and K-band radiometer systems, (2) to upgrade the K-band local oscillator, and (3) to provide engineering support to astronomers using these advanced systems.

10. JUSTIFICATION (WHY)

Since the discovery in 1963 of interstellar microwave emission from the hydroxyl radical OH, many diatomic and poly-atomic molecules and distinct radicals have been detected in interstellar space. The observational data are potentially rich in information about conditions in the interstellar medium, both now and when the molecules were first created. The use of the facilities of the Deep Space Instrumentation Facility (DSIF) 64 m antenna and the low noise X- and K-band (3.75 and 2.0 cm wavelengths) masers provides a cost effective method of performing the observations. In addition, measurements of abundance of the isotopes and various elements have great implication for the early history of the universe and its galaxies.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

The X- and K-Band masers, antenna feed systems, and receiving equipment have been installed on the 64 meter antenna. Tests indicate that the radiometer system is one of the most sensitive available at 2.0 and 3.75 cm. A 64 channel digital spectrometer has been installed for use with the radiometer (3.3 MHz bandwidth).

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	603-45520-0-8250		188-41-52-05-55

5. TITLE

INTERSTELLAR MICROWAVE SPECTROSCOPY/LAB PROGRAM

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr / Pasadena, Calif 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Poynter, R.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 2437	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	50	
CURRENT FY 48 (c)	48	
NEXT FY 55 (c)	55	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 25-10-10-50-5

The laboratory spectral line measuring program will support radio astronomical observations by providing accurately measured frequency and intensity data, along with the corresponding quantum assignments. In conjunction with other physical and chemical information, these laboratory data will be used to assist in planning of observing programs and in the interpretation of the astronomical data. The laboratory investigations use a commerical low frequency square wave Stark modulation type microwave spectrometer with a standard 6 ft. absorption cell and an automatic digital control system. The FY 73 effort will concentrate upon obtaining data for the molecules NH_3, H_2CO, and HCOOH.
Chemical theory will be used to predict those molecular species which are likely to be observed in future radio astronomical work. The laboratory program will also study the energy transfer mechanisms which can occur in the different molecules in the interstellar medium.

10. JUSTIFICATION (WHY)

While many molecules have been observed in the interstellar medium, good laboratory frequency measurements and spectral line intensity measurements are available for only a few of the NH_3, H_2O, H_2CO, HCN, and OH lines. Frequency measurements of only fair accuracy (0.05-1.0 MHz) have been reported for the remainder of the observed interstellar molecules, HCN, H_2CO, H-C=O-OH, HC_3N, etc. while virtually no other measurements of spectral line intensities have been either performed or reported.

Consequently, accurate experimental line intensities and frequencies will also have to be measured for both the presently observed interstellar molecules and for other predicted or potentially interesting molecules for which such information is now absent.

11. Main Achievements (Significant Progress)

1. The combined microwave spectrometer and computer control system configuration was determined and a purchase order was written. Laboratory facilities were modified in preparation for the spectrometer installation. The spectrometer delivery and installation is scheduled for April 72.

2. Nineteen previously unreported NH_3 microwave absorption lines have been observed and assigned to inversion transitions in the low lying $v=000^0\ 1^1$ vibrational state. The inversion frequency has been determined from our measurements.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-'72		N/A	188-41-52-12-55

5. TITLE

INTERSTELLAR MICROWAVE SPECTROSCOPY/OBSERVATIONS (o)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Gulkis, S.

TELEPHONE: 213 - 354 - 5708

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS:

PRINCIPAL INVESTIGATOR:

TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72		
CURRENT FY 73 (n)	15	
NEXT FY 74 (c)	30	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 0-0-50-50-0

This work unit uses the NASA 64 m DSIF antenna to detect and study microwave spectral lines of interstellar atoms and molecules at K-band (14-16 GHz) and X-band (8 GHz). Initially all radio sources which are known to show the formaldehyde line at 6 cm wavelength will be observed at 2 cm wavelength (15 GHz). A detailed comparison of the data at 2 cm and the previously published 6 cm data will be made in order to study the temperature, densities, radiation field and other physical conditions within the medium containing the observed formaldehyde. Heretofore undiscovered molecules and detected molecules with questionable identifications will be searched for in the interstellar medium. Some preliminary work will be done to determine the feasibility of studying HII regions and mapping the galaxy by using recombination lines.

10. JUSTIFICATION (WHY)

Radio Astronomical Observations of interstellar molecules provides fundamental data on the interstellar medium, which are important to the understanding of stellar and galactic evolution. In particular, observations of interstellar lines can be used to (a) map the galactic distribution of certain elements and their isotopes; (b) Determine temperature, pressure, velocity of interstellar material; (c) Determine the isotopic abundance of atomic elements; (d) Search for new molecular species: (e) Confirm old identifications by search for new lines; (f) Investigate anomalous behaviour of certain sources.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 4 72	603-45230-0-3310	N/A	188-41-52-09-55

5. TITLE
PULSAR ROTATION CONSTANCY (0)

6. RESPONSIBLE NASA ORGANIZATION
NAME
JET PROPULSION LABORATORY
California Institute of Technology
ADDRESS
4800 Oak Grove Dr. / Pasadena, Calif. 91103
RESPONSIBLE INDIVIDUAL Reichley, P. E.
TELEPHONE 213 - 354 - 2765

7. CONTRACTOR (IF APPLICABLE)
NAME N/A
ADDRESS
PRINCIPAL INVESTIGATOR
30-0-70-0-0

CONTRACT NO.
CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	4	0
CURRENT FY 73 (c)	7	0
NEXT FY 74 (c)	7	0

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The time-of-arrival and intensity of the pulses of electromagnetic radiation from pulsars will be measured. The timing data for each pulsar will be analyzed for the pulse repetition rate, position, proper motion and distance. The timing data from all pulsars will be analyzed simultaneously for effects due to the solar system. The intensity data for each pulsar will be analyzed for inhomogeneities in the interstellar electron cloud distribution, relative velocity between the pulsar and the clouds, and the pulsar spectrum. The observations will be made on a 26 meter antenna at a frequency near 2400 MHz. An on-line computer with a 16K word memory and 2μs cycle time will be used. The computer and a peripheral timing device will coordinate the data taking and will store the results on magnetic tape for further reduction. The timing device will be synchronized with the station clock which is to be referred to A.1 time. The system temperature will be taken periodically for use in determining pulse intensities. A small amount of data will be collected on the 64-meter antenna. This data will be integrated over shorter time scales so that rapid variations in pulse times-of-arrival can be studied and correlated with the 26-meter data.

10. JUSTIFICATION (WHY)
The objective of these observations will be to provide answers to the following questions: (a) Are pulsars losing energy by gravitational radiation, magnetic dipole radiation, or both? (b) How does a young erratic pulsar evolve to an older, more stable pulsar? (c) What is the nature of the medium causing fluctuations in pulsar signals, and how fast is the pulsar moving relative to this medium? (d) Do pulsars exhibit large proper motions? (e) How fast do pulsar intensities decrease with increasing observing frequency? Do they all behave identically? (f) Is there any correlation between a pulsar rate-of-change in the period and other observable properties? (g) Is the sun's gravitational red shift consistent with Einstein's theory?

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) During the past six months two data-reduction programs have been developed, one paper has been published, and the observations have continued on a weekly basis. A computer program was completed which integrates several hundred-thousand pulses to yield an average pulse template for each pulsar. Another program was completed which correlates these templates with the original data for the optimum determination of the pulse-arrival-time. We observed another large, discontinuous change in the repetition rate of the Vela pulsar. This observation was published in Nature Physical Science, Vol. 234, p. 48 (15 November 1971).

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
01 03 72		29, 44, 46, 81, 82	188-41-54

5. TITLE
RELATIVITY AND CELESTIAL MECHANICS

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002100; 009600

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '72

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

Objective: To support on a consulting basis and upon call the planning activities of NASA Headquarters in the areas of space probe missions relevant to the testing of gravitational theories and the cooperative planning of these missions with ESRO.

Approach: JPL technical personnel will follow and review the technical studies being conducted for the European Space Research Organization on the testing of gravitational theories in space. As required, a technical consulting team of senior personnel from several disciplines will be formed at JPL. Information obtained from ESRO will be periodically presented to the team for reaction and review. These evaluations will be forwarded to NASA Headquarters (SG). This activity will support the joint Mission Definition Group of ESRO and NASA formally agreed upon. Approximately twenty percent of the funding will be required for travel to ESRO facilities for technical interchange. Some interchange will take place at JPL.

13. KEYWORDS
Gravitational Theories
Theory of Relativity

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	4/3/72		

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
01 03 72	188-41-54	RELATIVITY AND CELESTIAL MECHANICS	2 OF 2

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY	FY	FY
DIRECT PROFESSIONAL	0.5	0.5			
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	0.5	0.5			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	25	25			
TOTAL FUNDS	25	25			

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
01 03 72	603-45440-0-1310	------	188-41-54-04-55

5. TITLE
TECHNICAL REVIEW OF ESRO STUDIES ON THE TESTING OF GRAVITATIONAL THEORIES

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Davies, R. W.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 4156	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72	25	
CURRENT FY '73	25	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

The planning activities of NASA Headquarters in the areas of space probe missions relevant to the testing of gravitational theories and the cooperative planning of these missions with ESRO will be supported on a consulting basis. JPL technical personnel will follow and review the technical studies being conducted for the European Space Research Organization on the testing of gravitational theories in space. As required, a technical consulting team of senior personnel from several disciplines will be formed at JPL. Information obtained from ESRO will be periodically presented to the team for reaction and review. These evaluations will be forwarded to NASA Headquarters (SG). This activity will support the joint Mission Definition Group of ESRO and NASA formally agreed upon. Approximately twenty percent of the funding will be required for travel to ESRO facilities for technical interchange. Some interchange will take place at JPL.

10. JUSTIFICATION (WHY)

This work is an outgrowth of NASA Headquarter's agreement with ESRO to have a joint mission definition group to evaluate ESRO's studies relevant to the testing of gravitational theories and is in response to the request by the Director of Physics and Astronomy Programs, OSSA, stated in a letter of May 28, 1971, to the Jet Propulsion Laboratory, Attention: Dr. W. H. Pickering, Director.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

ESRO has tailored studies in response to JPL advice.

JPL has forwarded technical data to ESRO.

83

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		46,85,26,27	Addendum 188-41-54

5. TITLE
Relativity and Celestial Mechanics

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI) 013700
002000,015900,006400,016700,003900,008200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

Superfluid helium is destined to find ever increasing application as a cryogen in future spacecraft missions. Its utility stems from certain unique properties which make it especially suited as a cryogen in "zero-G". However, aside from these evident properties, little if anything is known about the behavior of superfluid helium in "zero-G". In order to properly design superfluid cooling systems to operate in space, this behavior will have to be understood. Determination of this behavior is the purpose of the work to be carried out under this RTOP. There are many benefits in having superfluid helium cooling systems aboard a spacecraft. One source of noise in any electronic detector is thermal noise. At liquid helium temperatures 4.2°K this noise is quite low. However, liquid helium boils and in a weightless condition would form a froth. This froth, beside being difficult to handle, would become, because of its uneven cooling, again a source of noise. Superfluid helium, however, does not boil because of its astounding thermal conductivity -- and so does not froth -- and can easily be kept at a very uniform temperature of 1°K or less. A spacecraft with a superfluid helium cooling system not only allows virtually noiseless detectors, but also could utilize a host of unique superconducting devices. The properties of weightless superfluid helium will be studied using experiments performed in drop towers or in aircraft traveling along ballistic trajectories. These experiments, particularly those performed on weightless liquid helium films and droplets, may actually shed light on the basic nature of the superfluid helium itself.

13. KEYWORDS Superfluid helium cooling systems, electronic detector, superconducting devices, He II films and drops

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

Superfluid helium is destined to find ever increasing application as a cryogen in future spacecraft missions. It has already been used as a cryogen on several rocket flights, and currently there are plans to use it on two, perhaps three, contemplated spacecraft missions. Its utility stems from certain unique properties which makes it especially suited as cryogen in "zero-G". However, aside from these easily predicted properties, little if anything is known about the bahavior of superfluid helium in "zero-G". In order to properly design superfluid cooling systems to operate in space, this behavior will have to be determined. The determination of this behavior is the purpose of the work to be carried out under this RTOP.

15. OPERATING PLAN

A. Objectives

The objective of the work to be carried out under this RTOP is to determine the behavior of He II in weightless environments. This behavior must be known in order to properly design He II cooling systems which can operate in space. Consequently, the results of the novel experiments to be carried out clearly have engineering importance. Nonetheless, the results of these experiments will have scientific importance as well since they can shed new light on the fascinating phenomenon of superfluidity that endows He II with its many unusual properties.

In the first year, laboratory studies will be performed in order to perfect the equipment and the techniques to be used later in zero-G experiments. One or two tests on films and droplets will be performed in a drop tower. Simple experiments on falling drops and helium venting will be carried out in the laboratory.

The theoretical work will continue to help propose experiments, to help design the experiments, and to help interpret the experiments once they have been completed.

Next year, if not before, the actual experiments on weightless He II will be carried out.

B. Technical Approach

The experiments on weightless He II will primarily be carried out in the drop tower at NASA's Lewis Research Center. However, since the drop tower allows at most ten seconds of weightlessness, aircraft flying ballistic trajectories may be required. Using such aircraft allows weightlessness to be attained for from twenty to thirty seconds. Rocket flights allow minutes of weightlessness to be attained and, of course, satellites such as Skylab B for example, yield months of weightlessness.

Before attempting extensive experiments in weightlessness, experimental equipment and techniques will be perfected in the laboratory.

The drop tower tests will initially focus on experiments to determine the properties of weightless He II film, particularly film thickness, flow, and thermal conductivity. Subsequent drop tower tests will be carried out on the formation and evolution of He II fog. As the drop tower tests proceed, they will indicate if aircraft, rockets, or satellites will be required for further study. The experiments on weightless channel flow and weightless helium venting probably cannot be carried out in a drop tower and will probably require the use of aircraft to begin with.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

None.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	Addendum 188-41-54	Relativity and Celestial Mechanics		4 OF 5

	MAJOR MILESTONES	PRIOR FY ___ QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	NEXT FY 74 QUARTER 1	2	3	4
1	Staff the Task																				
2	Visit Lewis Zero G Facility at Lewis and Design Experimental Package																				
3	Construction of Experimental Package																				
4	Run Experiments at Lewis																				
5	Laboratory Work on He II Film Thickness Experiment Determine Most Suitable Drop Technique																				
6	Venting Studies																				
7	Fog Study																				
8	Possible Aircraft and Rocket Experiment																				
9	Experiments on Helium Drops																				
10	Theoretical Studies Based on Experimental Data																				

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEUDLE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	Addendum 188-41-54	Relativity and Celestial Mechanics	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL		1.0	2.0		
DIRECT SUPPORT		1.0	0.5		
TOTAL DIRECT MAN YEARS		2.0	2.5		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT		81	129		
TOTAL FUNDS		81	129		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

jpl → RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	Addendum 188-41-54-07-55

5. TITLE

LOW GRAVITY SUPERFLUID HELIUM COOLING SYSTEMS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)	CONTRACT NO.
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A	CONTRACT START DATE
ADDRESS: 4800 Oak Grove Dr / Pasadena, Calif. 91103	ADDRESS	
RESPONSIBLE INDIVIDUAL: Saffren, M.M.	PRINCIPAL INVESTIGATOR	
TELEPHONE: 213 - 354 - 2352	TELEPHONE	

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72		
CURRENT FY 73 (n)	81	
NEXT FY 74 (c)	129	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-0-0-80-10 The objective of the work of this task is to determine the behavior of He II in weightless environments. This behavior must be known in order to properly design He II cooling systems which can operate in space. Consequently, the results of the novel experiments to be carried out clearly have engineering importance. Nonetheless, the results of these experiments will have scientific importance as well since they can shed new light on the fascinating phenomenon of superfluidity that endows He II with its many unusual properties. In the first year, laboratory studies will be performed in order to perfect the equipment and the techniques to be used later in zero-G experiments. One or two tests on films and droplets will be performed in a drop tower. Simple experiments on falling drops and helium venting will be carried out in the laboratory. The theoretical work will be directed toward helping propose experiments, helping design the experiments, and helping interpret the experiments once they have been completed. Next year, if not before, the actual experiments on weightless He II will be carried out. The experiments on weightless He II will primarily be carried out in the drop tower at NASA's Lewis Research Center. Subsequent drop tower tests will be carried out on formation and evolution of He II fog. As the drop tower tests proceed, they will indicate if aircraft, rockets, or satellites will be required for further study.

10. JUSTIFICATION (WHY) Superfluid helium is destined to find every increasing application as a cryogen in future spacecraft missions. A spacecraft with a superfluid helium cooling system not only allows virtually noiseless detectors, but also could utilize a host of unique superconducting devices: extremely sensitive magnetometers, accelerometers superconducting magnets for use in high energy particle detection or in shielding a spacecraft from such particles; superinductors for microminiaturized circuits, extremely high-Q resonant cavities and waveguides, compact superconducting delay lines, and particularly a compact low power digital computer with superconducting circuit elements. Moreover, such a spacecraft could use a 1°K maser to detect commands from earth. For a fixed antenna power at earth, replacing present spacecraft receivers with such a maser receiver would allow a spacecraft either to receive signals further away from earth or, at the same distance, greatly increase the bandwidth of these signals. Superfluid helium has already been used as a cryogen on several rocket flights, and currently there are plans to use it on two, perhaps three, contemplated spacecraft missions. Its utility stems from certain unique properties which makes it especially suited as cryogen in "zero-G". However, aside from these easily predicted properties, little if anything is known about the behavior of superfluid helium in "zero-G". In order to properly design superfluid cooling systems to operate in space, this behavior will have to be determined. The determination of this behavior is the purpose of the work of this task.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) N/A

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		44, 46	188-41-55

5. TITLE
INFRARED ASTRONOMY

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002000, 002100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

OBJECTIVE

The objective of this task is to obtain and analyze high resolution (better than 1 cm^{-1}) spectra of selected cool stars in the 1.2 to 6 micron (1600-8000 cm^{-1}) region with the JPL Mk III Connes'-type Fourier Spectrometer at the coude' focus of the 107" telescope McDonald Observatory. The primary aim is to aid in the understanding of the chemical composition and evolutionary state of normal and variable late-type stars.

13. KEYWORDS
Stellar Astronomy, Fourier Spectrometry

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/21/72		

14. JUSTIFICATION

Conventional stellar spectroscopy has been chiefly aimed at the understanding of the properties of hot stars, whose spectra are largely atomic in origin. Attempts to use the same approaches to cool stars and stars showing strong interstellar and circumstellar extinction have been less successful because many of the processes involved are molecular in origin. It therefore seems pertinent to employ the classic method for the observation of molecular spectra, namely infrared spectroscopy, to the problems of these "cool" stars.

Since we are fortunate to have available to us a Connes'-type Fourier spectrometer, developed by us for planetary work, we are in a unique position to make a substantial contribution to our understanding of these objects.

15. OPERATING PLAN

A. Objectives

Our objective is to obtain interferograms (and, subsequently, high-resolution spectra) of a selected list of cool and obscured stars representative of the many different types within the galaxy.

B. Technical Approach

Using the JPL Connes'-type Fourier spectrometer and the University of Texas 107" telescope at McDonald Observatory, we undertake observations of selected (from a list of about 50) stars at every available opportunity. These times occur primarily during periods when there are no planets available and the program is conducted with the active participation of Dr. David L. Lambert and his colleagues at the University of Texas. Dr. Lambert is funded separately by the NSF and is the principal investigator in the program. Because of funding limitations, JPL participation is minor and is largely limited to the instrumentation and interferogram editing. It is our earnest wish to play a larger role in this program than present funds permit.

C. Progress

A paper announcing the discovery of the OH radical in the atmosphere of the M supergiant, α Orionis, and discussing the chemical composition and evolutionary state of this star has been published in the Astrophysical Journal (172, 89, (1972)).

C. Progress (Cont'd)

A paper discussing turbulence velocities in this same star (using the same spectra) has been published in the Astrophysical Journal (170, 551 (1971)).

A paper discussing the automatic analysis of astronomical (Fourier) spectra has been published in the Astronomical Journal (76, 711, (1971)).

A paper announcing the detection of the NH radical in α Orionis is in preparation.

Spectra of a number of objects have been obtained in the past year. Among "normal" stars: α Tauri and α Herculis, Shell stars: VY Canis Majoris, Mira variables: O Ceti, R. Leonis and a beginning has been made on several carbon stars. In each case, more data are needed to bring the signal-to-noise ratio up to an acceptable value. We have also repeated our observation of α Orionis over a wider wavelength range and at higher resolution (0.1 cm^{-1}) in order to complete this phase of the task.

Progress on the solar-telluric spectral atlas has been slowed due to the pressure of other commitments.

Although not directly germane to this task, it is worth noting that deuterium has been discovered in the atmosphere of Jupiter (as CH_3D) under the auspices of the planetary program and is mentioned here because of the profound cosmological significance of a new value for the primordial D/H ratio. The data are still undergoing analysis.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

Journal Articles

Hutchison, R. B., "Turbulence Velocities in the Atmosphere of Alpha Orionis," Astrophys. J., 170, 551-555, 1971.

Hutchison, R. B., "Automated Analysis of Astronomical Spectra," Astron. J., 76, No. 8, 711, 1971.

Beer, R., Hutchison, R. B., Norton, R. H., Lambert, D. L., "Astronomical Infrared Spectroscopy with a Connes-Type Interferometer. III. Alpha Orionis, 2600-3450 cm^{-1}," Astrophys. J., 172, 89-115, 1972.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	188-41-55	INFRARED ASTRONOMY	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL	0.2	0.2	0.2		
DIRECT SUPPORT	0.2	0.2	0.2		
TOTAL DIRECT MAN YEARS	0.4	0.4	0.4		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	20 K	20 K	20 K		
TOTAL FUNDS	20 K	20 K	20 K		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	603-45510-0-8250	N/A	188-41-55-08-55

5. TITLE

HIGH RESOLUTION INFRARED STELLAR ASTRONOMY (0)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: R. Beer	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 4748	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	20	
CURRENT FY 73 (c)	20	
NEXT FY 74 (c)	20	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 0-20-40-40-0

High resolution stellar spectra will be obtained in the 1.2 to 6 micron region with the JPL Connes'-type Fourier spectrometer at the 107 inch telescope, McDonald Observatory in collaboration with the Astronomy Department of the University of Texas.

10. JUSTIFICATION (WHY)

The new field of infrared astronomy is just beginning. Almost all work to date has been broad-band photometry or low-resolution spectroscopy. The few high-resolution spectra (resolution $\sim < 1\ cm^{-1}$) available have revealed startling new features in cool and "infrared" stars. We have a Connes interferometer on the 107″ at McDonald and propose to investigate these spectra.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

OH and NH have been discovered in α Orionis, and its turbulence and evolutionary state determined. Observations have been made of several normal, carbon and shell stars and two Mira variables.

95

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		44,46	188-46-53

5. TITLE

X-RAY AND GAMMA RAY ASTRONOMY

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002000,002100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

This describes the JPL part of a cooperative program with UCSD in X- and gamma ray astronomy. The objective is to observe line spectra in extraterrestrial X-ray and gamma-ray sources in the 0.05 to 10 MeV energy range. Observation of such sources would provide important information on nucleosynthesis, galactic history and the nature of cosmic X-ray sources.

Under this program, a gamma ray sensor which has been developed for lunar missions will be adapted to balloon flight systems for carrying out astronomical observations while simultaneously studying their properties and performance in a space-like radiation environment.

The specific objective for this program for FY'72 is to integrate an advanced solid state detector array, its cesium iodide shield, pulse-height analyzer, and data handling electronics into a balloon-flight system and perform a balloon flight in the last part of FY'73.

13. KEYWORDS

X-Ray Astronomy, Gamma Ray Astronomy

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald P. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. Justification

Thus far in the history of gamma-ray astronomy, no extraterrestrial gamma-ray line emissions have been observed. Such observations would provide invaluable information on nucleosynthesis, galactic history, and the nature of the various cosmic X-ray sources. The lack of a positive line observation points to the need for a high resolution gamma-ray spectrometer which has a sensitivity to line emissions in the .05 to 10 MeV energy region which is superior to any gamma-ray instrument now being used for astronomical purposes. Such an instrument for study in connection with possible lunar and planetary missions has been procured jointly with UCSD under NASA Program 195, and represents a unique opportunity to provide direct information on supernova mechanisms, nucleosynthesis, the distribution of heavy elements outside the solar system, and many other important astrophysical questions. Under this task, we propose to use this instrument for such astronomical observations from a balloon-borne platform.

15. Operating Plan

A. Objectives

The prime objective of this task is to utilize radiation detection instruments, developed under another task, to measure X-ray and gamma radiation in the .05 to 10 MeV energy range from extraterrestrial objects in an attempt to understand the physical processes which are acting in these objects. This task is also to support the reduction and publication of the data obtained.

B. Technical Approach

Recently balloon flights were made by JPL to observe the Crab Nebula and Scorpius XR-1 with a small solid state detector. For these flights an effective capability both in hardware and technical experience were built up. In FY'73, this capability will be put to use in observing with and testing an advanced solid state detector system being developed. This is composed of a cluster of four (Ge(Li) crystals with a total volume of 160 cm^3 and an area of 50 cm^2 surrounded by a large CsI(Na) anti-coincidence shield.

Portions of a balloon gondola framework have been loaned to us for the performance of a balloon flight to study this instrument. The data handling system and detector associated electronics subsystems will be integrated on the gondola at JPL. The ground station has been expanded somewhat and is being installed into a new van large enough to accommodate it and the new gondola.

A balloon flight is to be carried out in late FY'73 or early FY'74 using the facilities of the NCAR Scientific Balloon Facility at Palestine, Texas. The purpose of the flight will be to measure the instrument's true detector background and the behavior of the sensor materials in the radiation environment. For these measurements, the gondola mechanisms will allow several objects to be rotated into the field of view of the detector. One of these is a blocking scintillation crystal which will provide 4π shielding so that shield leakage radiation can be measured. We will also attempt to arrange the flight schedule so as to observe any cosmic X-ray sources which transit close to the zenith at the balloon position. The reduction of

accumulated data will be carried out using a combination of our ground station facilities and the JPL Scientific Computing Facility.

An instrument similar to the one we have developed under NASA Program 195 has been selected for integration study on the second High Energy Astronomy Observatory (HEAO-B) mission.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. Publications in Last Year

None

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	188-46-53	X-RAY AND GAMMA-RAY ASTRONOMY		4 OF 5

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY '73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY '74 QUARTER 1	2	3	4	FY QUARTER 1	2	3	4	FY QUARTER 1	2	3	4
Calibrate sensor																												
Design, fabricate & test Elec. Data System																												
Plan, assemble, and test gondola																												
Perform balloon flight																												
Reduce and analyze data																												

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- 1 RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	188-46-53	X-RAY AND GAMMA-RAY ASTRONOMY	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
DIRECT PROFESSIONAL	0.5	2.2	2.5		
DIRECT SUPPORT	1.2	1.2	1.5		
TOTAL DIRECT MAN YEARS	1.7	3.4	4.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	75	150	180		
TOTAL FUNDS	75	150	180		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY '72	FY '73	FY '74	FY	FY
TOTAL MAN YEARS	0	1.0	1.0		

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	603-55310-0-8280	N/A	188-46-53-01-55

5. TITLE

X-RAY AND GAMMA-RAY ASTRONOMY (B)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Metzger, A. E.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 4017	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72 (c)	75	
CURRENT FY '73 (c)	150	
NEXT FY '74 (c)	180	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 15-25-10-25-15

This describes the JPL part of a cooperative program with UCSD in X- and gamma-ray astronomy. The objective is to observe line spectra in extraterrestrial X-ray and gamma-ray sources in the 0.05 to 10 MeV energy range. Observation of such sources would provide important information on nucleosynthesis, galactic history, and the nature of cosmic X-ray sources. Under this program, a gamma-ray sensor which has been developed for lunar missions will be adapted to balloon flight systems for carrying out astronimical observations while simultaneously studying their properties and performance in a space-like radiation environment. The specific objective for this program for FY'73 is to integrate an advanced solid state detector array, its cesium iodide shield, pulse-height analyzer, and data handling electronics into a balloon-flight system and perform a balloon flight in the last part of FY'73 or FY'74.

10. JUSTIFICATION (WHY)

Thus far in the history of gamma-ray astronomy, no extraterrestrial gamma-ray line emissions have been observed. Such observations would provide invaluable information on nucleosynthesis, galactic history, and the nature of the various cosmic X-ray sources. The lack of a positive line observation points to the need for a high resolution gamma-ray spectrometer which has a sensitivity to line emissions in the .05 to 10 MeV energy region which is superior to any gamma-ray instrument now being used for astronomical purposes. Such an instrument is presently being developed for lunar and planetary missions jointly with UCSD and represents a unique opportunity to provide direct information on supernova mechanisms, nucleosynthesis, the distribution of heavy elements outside the solar system, and many other important astrophysical questions. Under this task, we propose to use this instrument for such astronomical observations from a balloon-borne platform.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

During FY'71, a balloon-borne small solid state detector system was flown from the NCAR balloon-flight facility in Palestine, Texas. Flights were made to observe the Cran Nebula and Scorpius XR-1. Data reduction and analysis have been carried out in FY'72. For these flights, an effective capability both in hardware and technical experience were built up. A mobile ground station was developed which will be expanded to serve as ground station and check-out equipment for the advanced solid state detector system.

101

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		44,27	188-46-53 Addendum

5. TITLE
X-Ray and Gamma Ray Astronomy

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
188-46-53

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002100, 002000

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The studies carried on under this program will lead to modifications of the HEAO-B gamma ray spectrometer concept to make it suitable for follow-on experiments aboard the space shuttle.

The HEAO-B instrument is designed primarily to perform an exploratory search for extra-terrestrial sources of x-ray and gamma ray line emissions in the .06 to 10 MeV energy range. This experiment should be followed by one in which individual sources are picked out for specific and detailed study. Space shuttle provides an ideal platform for such experiments.

The instrument required to perform this function must have improved angular resolution and line radiation sensitivity. To achieve this, a long active collimator and neutron shielding will be added to an existing high spectral resolution gamma ray spectrometer and properties of the system in this configuration will be studied in the stratospheric radiation environment on a balloon flight. Additionally required modifications in cooling techniques and mechanical design and packaging will be studied.

13. KEYWORDS
Gamma Ray Astronomy, Space Shuttle

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. Justification

The observations of gamma ray line emissions could provide invaluable information on nucleosynthesis, supernova theory, galactic history and the nature of various cosmic X-ray sources. No such lines have been observed so far and an effort is now underway here at JPL to perform an exploratory survey of the celestial sphere with a high spectral resolution gamma ray spectrometer (HSR/GRS) aboard the High Energy Astronomical Observatory (HEAO-B) spacecraft. This survey should be followed by an experiment in which specific sources are studied in detail. Such studies would involve almost continuous observations for several days to get good statistics on spectra and time variations. This could be accomplished by an instrument with high angular resolution which is mounted on a stable platform and pointed at the source. The instrument involved in such an experiment would be fairly large and heavy and require a vehicle with large pay-load capability such as the space shuttle.

Recommendations regarding a general packaging philosophy and developmental approach are being developed by JPL in a task (Space Shuttle Instrument Development Study), which is currently funded by the Space Shuttle Office of Advanced planning. The purpose of the engineering portions of this task are to perform a detailed engineering design analysis and packaging study based on the recommendations of the instrument development study.

15. Operating Plan

A. Objectives

The objective of this task is to use an existing high spectral resolution gamma ray spectrometer which was developed under another task, and the HEAO-B instrument concept presently under development, to study the requirements for a high angular resolution solid state detector with enhanced sensitivity and the ways in which the HEAO-B instrument concept may be efficiently modified to meet these requirements. Collimation and shielding techniques will be tested with the existing instrument on a balloon flight which will be performed during a balloon flight expedition to be carried out under another task.

B. Technical Approach

To accomplish the objectives of this task, we will do the following:

1. Improve angular resolution. For this, we would determine the geometrical requirements for the collimator. We would purchase such a collimator for our existing solid state detector cluster model and perform a balloon flight which, among other things, would measure the collimator's properties and effectiveness. This balloon flight will take place during a scheduled expedition conducted under our on-going balloon program. Potential delays in the procurement and delivery of the collimator crystal may cause us to miss the presently planned balloon expedition. If this happens, the flight will be made during our next field expedition one year later. As in all the activities, we will take maximum advantage of existing hardware. The flight will be followed by data reduction and analysis of the collimator's properties and the comparison of these with theoretical properties. These comparisons will form the bases for refinements to the collimator design or collimation techniques.

2. Improve overall detector sensitivity. Extend our present studies into the effects of interactions between the sensor and various cosmic ray primaries and secondaries. Fabricate a neutron moderation and absorption shield to augment our anticoincidence shield and study it with our existing solid state detector cluster on the balloon flight.

3. Investigate any modifications which may be necessary in our present cooling concepts to make the instrument appropriate for the shuttle-type missions. Our HEAO-B instrument cooling technique and configuration will have to be modified to affect its appropriateness for short duration missions and high angular resolution, the latter because shield penetrations for cold conduction paths will become significant in size when compared to the instrument aperture. This will be a part of a detailed engineering design analysis to arrive at an instrument configuration suitable for space shuttle missions.

4. Perform a preliminary packaging design and layout of the space shuttle instrument.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72		X-Ray and Gamma Ray Astronomy		4 OF 5

MAJOR MILESTONES	PRIOR FY ___ QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4
Design, procure CsI collimator																												
Fabricate collimator housing, assemble & test																												
Design and fabricate neutron shield																												
Modify gondola																												
Balloon flight test																												
Perform data reduction and analysis																												
Engineering design analysis																												
Packaging design																												
Feas. model development																												

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- 1 RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

104

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72		X-Ray and Gamma Ray Astronomy	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY	FY	FY
DIRECT PROFESSIONAL		2.7			
DIRECT SUPPORT		.5			
TOTAL DIRECT MAN YEARS		3.2			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT		300			
TOTAL FUNDS		300			

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72			Addendum 188-46-53-XX

5. TITLE

A Gamma Ray Spectrometer for Space Shuttle (B)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)	
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A	CONTRACT NO.
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS	CONTRACT START DATE
RESPONSIBLE INDIVIDUAL: Metzger, A. E.	PRINCIPAL INVESTIGATOR	
TELEPHONE: 213 - 354 - 4017	TELEPHONE	

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY '73 (n)	300	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 5-75-0-10-10

The studies carried on under this program will lead to modifications of the HEAO-B gamma ray spectrometer concept to make it suitable for follow-on experiments aboard the space shuttle. The HEAO-B instrument is designed primarily to perform an exploratory search for extra-terrestrial sources of X-ray and gamma ray line emissions in the .06 to 10 MeV energy range. This experiment should be followed by one in which individual sources are picked out for specific and detailed study. Space shuttle provides an ideal platform for such experiments. The instrument required to perform this function must have improved angular resolution and line radiation sensitivity. To achieve this, a long active collimator and neutron shielding will be added to an existing high spectral resolution gamma ray spectrometer and properties of the system in this configuration will be studied in the stratospheric radiation environment on a balloon flight. Additionally required modifications in cooling techniques and mechanical design and packaging will be studied.

10. JUSTIFICATION (WHY)

The observation of gamma ray line emissions could provide invaluable information on nucleosynthesis, supernova theory, galactic history and the nature of various cosmic X-ray sources. No such lines have been observed so far and an effort is now underway here at JPL to perform an exploratory survey of the celestial sphere with a high spectral resolution gamma ray spectrometer (HSR/GRS) aboard the High Energy Astronomical Observatory (HEAO-B) spacecraft. This survey should be followed by an experiment in which specific sources are studied in detail. Such studies would involve almost continuous observations for several days to get good statistics on spectra and time variations. This could be accomplished by an instrument with high angular resolution which is mounted on a stable platform and pointed at the source. The instrument involved in such an experiment would be fairly large and heavy and require a vehicle with large pay-load capability such as the space shuttle. Recommendations regarding a general packaging philosophy and developmental approach are being developed by JPL in a task (Space Shuttle Instrument Development Study) which is currently funded by the Space Shuttle Office of Advanced Planning. The purpose of the engineering portions of this task are to perform a detailed engineering design analysis and packaging study based on the recommendations of the instrument development study.

11. Main Achievements N/A

107

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		43	192-55-63

5. TITLE
LIFE DETECTION

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002300, 012100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 1973

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

In preparation for missions to the planets, research is required to define and develop scientific strategies for flight experiments which will detect and identify extraterrestrial life and organic molecules characteristic of past or present life. Under this program are eight separate tasks which entail a wide variety of disciplines from organic chemistry, geochemistry, biochemistry through various types of molecular spectroscopy:

Metabolism and Photosynthesis
Geochemistry of Biomolecules
Reaction mechanisms in Thermal Decomposition
Volatile derivaties of Organic Compounds
Analytical Technique in Mass Spectrometry
Advanced Techniques in Organic Analysis
Kerogens of Harsh Environmental Soils
Biospheric Recycling Processes

13. KEYWORDS
Life Detection, Organic Analysis

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rea ASSISTANT LABORATORY DIRECTOR	3/27/72		

Work is continuing on an advanced carbon assimilation life detection experiment which will provide specific biochemical information besides indicating the existence of active biology. The approach involves incubation of soil samples with isotopically labelled gas and subsequent pyrolysis to ascertain the nature and quantity of any new labelled biomolecules and metabolites formed by active biology.

Another approach to life detection being investigated is based on elemental recycling processes in the biosphere. These processes should occur on all life-bearing planets and should be reflected in the distribution of gas concentrations between the atmosphere and the subsurface regions of a soil. This work is aimed at developing sensitive analysis techniques for a variety of gases in soils and to examine the problem of distinguishing between physical-chemical effects on gas concentrations in soil and the effects of biological processes.

A study closely related to the interpretation of the life detection and molecular analysis experiments seeks to understand the abiogenesis of organic compounds which could occur on the Martian surface. As demonstrated in previous work under this program simple organics can be formed from CO and water on silicons of alumina surfaces irradiated with ultraviolet light of <2100Å, characteristic of that reaching Mars. Elucidation of the reaction mechanisms, the role of the substratum and influence of other gases in this abiogenic synthesis are under active investigation.

One of the prime techniques for producing volatile molecules from complex biomolecules and other teochemically important organic molecules is pyrolysis. Although there is considerable literature on pyrolysis, the majority concerns compounds of little biological importance and is of minor mechanistic significance. Our work will approach the problem from a variety of viewpoints. A detailed mechanistic study is being conducted on selected members of particular classes of compounds. Both singly and doubly isotopically labelled compounds will be used to determine the intermediates and pathways leading to the observed pyrolysis products. Studies are being made with model compounds of dimers, oligimers and eventually biological polymers. This type of systematic approach is essential to an accurate understanding of data obtained from pyrolysis studies on material from an unknown source and can provide a method for differentiating between biopolymers and geopolymers.

In development of analytical procedures that require derivatization of organic fractional groups and which potentially are to be automated, the relevant chemical reactions must be understood in detail and optimum conditions for a particular analysis must be definable. Paramount to such a situation are knowledge of the yields of reactions, detailed understanding of reaction mechanisms, structure and stability of reagents, rates of reactions, nature of any reaction equilibria, structure of products, and the stability and suitability of derivatives for gas chromatographic and mass spectral analyses. We are examining these aspects of potential derivatization analytical schemes for organic compounds extractable from soils.

The distribution and persistence of bio-organic compounds in geological samples of different ages are being studied by means of absorption and fluorescence spectroscopy as well as by high resolution mass spectroscopy. Aromatic hydrocarbons, highly conjugated nitrogen heterocycles and biologically important pigments such as porphyrins are being extracted from geological samples. These same classes of

compounds are also being sought in the organic extracts of meteorites and various kerogen samples. Characterization of any isolated compounds are being carried out by various physical, chemical, optical and isotope techniques.

The isolation of organic matter from soils and other geochemical samples is a complex problem requiring selective solvation and/or hydrolysis of biopolymers. The physical and chemical processes associated with the extraction and separation of various classes of organic compounds are poorly understood and complexation of biologically important compounds with multivalent metal cations is a seriois problem. The efficiency and selectivity of various solvent systems for the recovery and partial fractionation of soil organics are being studied. Low molecular weight solvents, preferably of high volatility are attractive in terms of ease of removal, however, any wet chemical system must also be compatible with subsequent analysis of isolated compounds by gas chromatography or GC/MS.

14. Justification

Ideally, the results from the Viking '75 missions should be used as a base for planning post '75 missions. Since this is not practical, planning advanced experiments should allow for several possible outcomes of the '75 mission. If one or more of the '75 Viking biology experiments give positive results, verification should be obtained with similar experiments but with additional capabilities for checking false positives. In addition, the later experiments should provide specific information about the nature of Martian biology. The studies currently underway on the abiogenic synthesis of organic compounds from CO and ultraviolet light will be useful in interpreting these experiments.

Another approach to life detection is based on determining if there are recycling processes on a planet. If physical and chemical processes controlling the interactions of the Martian atmosphere with the upper layers of surface material can be adequately modeled and/or characterized, perturbations from predicted gas concentration distributions in surface matter should provide strong evidence for biological recycling of atmospheric constituents.

Another experiment selected for the Viking Mars probe is the detection of life-related organic compounds by pyrolysis-gas chromatography, with mass spectrometric identification of the pyrolusis products. To prepare for interpretation of the data from such an experiment, it is necessary to investigate the pyrolysis behavior of the major classes of terrestrial organic molecules in order to assure an ability to infer the structure and amount of the material originally present from analysis of a pyrolysate.

Future experiments will require development of sophisticated methods of soil sample preparation to derive maximum benefit from analytical instrumentation. Methods of chemical analysis must be developed which have a high probability of recognizing and distinguishing chemistries of biological origin from those derived abiogenically. Techniques that involve relatively little structural degradation of the indigenous organic matter and include procedures for the enrichment and isolation of trace organic constituents of potential biological interest can be be expected to accomplish the latter objectives. In the case of most biological molecules, such as amino acids, sugar, lipids, organic pigments, and other

polyfunctional polar molecules, it is most often necessary to convert them to derivatives which are volatile enough for GC/MS analysis. Techniques must be perfected to process the organic extracts from these soils so as to convert them to suitable volatile derivatives which can be analyzed by GC and/or a combined GC/MS system.

A knowledge of the distribution and persistence of biological compounds in terrestrial samples is important for formulating unambiguous criteria for the chemical identification of ancient life. Also, the results and techniques of this type of study have potential for development and understanding of future Mars surface chemical analysis experiments.

15. Technical Plan

A. Objectives

The objective of this program is to carry out research directed toward the development of techniques for the detection of extraterrestrial life and life-related molecules, including evidence of life, past, present or future, through the search for organic molecules, metabolic activity, growth, and reproduction and visual identification.

B. Technical Approach

In this section some of the more significant results that have been achieved in FY'72 under this program will be mentioned along with a brief indication of where they are leading.

A promising *in situ* soil gas sampling technique has been developed but it still needs refinement. A probe testing apparatus has been developed for this technique so work will be begun to study the effects of channeling and the volume of gas withdrawn from soils on the gas concentrations which can be measured. The present studies of the vertical and horizontal distributions of CO_2 and other gases in soils will be extended along with development of *in situ* procedures for measuring gas diffusion rates and studying the relationship between gas production rates by soil microflora, diffusion rates and gas concentration existing at any time in a given soil.

It has been demonstrated that the abiogenic synthesis of organic compounds from CO and H_2O vapor using UV of 2100Å is very dependent on the nature of the surface material receiving the irradiation. Available evidence indicates that the reactions are initiated by the excitation of surface-adsorbed CO. Abiogenic synthesis will be performed on a wider variety of substrata, especially those which are regarded as models for the Martian surface material. In experiments simulating primitive terrestrial conditions nitrogenous and sulfur containing compounds will be added to the gas mixtures in attempts to produce other types of organic compounds.

The gross features of the pyrolysis of the aliphatic amino acids have been established. Major products include simple aliphatic amines and N-alkyl aldimines. Nitriles of both the same carbon number and one carbon less are obtained in

significant amounts along with amides of the same carbon number and aldehydes of one carbon less. Both saturated and unsaturated hydrocarbons are obtained, possibly via a free radical process. Future work will be conducted to elucidate the specific intermediates involved in their formation using model compounds and isotopically labelled substrates. Pyrolysis studies will be carried out in a systematic way on molecules containing a variety of functional groups. These studies on model organic compounds will be augmented by further work on the pyrolysis of micro-organisms. Three fungi representing two distinct classes have been pyrolyzed. Initial studies show definite qualitative differences. Organisms from several phylogentic classifications will be studied. Pyrolysis will be carried out on the intact organisms as well as the individual cellular components. The on-line digital computer has been attached to one of our MS and will allow file searching with an output consisting of probable structure and a reliability estimated besides providing a printout of both mass number and relative intensities for our exper-mental spectrum, thus alleviating the need for manual peak counting.

An organic solvent extract of billion year old Nonesuch Shale was examined for porphyrins by means of fluorometry and high resolution mass spectrometry. This shale contains three fundamental types of porphyrins: an alkul (etio) type; a cycloalkano (DPEP) type, which retains the isocyclic ring of chlorophyll, and a porphyrin macrocyclic highly aromatic character. From a solvent extract of 5 gm of Murchison meteorite a tentative identification of nanogram quantities of porphyrin-like pigment has been made. Further characterization of this compound from a larger amount of sample is in progress. A fluorometric method for the determination of amino acids in geological sample is being sought. Condensation reactions of ninhydrin with aldehydes and primary amines are being explored.

Kerogen of some ancient rocks, coal, and the Allende meteorite were found to be insoluble in liquid NH_3 but this solvent extracted further nonpolymeric material from samples which had already been "thoroughly" extracted with a variety of organic solvents. We have also isolated kerogens from the Orgeuil and Murchison chondrites and studies of their solubility and oxidative DTA behavior are under way. Stereoscan electron microscopy has shown that these meteorite kerogens are present in the form of spherical particles about 1000Å in diameter. The solubility of meteorite and Precambrian kerogen in nitrogen tetraoxide dimethylformamide mixture is being evaluated.

Several special mass spectrometric techniques developed previously have been applied to the identification and characterization of trace amounts of carotenoids and porphyrins in several geochemical samples (Antarctic and Nonesuch Shales) and have led to discovery of a variety of previously unreported natural products. Substantial progress has been made in understanding the ionization and fragmentation processes of three classes of pigments and the related glucosides. The delivery and installation of a real time data system for our MS-9 spectrometer has been completed. The adaptation of existing software to the new system and the generation of new software specifically for the real time/on-line operation is being completed. With this new capability it will be possible after a high resolution spectrum has been recorded to process and output it for visual scrutiny while the compounds are still in the spectrometer source. This is a vast improvement over having to wait three days to a month for digitization and processing as we have had to until now.

Development of new separation procedures are important in planning automated analytical schemes for Martian life detection experiments for post-Viking missions. Specific attention is being directed towards conceiving new methods for isolation of organic materials from an inorganic matrix by systematically developing an understanding of the physical and chemical processes which determine the effect of pH on relative solubilities of constituents, and on the rates and equilibria of partitioning between different phases. Results thus far indicate that for comparative extractions of soils with solutions of 6 N HCl and formic acid, formic acid is as effective as HCl for removing organic matter from the mineral matrix. Furthermore formic acid does not solubilize as much inorganic salt as does the HCl. A detailed investigation of the organic matter extracted by the formic acid is now in progress. In future work emphasis will be placed on ascertaining what solvents are most selective for lipids.

In development of analytical procedures that require derivatization of organic functional groups and which potentially are to be automated, the relevant chemical reactions must be understood in detail and optimum conditions for a particular analysis must be definable. We are examining many chemical aspects of several potential derivatization analytical schemes for organic compound extractable from soils. A rapid analytical scheme has been developed whereby the 20 common amino acids can be derivatized into the volatile N-trimethylsilyl-O-n-butyl esters which can be subsequently analyzed gas chromatographically by one column. This procedure has advantages over previously reported ones. Close examination of the esterification reaction of the amino acids which must be affected prior to trimethylsilylation has revealed that the production of significant amounts of water in the alcohol/HCl reagent traditionally used as the esterification reagent has a significant influence on the equilibrium position of the esterification reactions. The detailed examination of this well-known chemical reaction is now in progress. A novel acetylating agent, bistrifluoromethyl ketene (experimental sample given to us by du Pont) has been successfully used to quantitatively derivatize amino and hydroxyl groups in a variety of compounds. The GC and MS suitability of these derivatives is encouraging. This new derivatizing reagent may be particularly useful for automated chemical reactors since it is a gas and reacts by addition without the formation of any by-products. Extension with bistrifluoromethyl ketene work, further exploitation of trimethylsilylation derivations, and studies of esterification reagents will receive attention in future work.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

A. Journal Articles

1. Bauman, A. J. and J. H. Richards, A Simple Electrostatic Model for the Chromatographic Behavior of the Primary Dithizonate, Separation Sci. 6, 715-725 (1971).

2. Laurentii, B. M., T. H. Lee, H. Yokoyama, H. G. Boettger, The Occurrence of Plectaneaxanthin in Cryptococcus, Phytochemistry 10, 625-629 (1971).

3. Weber, W. P., H. G. Boettger, A. K. Willard, Mass Spectra of Organo-Silicon Compounds, J. Org. Chem. 36, 1620 (1971).

4. Bauman, A. J., H. Yokoyama and H. G. Boettger, Isolation and High Resolution Mass Spectrometric Characterization of New Ketocarotenoids, European J. of Biochem. 22, 287-293 (1971).

5. Weber, W. P., R. A. Felix, A. K. Willard, R. M. Laine and H. G. Boettger, Transannular Interactions of the Silyl Center with Distant Keto-groups in the Mass Spectra of Medium-Sized Organo-silicon Heterocycles, J. Org. Chem. 36, 4060 (1971).

6. Hardy, J. P., A. Diaz and S. Winstein, Carbon-to-Metal Chlorine Exchange V: Mercuric Salt Promoted Acetolysis of Exo-Norbornyl, J. Am. Chem. Soc. 94, In Press. (1972).

7. Hardy, J. P. and S. L. Kerrin, A Rapid Analysis of Twenty Amino Acids by Gas Chromatography, Anal. Chem. 44, In Press. (1972).

8. Horowitz, N. H., J. S. Hubbard and G. L. Hobby, The Carbon-Assimilation Experiment for Viking, Icarus. In Press.

9. Rho, J. H., Grating Anomalies in Porphyrin Spectra, Geochim. Cosmochim. Acta, 35, 743-747 (1971).

10. Rho, J. H., Fluorescence Spectroscopy, A Review, Space Life Science, In Press. (1972).

11. Rho, J. H., A. J. Bauman, H. G. Boettger and T. F. Yen, A Search for Porphyrin Biomarkers in Nonesuch Shale and Extraterrestrial Samples, Space Life Sci. J. In Press (1972).

B. Meetings and Symposia

1. Boettger, H. G., A. M. Kelly, A. J. Bauman, and H. Yokoyama, The Use of Mass Spectrometry in the Identification of Organic Compounds in Arid Soils from Antarctica and the Mojave Desert, 19th Ann. Conf. on Mass Spectrometry and Allied Topics, May 2-7, 1971, Atlanta, Ga.

2. Boettger, H. G., A. M. Kelly, H. Yokoyama and A. J. Bauman, Advances in the Structural Analysis of Carotenoid Pigments by High Resolution Mass Spectrometry, Pacific Conference on Chemistry and Spectroscopy, October 18-20, 1971, Anaheim, Calif.

3. Hubbard, J. S., Abiogenic Synthesis under Simulated Martian Conditions. Lunar Science Institute Conference on Space Biology, October 11-12, 1971, Houston, Texas.

4. Cohen, E. A. and J. H. Rho, Computer Enhancement of Weak Porphyrin Fluorescence Spectra, American Chemical Soc. Meeting, Abstract No. 25, September 1971, Washington, D. C.

5. Rho, J. H., Fluorescence Spectroscopy, presented at the Meeting on the Significance of Lunar Organic Analyses to Exobiology, October 26, 1971, College Park, Maryland.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15-04-72	192-55-63	LIFE DETECTION	9 OF 9

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR FY 72	CURRENT FY 73	FISCAL YEAR FY 74	FY	FY
DIRECT PROFESSIONAL	9.6	9.6	10.0		
DIRECT SUPPORT	2.3	3.0	3.0		
TOTAL DIRECT MAN YEARS	11.9	12.6	13.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR FY 72	CURRENT FY 73	FISCAL YEAR FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	564	608	641		
TOTAL FUNDS	564	608	641		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR FY	CURRENT FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56320-0-8260		192-55-63-20-55

5. TITLE

METABOLISM AND PHOTOSYNTHESIS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)	CONTRACT NO.
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME	CONTRACT START DATE
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS: N/A	
RESPONSIBLE INDIVIDUAL: Hubbard, J.S.	PRINCIPAL INVESTIGATOR	
TELEPHONE: 213 - 354 - 5526	TELEPHONE	

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	77	
CURRENT FY 73(c)	78	
NEXT FY 74(c)	78	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-0-0-90-0

The abiogenic synthesis will be continued to further define the organic compounds that are formed on surfaces when CO, H_2O and nitrogenous or sulfur-containing gases are irradiated with long wavelength ultraviolet ($\lambda < 2100$Å). Similar experiments will be performed with surfaces and gas mixtures simulating primitive terrestrial conditions. The role of the surface in these processes will be further defined. Possible methods that can be used to increase the information obtainable from the present carbon-assimilation experiment will be investigated for post Viking applications. This will include various approaches for performing the experiment in situ, and for obtaining biochemical information from the labelled pyrolysis products obtained.

10. JUSTIFICATION (WHY)

The observation of abiogenic synthesis of organic compounds on surfaces under simulated conditions of Martian atmosphere and ultraviolet irradiation is of great planetological importance. An understanding of this process may provide a basis for development of experiments and strategies for exploration of Mars. It should also be determined if abiogenesis of organic compounds on surfaces could have been of importance in biochemical evolution on the primitive Earth. The capability of not only detecting the presence of carbon-assimilation by extraterrestrial soil organisms but also acquiring information about their gross chemical composition is a logical second phase experiment for post-Viking missions. This pyrolysis approach, using both radioactive and stable isotopes in conjunction with a GC-MS system has the advantage of not requiring complicated wet chemical extractions.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

The abiogenic synthesis of organic compounds from CO and H_2O vapor using UV of $\lambda > 2100$Å is dependent on the appropriate surface material receiving the irradiation. Available evidence indicates that the reactions are initiated by the excitation of surface-adsorbed CO. A variety of soils and mineral substances tested as substrata gave varying yields of organic products. Their effectiveness appears to be related to surface area, the amount of surface hydroxyl groups and ability to protect the products from photodestruction. Tests were made to determine if organic pyrolysis products trapped on a column of firebrick could be analyzed directly by a mass spectrometer. The spectra obtained by heating the firebrick packing, loaded with pyrolyzate, and flushing the released organics into the mass spectrometer were too complex for interpretation. Experiments are currently being performed to determine the feasibility of obtaining separations on gas chromatographic columns operated at high temperatures.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56321-0-8260	N/A	192-55-63-21-55

5. TITLE

GEOCHEMISTRY OF BIOMOLECULES (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Rho, J.H.	PRINCIPAL INVESTIGATOR: N/A
TELEPHONE: 213 - 354 - 3800	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	74	
CURRENT FY 73(c)	74	
NEXT FY 74(c)	74	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The distribution and persistence of bio-organic compounds in geological samples of different ages are being studied by means of absorption and fluorescence spectroscopy as well as by mass spectrometry. Aromatic hydrocarbons, highly conjugated nitrogen heterocycles and biologically important pigments such as porphyrins are being extracted from geological samples. These same classes of compounds are also being sought in the organic extracts of meteorites (Murchison) and various kerogen samples. Characterization of any isolated compounds are being carried out by various physical, chemical, optical and isotope techniques. 10-0-0-90-0

10. JUSTIFICATION (WHY) A knowledge of the distribution and persistence of biological compounds gained in this task is important for formulating unambiguous criteria for the chemical identification of ancient life in geological samples. Interpretation of the results will be directed towards establishment of the sequence of geological and chemical events that result from increasing geological age, variation of sediment depth, past thermal history and other aspects of a particular geological column and which result in relatively intact, biomolecules undergoing degradation and change to the kerogen and highly stable porphyrin type molecules. Also, the results and techniques of this study have potential for development into a potential Mars surface chemical analysis experiment.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) 1. An organic solvent extract of billion year old Nonesuch Shale was examined for porphyrins by means of fluorometry and high resolution mass spectrometry. This shale contains three fundamental types of porphyrins: an alkyl-(etio) type; a cycloalkano (DPEP) type, which retains the isocyclic ring of chlorophyll; and a porphyrin macrocyclic highly aromatic character. It appears that a continuous spectrum of porphyrins has been derived from some primary chlorophyll-like pigment. 2. A solvent extract of Murchison meteorite was examined for the presence of porphyrins by means of fluorescence. A tentative identification indicates the presence of an approximately nanogram quantity of porphyrin-like pigment in 5gm. sample. Further characterization of this compound from a larger amount of sample is in progress. 3. A fluorometric method for the determination of amino acids in geological sample has been examined. Condensation reactions of ninhydrin with aldehydes and primary amines is being studied in order to maximize the yield of fluorescent reaction products and minimize the background fluorescence.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56325-0-8260	N/A	192-55-63-25-55

5. TITLE

REACTION MECHANISMS IN THERMAL DECOMPOSITION (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Ratcliff, M. Jr.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 2677	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	89	
CURRENT FY 73 (c)	87	
NEXT FY 74 (c)	90	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The specific products produced during the thermal decomposition of the simple aliphatic amino acids have been established. Future work will be conducted to elucidate the specific intermediates involved in their formation. Free radical chains as well as unimolecular processes appear to be involved and experiments utilizing both singly and doubly labelled substrates are planned to establish the mechanistic significance of each. In addition, pyrolysis studies will be carried out in a systematic way on molecules containing a variety of functional groups. The effects of the isomeric positioning of these groups and of various physical parameters (i.e., temperature, solid supports) will be studied to determine the extent to which they might alter the thermal cleavage patterns. These studies on model organic compounds will be augmented by further work on the pyrolysis of microorganisms. Organisms from different phylogenetic classifications will be studied. Pyrolysis will be carried out on the intact organisms as well as the individual cellular components. The cellular origin of the various pyrolysis products will thereby be established. The on-line digital computer will be used for file searching with an output consisting of probable structure and a reliability estimate.

10. JUSTIFICATION (WHY) The mechanistic details for the thermal decomposition of organic substances must be understood if pyrolysis studies of unknown materials are to be meaningful. Only when the individual products from a pyrolysis experiment can be unequivocally related to a particular precursor substance via a logical mechanism will the analysis of unknown material acquire a high degree of reliability. Furthermore, pyrolysis experiments offer the optimum possibility for obtaining structural information on micro-quantities of biological compounds. The complex nature of these biomolecules, however, further emphasises the necessity for having a fundamental understanding of the pathways followed during thermal decomposition. 10-0-0-90-0

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) The gross features of the pyrolysis of the aliphatic amino acids have been established. Major products include simple aliphatic amines and N-alkyl aldimines. Nitriles of both the same carbon number and one carbon less are obtained in significant amounts. Amides of the same carbon number and aldehydes of one carbon less are found; these tentatively are thought to arise from α-lactams and α-lactones respectively. Both saturated and unsaturated hydrocarbons are obtained, possibly via a free radical process. Three fungi representing two distinct classes have been pyrolyzed. Initial studies show definite qualitative differences. The structures of the fragments responsible for these differences are being determined. Our computing capabilities now include a printout of both mass numbers and relative intensities, alleviating the need for manual counting.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56326-0-8260	N/A	192-55-63-26-55

5. TITLE

VOLATILE DERIVATIVE OF ORGANIC COMPOUNDS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Manatt, S.L.	PRINCIPAL INVESTIGATOR: N/A
TELEPHONE: 213 - 354 - 3227	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	76	
CURRENT FY 73 (c)	73	
NEXT FY 74 (c)	87	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) In development of analytical procedures that require derivatization of organic functional groups and which potentially are to be automated, the relevant chemical reactions must be understood in detail and optimum conditions for a particular analysis must be definable. Paramount to such a situation are knowledge of the yields of reactions, detailed understanding of reaction mechanisms, structure and stability of reagents, rates of reactions, nature of any reaction equilibria, structure of products, and the stability and suitability of derivatives for gas chromatographic and mass spectral analyses. We are examining these aspects of potential derivatization analytical schemes for organic compounds extractable from soils.

10-0-0-90-0

10. Justification (Why) Concepts under active consideration for post-Viking missions designed to explore planetary surfaces will accomplish separation of polar organic compounds of biological significance from the soil matrix. Techniques must be perfected to process the organic extracts from these soils so as to convert them to suitable volatile derivatives which can be analyzed by gas chromatography and/or a combined gas chromatographic-mass spectrometric system. Of the several derivatization analytical procedures currently practical, it appears that the most general is the trimethylsilyation. If this scheme be considered for incorporation into an automated, remote analytical device as a part of a future flight experiment, detailed chemical information regarding this chemical reaction and the reagents for this reaction must be in hand. This task is studying all aspects of the reaction of silylating agents with organic fractional groups so that proper conditions for a particular analytical problem can be defined. Also new and novel organic and inorganic reagents for derivation analytical schemes, other than silylation one, will be sought which would also be suitable for automation and analyses of biologically significant organic molecules.

11. Main Achievements (Significant Progress) A rapid analytical scheme has been developed whereby 20 common amino acids can be derivatized into the volatile N-trimethylsilyl-O-n-butyl esters which can be subsequently analyzed gas chromatographically by one column of lightly loaded textured glass beads in less than 35 minutes. This procedure has advantages over previously reported ones. Close examination of the esterification reaction of the amino acids which must be effected prior to trimethylsilylation has revealed that the production of significant amounts of water in the alcohol/HCl reagent traditionally used as the esterification reagent has a significant influence on the equilibrium position of the esterification reaction. The detailed examination of this well-known chemical reaction now in progress has demonstrated that existing data and discussions concerning the mechanism and equilibria involved in this reaction have failed to appreciate or understand the water problem.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-65335-0-8260		192-55-63-27-55

5. TITLE

BIOSPHERIC RECYCLING PROCESSES (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Hobby, G.L.

TELEPHONE: 213 - 354 - 2458

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS:

PRINCIPAL INVESTIGATOR:

TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	65	
CURRENT FY 73 (c)	82	
NEXT FY 74 (c)	88	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-0-0-90-0

Techniques for sampling and analyzing gases in soil are being developed. Gases are withdrawn from soil plots into specially designed gas sample loops that are attached to stainless steel probes inserted into the soil. The loops are removed and connected to a gas chromatograph system where the gas samples are injected and analyzed for CO_2, O_2, and N_2. Variations of CO_2 concentrations as a function of depth and areal distribution are being studied. Biological and physical factors affecting soil gas distribution are to be determined. Several kinds of probes for extracting gases from soil with minimum disturbance are being developed. The probes will be tested with an apparatus now under construction. This work will be extended to include a study of the role of various soil types in recycling elements that are essential in the biosphere, through gas phase processes. Highly sensitive analysis techniques for trace gases will be developed for this purpose.

10. JUSTIFICATION (WHY)

The study of gas distribution in soil and the development of techniques for sampling and analyzing soil gases are directly related to life detection approaches that could be used on post-Viking Mars landers. If a soil biota exists on Mars its activity should produce gas concentration profiles of some atmospheric components in soil that would be different if no biota existed. By soil gas analysis and suitable analysis of the physical and chemical factors present it should be possible to infer the existence of life in the soil. If this condition existed it would suggest that biological recycling of elements through gas phase processes were occurring.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A technique for sampling and analyzing soil gases has been developed. This includes a probe that can be inserted into the soil, and gas sample collection loops that can be attached to the probe and then to a gas chromatograph in the laboratory. A gas chromatographic system was developed for the analysis of CO_2 in soil against a very large background of O_2 and N_2. Carbon dioxide concentration profiles in soil at different kinds of sites have been obtained. A systematic study of the carbon dioxide distribution in a selected soil plot is currently being made to determine factors responsible for this distribution. An apparatus is being fabricated for testing various soil probe designs and for developing an in situ method for measuring gas diffusion in soils. A laboratory apparatus is being set-up for making very sensitive tests for the capacity of soil to produce trace gases important in elemental recycling processes.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56330-0-8260		192-55-63-30-55

5. TITLE
ANALYTICAL TECHNIQUE IN MASS SPECTROMETRY (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS: N/A
RESPONSIBLE INDIVIDUAL: Boettger, H. G.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 6018	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	43	
CURRENT FY 73(c)	57	
NEXT FY 74(c)	65	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The objective of this project is to study methods of analysis for biochemically important compounds through the use of mass spectrometry as the primary technique for identification and characterization. This effort involves the study of (1) techniques for sample preparation and introduction into the mass spectrometer, (2) the mechanisms of interaction between the molecules of the sample with ionizing beams of electrons, ions, and/or photons, and (3) the pathways of decomposition of ionized sample molecules. Currently, we are studying the behavior of three classes of geochemically interesting organic pigments, namely carotenoids, porphyrins and flavonoids, and related glucosides under conditions of electrons impact, ion-molecule (C.I.), and electron attachment ionization. Furthermore, we are investigating ways of making substances of this nature more amenable to mass spectrometry. In order to carry out these tasks, it is necessary to maintain the hardware and methodology of mass spectrometry and the associated automated data analysis methods at the state of the art. Therefore, a portion of the effort is devoted to the study and development of novel ionization methods and the updating of the "Real Time" data system. 10-0-0-90-0

10. JUSTIFICATION (WHY) Mass spectrometry in conjunction with the various chromatographic methods has been recognized as one of the most powerful tools in the study of biochemically interesting compounds. It is particularly powerful for the study of these compounds in geochemical and cosmochemical samples where these substances are present in minute amounts. These investigations are of importance not only from the standpoint of the search for the origin of life and its evolution to its present form, but also as an important aid in maintaining it through the control of pollution. In all of these investigations, mass spectrometry in general and high resolution mass spectrometry with computerized data systems in particular, are playing a major role. This development of advanced mass spectrometric technique and the understanding of the behavior of biochemically important compounds in a mass spectrometer is therefore of great significance.

11. Main Achievements (Significant Progress) The previously developed techniques for the identification and characterization of carotenoids and porphyrins have been employed successfully in the study of several geochemical samples (Antarctica and Nonesuch Shale) which has led to the discovery of a variety of previously unreported compounds. Great progress has been made in the understanding of the ionization and fragmentation processes of the three classes of pigments and the related glucosides. Many compounds have been added to our reference library of mass spectra. The delivery and installation of the Real Time data system hardware has been completed. The adaptation of existing software to the new system and the generation of new routines specifically for the Real Time/ON-line operation have progressed to a point where routine operation will be in existence during the last quarter of FY'72. This will make studies in analytical mass spectrometry as well as our support of other bioscience activities, such as geochemical research, life detection experiments, analytical pyrolysis, and development of GC techniques, much more efficient.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56331-0-8260	N/A	192-55-63-35-55

5. TITLE

ADVANCED TECHNIQUES IN ORGANIC ANALYSIS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Simmonds, Peter G.	PRINCIPAL INVESTIGATOR: N/A
TELEPHONE: 213 - 354 -6456	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	81	
CURRENT FY 73 (c)	89	
NEXT FY 74 (c)	94	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The extraction of organic matter from soils and other geochemical samples is being investigated from the standpoint of developing an organic analysis scheme which could subsequently be included in an automated chemical processor for advanced GC-MS instruments and/or other detection systems. Of particular interest is the efficiency and selectivity of various solvents in the extraction of organic matter from an inorganic matrix. Since ease of removal of solvents is of primary importance, particular attention will be given to solvents of high volatility. The possibility of converting certain solvents to gases which can easily be removed will also be investigated. Emphasis will be placed on solvents which are selective for lipids; and single step derivatization methods will be explored to develop derivatives which are specific for high sensitivity electron capture detection systems. 10-0-0-90-0

10. JUSTIFICATION (WHY) Future exploration of the surface chemistry of other planets will require development of sophisticated methods of soil sample preparation to derive maximum benefit from the analytical instrumentation. Wet chemical extraction and the preparation of derivatives for high sensitivity detectors are two useful methods for determining the presence of trace organic constituents of potential biological interest.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) Comparative extractions of soils with solutions of 6 N HCl and formic acid indicates that formic acid is as effective as HCl for removing organic matter from the mineral matrix. Furthermore formic acid does not solubilize as much inorganic salt as does the HCl. A detailed investigation of the organic matter extracted by the formic acid is now in progress. A novel acetylating agent, bistrifluoromethyl ketene has been successfully used to quantiatively derivatize amino and hydroxyl groups. The reagent may be particularly useful for automated chemical reactors, since it is a gas and reacts by addition without the formation of any by-products.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56332-0-8260	N/A	192-55-63-36-55

5. TITLE

KEROGENS OF HARSH ENVIRONMENTAL SOILS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Bauman, A. J.	PRINCIPAL INVESTIGATOR: N/A
TELEPHONE: 213 - 354 - 6040	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	47	
CURRENT FY 73 (c)	68	
NEXT FY 74 (c)	65	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) Kerogens will be extracted from desert soils, rocks and meteorites in such a way as to minimize artifact formation. They will then be characterized, first by gel-permeation chromatography to isolate repeating units, then by instrumental means which yield structural chemical information. For example, isolation will be carried out by extraction with non-oxidizing trifluoromethylsulfonic acids, the polymer will be solvated with perfluoro solvents and then subjected to gamma radiation in order to cleave the weakest stretched bonds. Microwave-activated oxygen will also be used in conjunction with stereoscan electron microscopy to determine the degree of order of the semicrystalline polymers. After chromatography the fragments will be examined by means of NMR, by MS and possibly by GC following silylation. These studies should yield fundamental structural information on relatively unaltered kerogen fragments, unlike the conventional studies based on the myriad recombination reactions of pyrolysis.

10-0-0-90-0

10. JUSTIFICATION (WHY) Kerogens are cross-linked insoluble carbon polymer and comprise the great bulk (ca. 90%) of organic matter in meteorites, terrestrial rocks and soils of all ages. Post-Viking landers will thus, by analogy, be dealing mostly with kerogens in their chemical studies of planetary surfaces. The kerogens represent a sort of "sink" of the most resistant residues of life in the soil and thus one should find them present if life had ever existed in a particular soil. By exploring non-destructive extraction procedures and chromatographic resolution procedures, this work should complement all lander chemical experiments.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) We have begun by attempting to dissolve mechanically isolated Nonesuch and Green River Shale kerogens in liquid ammonia. Kerogens of several types will be characterized. We have also isolated kerogens from the Orgeuil, Murchison and Allende chondrites and studies of their solubility and oxidative DTA behavior are under way. Stereoscan electron microscopy has shown that these meteorite kerogens are present in the form of spherical particles about 1000Å in diameter.

124

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		43	192-55-64

5. TITLE
BIOLOGICAL ADAPTATIONS

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002600, 010100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 -3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 1973

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The results from the study of the ecology and biochemistry of organisms which can survive and grow in extreme environments is important for planning and interpreting the results of planetary biology experiments. One area of study in this task is the ecology of microorganisms that exist in extreme environments, especially desert soils. The desert soils of Antarctica constitute our best model of Martian ecology. By studying the ecology of the microorganisms and their enzymes, a better understanding of the survival and growth of life in such environments can be obtained. The current work continues microbial, physical, and chemical analyses of soils and microbial isolants from harsh environments, viz., the Antarctic dry valleys, Transantarctic Mts., and from Don Juan Pond. Measurements of metabolic activities will be continued on soils recently collected in Antarctica. Based on relationships between the occurrence of organisms and environmental factors established in our field work and recent MM'71 results, an attempt will be made to develop descriptive criteria for selection of the most promising areas to search for active or past biology on Mars.

Because of the aridity of Mars, it is appropriate to investigate halophilic microorganisms since they are uniquely adapted to an environment of limiting water. The two proposed areas are under study with the halophiles: the characterization of intracellular enzymes and the mechanisms for uptake of extracellular substrates. Understanding these processes may provide some insight as to how Martian life-forms perform metabolic transformations in the arid environment.

13. KEYWORDS
Life Detection, Enzymes, Antarctic, Ecology, Halophile

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

The basic long-range program in microbiology and biochemistry which is in progress at JPL is providing results which are directly related to the establishment of proper mission objectives, good experimental design, proper flight data interpretation, lander site selection, and definition of quarantine requirements. In preparation for the Viking mission special emphasis has been directed toward characterization and understanding terrestrially occurring harsh environments. The best models of the presumed Martian environment are the cold, dry, barren areas of the Antarctic. Studies of these areas and other less extreme terrestrial environments are yielding significant new information on the environmental extremes which terrestrial microbiota will withstand and the relationships between occurrence of organisms and environmental parameters which should allow definition of criteria for favorable lander site selection.

Available data indicate that Mars is a desert with little water. Halophilic microorganisms have adapted to a water-limited existence so they are conceivable candidates for Martian life forms and appropriate organisms for laboratory studies relating to Martian life detection experiments. Studies directed to the characterization of intracellular enzymes and the detailed elaboration of the biochemical mechanisms for uptake of extracellular substrates by these microorganisms are necessary so that insight can be established on how a Martian life-form might perform metabolic transformations in its arid environment. Subtle differences in enzyme structure between species and/or various strains are one of the primary reasons many organisms can adapt to a variety of environments. An understanding of this adaptation can be achieved by defining the physical and chemical properties of the important enzymes. A specific model for a Martian organism has been chosen and studies are in progress which should establish a better understanding of how microorganisms assimilate metabolites from an arid environment.

15. TECHNICAL PLAN

A. Objectives

The objectives of this program are to:

1. Improve understanding of the ecology of microorganisms that exist in extreme environments, especially desert soils.

2. Improve our understanding of the mechanisms by which halophilic microorganisms adapt to environments of limiting water.

3. Continue to apply the results of the above studies to defining new biological experiments for planetary missions.

B. Technical Approach

Field trips during the past austral summer were concurrent with studies conducted by the dry valley drilling team in Wright, Taylor, and Victoria Valleys. Sixteen soil samples were collected aseptically from nine sites. Air samples were collected for bacterial contamination. Additional samples of soil and water were collected from the

unique calcium chloride environment at Don Juan Pond and similar salt ponds in Wright and Taylor Valleys. Two permafrost samples were collected from Matterhorn Valley.

The current plans are to continue analyzing soils and microbial isolants from harsh environments, especially the Antarctic dry valleys and Transantarctic Mts., which have been collected during 1972 and earlier field trips. Microbial tests will be used to identify organisms on the basis of broad classification. Physical and chemical tests will be performed to correlate the results of the microbiological tests with the ecology. Aerial monitoring has been undertaken and samples collected at Antarctic dry valley drilling sites. Samples are being analyzed to determine the presence of aerial contamination bacteria. Selected soil and water samples will also be tested by a metabolic assay in which samples are incubated with ^{14}C-glucose and ^{14}C-amino acids and the evolution of $^{14}CO_2$ is measured. Previous use of this method has suggested that some Antarctic soils contain higher levels of active metabolic enzymes than would be expected on the basis of cultural determinations.

Past studies in Antarctica and other harsh environments have sought to correlate the microbial abundances and diversity with climatic, topographic and geological features. Based on this knowledge the favorability of an ecosystem to support a microbial ecology can be predicted. The MM'71 television and other experiments have shown many geologic features on the surface of Mars. It is probable that similar criteria can be used for selection of a favorable ecosystem in the extreme environm ents of Earth and on Mars since the two major factors on either planet for the limitation of biology will be the low temperatures and the paucity of water. A small effort will be directed toward formulating a predictive Martian biomodel, i.e., which areas on Mars would be most favorable for life in the past or present. Such information may be useful in definition of preferred landing sites for future missions to Mars.

One current theory on the dependence of halophilic enzymes on low water activity is based on the assumption that these proteins have intramolecular, repulsive charges. Salts are presumed to neutralize these charges and thereby maintain the protein in its active conformation. However, this theory is not supported by our studies on salt specificity and our findings that non-ionic substances can replace salts in maintaining the cative conformation of an halophilic isocitrate dehydrogenase. Another theory is that halophilic proteins have intramolecular hydrophobic areas which must be protected in order to maintain the active conformation. Again, this theory was not supported on the basis of the ion specificity in stabilizing the isocitrate dehydrogenase. Thermodynamic analysis of the reversible inactivation induced by low ionic strength or chemical denaturants indicated that a high-salt environment is required to maintain the proper solubilization of the enzyme. Examination of the primary structure of the purified protein by amino acid analysis provided a molecular basis for this theory, viz., an excess of acidic amino acids in the protein accounts for its polarity.

Since it appears that a complete understanding of the molecular basis for this adaptation will involve in-depth studies in protein chemistry, further work on this isocitrate dehydrogenase will not be pursued at this time.

Preliminary characterization has been made on the glutamine synthetase from Ectothiorhodospira halophila, an anerobic, photosynthetic halophile. This enzyme also undergoes a reversible inactivation which is mediated by the presence or absence of the high salt environment. The glutamine synthetase and isocitrate dehydrogenase proteins are quite different in respect to their origin, catalytic function, molecular weight and subunit structure. It will be determined if the theories formulated in studies with isocitrate dehydrogenase are valid for other halophilic proteins of diverse properties. These studies will encompass the salt-mediated reversible-inactivation, conformation changes during inactivation, salt specificity for stabilization of enzyme activity and inactivation with chemical denaturants. If the glutamine synthetase can be completely purified, its amino acid composition and α-helix structure will be determined.

Preliminary studies have also been conducted on the uptake of extracellular substrates by E. halophila. Kinetic measurements on uptake of ^{14}C-glutamic acid indicated that the amino acid enters the cell by passive diffusion. Other bacteria have energy dependent systems for concentrative uptake of this amino acid. Additional studies on uptake of a variety of substrates will be made and the influence of the high salt environment will be examined.

16. REVIEW and REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

Work in this program has resulted in nine literature publications during the past year.

17. PUBLICATIONS

A. Journal Articles

1. Cameron, R. E., Antarctic Soil Microbial and Ecological Investigations. In Quam, L. O. and H. D. Porter, eds. pp. 137-189 (1971). AAAS Publ. No. 93, Wash., D. C.

2. Cameron, R. E., G. H. Lacy, F. A. Morelli, and J. B. Marsh, Farthest South Soil Microbial and Ecological Investigations. Antarctic J. of the U.S. 6(4), 105-106 (1971).

3. Cameron, R. E., H. P. Conrow, D. R. Gensel, G. H. Lacy, and F. A. Morelli, Surface Distribution of Microorganisms in Antarctic Dry Valley Soils: A Martian Analog. Antarctic J. of the U.S. 6(5), 211-213 (1971).

4. Wulff, K., J. S. Hubbard and A. B. Miller, Reversible Inactivation of the Isocitrate Dehydrogenase from an Obligate Halophile: Changes in the Secondary Structure. Arch. Biochem. Biophys, 148 318-319 (1972).

5. Cameron, R. E., North American Desert. Encyclopaedia Britannica, In Press, 1972.

6. Cameron, R. E., Ecology of Blue-green Algae in Antarctic Soils. Proc. of the First International Symp on Taxonomy and Biology of Blue-green Algae, Univ. of Madras, Madras, India. January 1970. In Press.

7. Cameron, R. E. and R. E. Benoit. Microbial and Ecological Investigations in Victoria Dry Valley, Southern Victoria Land, Antarctica. In G. A. Llano, ed., Antarctic Terrestrial Ecology. Amer. Geophys. Union. In Press.

8. Cameron, R. E., Conservation and Pollution of the Antarctic Terrestrial Ecosystem. In Parker, B. ed., Conservation Problems of Antarctica and Circumpolar Water, Allen Press. In Press.

9. Horowitz, N. H., R. E. Cameron and J. S. Hubbard, Microbiology of the Dry Valleys of Antarctica, Science. In Press.

10. Cameron, R. E., Application of Low Latitude Microbial Ecology to High Latitude Deserts. In T. A. Smiley, ed., Proc. of the Symposium, Polar Deserts, Philadelphia, Pa., 1971. AAAS and Univ. of Arizona Press, Tucson. In Press.

B. Meetings and Symposia

1. Hubbard, J. S. and A. B. Miller, Conformational Changes During the Reversible Inactivation of a Halophilic Isocitrate Dehydrogenase. Bacteriol. Proc., Abstract, p. 128 (1971).

2. Horowitz, N. H. and R. E. Cameron, Microbiology of the Dry Valleys of Antarctica. Abst. p. 253. Comm. Space Res., Intern. Counc. Sci. Unions. 14th Plenary Meeting, Seattle, Wash. (1971).

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	192-55-64	BIOLOGICAL ADAPTATION	6 OF 6

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
DIRECT PROFESSIONAL	1.9	2.9			
DIRECT SUPPORT	0.7	-			
TOTAL DIRECT MAN YEARS	2.6	2.9			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	120	120			
TOTAL FUNDS	120	120			

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56403-0-8260	N/A	192-55-64-03-55

5. TITLE

MICROBIOLOGY (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Hubbard, J.S.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 5526	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	57	
CURRENT FY 73(c)	61	
NEXT FY 74(c)	60	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

Further purification will be performed on an enzyme (glutamine synthetase) from an anaerobic, photosynthetic halophile (Ectothiorhodospira halophila). The salt-mediated, reversible inactivation of this enzyme will be examined to determine if the theories developed in previous investigations with the isocitrate dehydrogenase from Halobacterium cutirubrum are valid for other halophilic proteins. Also to be examined are the effects of the high salt environment on the regulation of the glutamine synthetase and on the mechanisms for a nutrient uptake by E. halophila. Measurements of metabolic activities will be made on the highly saline soils and water samples collected from Don Juan Pond in Antarctica.

10. JUSTIFICATION (WHY)

Since Mars is a desert, it is appropriate to investigate halophilic microorganisms since they are uniquely adapted to an environment of limiting water. The study of these adaptations can best be approached by defining their molecular bases. The two proposed areas of study with the halophiles are the characterization of intracellular enzymes and mechanisms for uptake of extracellular substrates. Understanding these processes may provide some insight as to how Martian life-forms perform metabolic transformations in the arid environment. Studies on the microorganisms from the dry valleys of Antarctica may also provide a useful model for Martian organisms.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

In FY 72, characterization was completed on an enzyme, isocitrate dehydrogenase, from an obligately halophilic bacterium, H. cutirubrum. Thermodynamic analysis of the reversible inactivation induced by low ionic strength or chemical denaturants indicated that a high-salt environment is required to maintain the proper solubilization of the enzyme. Examination of the primary structure of the purified protein by amino acid analysis provided a molecular basis for this theory, viz., an excess of acidic amino acids in the protein accounts for its polarity. The glutamine synthetase from E. halophila was partially purified and preliminary studies were performed on its salt-dependent, reversible inactivation. Studies with Antarctic soils indicated that surface samples may contain entities which are metabolically active but non-viable.

131

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-56401-0-8260	N/A	192-55-64-01-55

5. TITLE

MICROBIAL ECOLOGY IN HARSH ENVIRONMENTS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
	CONTRACT NO.
	CONTRACT START DATE
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Cameron, R.E.	PRINCIPAL INVESTIGATOR: N/A
TELEPHONE: 213 - 354 - 3339	TELEPHONE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	64	
CURRENT FY 73(c)	59	
NEXT FY 74(c)	60	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The main objective of this task is to study the ecology of microorganisms that exist in extreme environments, especially desert soils. The current plans are to continue analyzing soils and microbial isolants from harsh environments, especially the Antarctic dry valleys and Transantarctic Mts., which have been collected during 1972 and earlier field trips. At the present time, all soil, snow, and some microbial air samples are stored at -30°C at JPL. Approximately two thirds of the samples have been processed and analyzed following the latest acquisition of samples. Microbial tests will be used to identify organisms on the basis of broad classification. Physical and chemical tests will be performed to correlate the results of the microbiological tests with the ecology. Aerial monitoring are has been undertaken and samples collected at Antarctic dry valley drilling sites. Samples are being analyzed to determine the presence of aerial contamination bacteria. A small fraction of the work will be devoted to desert areas other than the Antarctic. Based on relationships between the occurrence of organisms and environmental factors established in our extensive field studies of harsh environments and recent MM'71 results, an attempt will be made to develop some descriptive criteria for selection of promising Martian sites to search for active or past biology.

10. JUSTIFICATION (WHY) The basis for this task is that naturally occurring harsh terrestrial environments, especially the cold, dry, barren regions of the Antarctic, represent the best approach to investigating a model Martian ecology, if it exists. From studies of ecological factors in harch environments, including the non-biotic environment and its information is obtained on environmental limitations placed upon terrestrial microbiota. This information can then be applied to planning Martian life detection experiments and spacecraft sterilization requirements. Soil samples, microbial isolants and analytical data have been given to various NASA experimenters. This work is not being duplicated elsewhere in NASA or other agencies.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) Field trips during the past austral summer were concurrent with studies conducted by the dry valley drilling team in Wright, Taylor and Victoria Valleys. Sixteen soil samples were collected aseptically from nine sites. Forty air samples were collected for bacterial contamination. Additional samples of soil and water were collected from the unique calcium chloride environment at Don Juan Pond and similar salt ponds in Wright and Taylor Valleys. Two permafrost samples were collected from Matterhorn Valley. One-hundred fifty Antarctic and other desert bacterial isolants have been identified.

132

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		43	192-55-65

5. TITLE
BIOINSTRUMENTATION

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
012100, 002200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

In this task a major effort will be made to develop fully wet chemical analytical techniques and instrumentation needed to insure the successful conversion of potential post-1976 candidate experiments for detection of active biology and biomolecules into flight experiments. It is expected that such experiments will be proposed by extra-JPL NASA-supported scientists and might be expected to originate from several SRT tasks presently in progress at JPL. Careful attention will be given to means by which the existing Viking GC/MS technology can be incorporated into these future potential flight experiments involving wet chemical front ends and atmospheric trace constituent analysis schemes. Every attempt will be made in this task to bring together the scientific investigator and the development engineer early in the conceptual phase of potential experiments. By making careful engineering evaluations and supplying appropriate engineering support at an early stage, alternatives which will lead to more feasible automation and remote data acquisition should be implemented. Such a strategy can be expected to result in a more ready development of a scientific concept into a scientific breadboard or engineering prototype stage than has traditionally taken place.

13. KEYWORDS
Life Detection, Organic Chemistry, Gas Chromatography, Mass Spectrometry, Automation

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

A major scientific objective for investigation by future landed planetary instruments is the detailed analysis of the chemistry and biology of the surface and subsurface layers of Mars. The analysis to be performed by the Viking GC/MS is essentially a survey type of organic analysis. Thermal release of volatiles and thermal degradation (pyrolysis) of less volatile organics are the mechanisms by which the organic content is to be freed from the soil matrix. Based on the hope that some organic matter is detected by Viking on Mars, more sophisticated isolation and analysis schemes are being considered for future missions. Development of instrumentation to perform these necessarily more complex experiments must be started. Although groups funded by NASA are currently engaged in developing instrumentation for post-Viking missions to analyze soil samples for amino acids, the state-of-the-art of such wet chemical instrumentation is not well advanced. The bioinstrumentation task will attempt to remedy this situation by supporting, as appropriate, existing instrument development activities at other NASA centers and of other NASA-supported scientists besides providing instrument development support for promising scientific concepts originating in JPL SRT programs.

15. TECHNICAL PLAN OBJECTIVES AND TECHNICAL APPROACH

A. Objectives

The FY'73 objectives are given below:

1. Work will be continued on consideration of the feasibility of sensitive electron capture GC detectors (i.e., 10^{-14} moles/ml) for organic derivatives containing halogens or other second row elements. In support of this activity we are funding Dr. James Lovelock on a consulting and small contract basis.

2. Carry out high resolution MS spectral studies of several classes of volatile derivatives of amino acids and with this data perform spectral file search tests with the mass peaks below 200 to determine whether a Viking-type MS system, which has a mass range of 200, can be utilized to achieve unambiguous chemical identifications.

3. Continue GC tests of the amino acid N-trifluoroacetyl-1-2-butyl esters and other volatile derivatives in a system with a hydrogen-generator separator which is similar to that in the Viking GC/MS system.

4. One of the unit operations in any wet chemical processing scheme, which has in general not received sufficient attention previously, is small scale devices for the evaporation and concentration of extracts. Development of some devices for this operation will be carried out with consideration of their interface to an extraction scheme and to a GC system.

5. Achieve a detailed understanding and maintain an awareness of the status of the NASA-Ames amino acid analysis experiment; continue close cooperation with Glen Pollock at Ames with the purpose of collaborating in solution of basic problems related to this experiment in areas where JPL has unique expertise.

6. Carry out specific device development and engineering assistance for several current bioscience tasks at JPL which are concerned with conception of new or improved life detection experiments. It is apparent that there is need in several of these tasks for engineering support to automate measuring devices and control systems to test realistically certain concepts so that extrapolation to automated flight-type experiments can be made. Hopefully such an approach will allow early recognition of processes and situations which it may not be feasible to automate.

7. Carry out further work on the development of electrophoresis techniques as a means of separation of inorganic ions from amino acids and other organics in soil extracts.

8. In collaboration with Stanley Miller at UCSD consider the feasibility of a UV photometer for detection of nucleotide bases separated in a column chromatography, wet chemical separation scheme.

9. Continue work utilizing precolumn/back flush techniques to overcome for advance missions the inorganic gas overload system weakness existing with current Viking GC/MS instrument concept.

Longer term objectives are:

1. Seek new and further develop techniques for wet chemical analysis by automating extraction and isolation methods for removing organic materials from soils, for automating subsequent physical and chemical treatments of extracts and for automating final physical measurement methods. Because the development of automated wet chemical systems is not well advanced, a variety of concepts and unit operations will be evaluated and it is expected some will be implemented through to device stage for realistic testing and evaluation.

2. Explore and develop means for interfacing a Viking-type GC/MS system to any potential life-detection or wet chemical analytical experiment or combination of experiments and for overcoming the inorganic gas overload problems of the latter instrument.

3. Carry out, as appropriate, instrumental and system design studies and development of any potential life-detection or wet chemical analytical experiments suggested by results or needs from JPL SRT tasks, other NASA-supported scientists and the general scientific community.

B. Technical Approach

In previous years this task was concerned with development of advanced GC/MS technology. A change in direction from this area to the bioinstrumentation and wet chemical areas occurred during F Y'72. Prior to this change, several significant items of technology in the GC/MS area were finished and are being published.

Work on palladium-hydrogen separator interfaces in the GC/MS systems led to the development of a simple palladium-silver hydrogenator for gas phase hydrogenation. This device has potential application in analytical and synthetic continuous gas phase hydrogenation. A single gas chromatographic system that employs a palladium transmodulator has been developed for accurate

analysis of permanent gases and with a sensitivity of parts per 10^{-6} by volume. This device has potential application for planetary atmospheric analysis of both rare gases and trace constituents of biological interest.

Initial work in the new bioinstrumentation area has involved study and analysis of existing data on wet chemical procedures for amino acid analysis. Preliminary work on the application of electrophoresis techniques to separation of inorganic ions from amino acids has been carried out. In some cases the degree of separation ranged from 50-95% for removal if iron and 50-97% for removal of aluminum from amino acid extracts. Work is now in progress to generate an instrument delivery schedule which could serve as a guide as to how soon potential experimenters must have in hand their scientific concepts and strategies to define experiment specification for an advanced mission. Computer programs to allow mass spectral file search exercises in any particular mass range have been generated and will be used to analyze data on various classes of volatile derivatives.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when required.

17. PUBLICATIONS

A. Journal Articles

J. E. Lovelock, P. G. Simmonds, and G. R. Shoemake, "Rare Gases of the Atmosphere: Gas Chromatography Using a Thermal Conductivity Detector and a Palladium Transmodulator", Anal. Chem., **43**, 1958, (1972).

P. G. Simmonds and C. F. Smith, "A Novel Type of Hydrogenator", Anal. Chem., **44**, in press, (1972).

B. Meetings and Symposia

C. E. Giffin, G. R. Shoemake, P. G. Simmonds, and M. R. Stevens, "A Portable, Self-sustained Gas Chromatograph", Abstracts, Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, Cleveland, Ohio, Paper 106, March 7, 1972.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15-04-72	192-55-65	BIOINSTRUMENTATION	OF

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
DIRECT PROFESSIONAL	3.5	3.0			
DIRECT SUPPORT	1.0	0.4			
TOTAL DIRECT MAN YEARS	4.5	3.4			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS	10	10	10		
IN-HOUSE SUPPORT	190	195	190		
TOTAL FUNDS	200	205	200		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	604-5653 -0-8260	N/A	192-55-65-35-55

5. TITLE

BIOINSTRUMENTATION (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Manatt, S.L.

TELEPHONE: 213 - 354 - 3227

7. CONTRACTOR (IF APPLICABLE)

NAME: Brazzos, Ltd. (J. Lovelock) Bowerchalke Nr. Salisbury England

CONTRACT NO.: Pending

CONTRACT START DATE:

ADDRESS:

PRINCIPAL INVESTIGATOR: N/A

TELEPHONE:

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (¢)	190	10
CURRENT FY 73 (¢)	195	10
NEXT FY 74 (¢)	300	10

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The objectives of this task are to develop fully wet chemical analytical techniques and instrumentation necessary to support several potential post-1975 biological exploration experiments proposed by several extra-JPL NASA-supported scientists expected to originate from several present JPL SRT tasks and originating in the future from other extra- NASA scientists. Also analysis on how a Viking-type GC/MS system will interface with any proposed experiments is being made. Because the state-of-the-art in automated wet chemical analytical systems is not well advanced, a variety of concepts will be pursued from both scientific standpoints and engineering standpoints. A variety of concepts will be implemented through to the device and data acquisition stage for realistic testing and evaluation.

10. Justification (Why) A major scientific objective for investigation by post-1975 Mars missions is the detailed analyses of the chemistry, especially the organic constituents, of the surface and subsurface layer of the planet. To accomplish this goal, it now appears that automation of a wet chemical soil extraction procedure coupled with an automated GC/MS system is scientifically the most informative and sensitive approach. Because the state-of-the-art in automated wet chemical systems interfacing to GC/MS systems is not well advanced, this task seeks to apply sound scientific and engineering principles to the development and testing of improved and novel devices for the various unit chemical operations and interfaces which compose any candidate wet chemical analytical schemes. This task will be closely coordinated with other on-going bioscience tasks at JPL and basic research being conducted at other NASA centers and NASA-supported research at other institutions.

11. Main Achievements (Significant Progress) In previous years this task has been concerned with development of advanced GC/MS technology. A change in direction from this area to the bioinstrumentation and wet chemical areas occurred during FY'72. Prior to this change, several significant items of technology in the GC/MS area were finished up and are being published. Work on palladium-hydrogen separator interfaces in the GC/MS systems led to the development of a simple palladium-silver hydrogenator for gas phase hydrogenation. This component has potential application in analytical and synthetic continuous gas phase hydrogenation. A single gas chromatographic system employing a palladium transmodulator for accurate analysis of permanent gases and with a sensitivity of parts per 10^{-6} by volume level has been developed. This device has potential application for planetary atmospheric analysis of both rare gases and trace constituents of biological interest. Initial work in the new bioinstrumentation area has involved study and analysis of existing data on wet chemical procedures for amino acid analysis. Preliminary work on the application of electrophoresis techniques to separation of inorganic ions from amino acids has been carried out. In some cases the degree of separation ranged from 50-95% for removal of iron and 50-97% for removal of aluminum from amino acids.

138

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		42	195-42-55

5. TITLE
GEOLOGY AND MINERALOGY

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
006800, 007100, 013900

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The Geology and Mineralogy program is a coordinated group of researches directed at understanding the surface and subsurface properties of the Moon, the evolutionary history of this body and its relation to the origin of the solar system. The specific tasks involved are:

1. Analysis of lunar gravity and associated lunar structures.
2. Analysis of electromagnetic techniques for lunar interior exploration.
3. Thermal and thermoelastic histories of the body, based on previous investigations of lunar thermal history.
4. Investigations of thermal deformation as a mechanism for modification of lunar surface features.
5. Studies of the reflectance and radiative properties of rocks and rock-forming minerals, and their use in interpretation of telescopic and spacecraft observations.
6. Irradiation of known composition targets to observe induced gamma ray spectra as a supplement to interpretation of Apollo 15 and 16 gamma ray spectroscopy data.
7. Study of the relation between lunar surface rock (or particulate) sizes and radar back scattered energy, using by-product data from the Apollo Lunar Sounder Experiment.
8. Produce a radar map of the Moon at 7.5 m wavelength from data previously obtained at Arecibo Observatory.
9. Obtain new magnetic resonance data on terrestrial and meteorite, as well as lunar samples, to further our basic understanding of the nature of lunar materials.

13. KEYWORDS
Moon, Lunar Geology, Mineralogy, Geochemistry, Gamma Ray Spectroscopy

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rea ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

This research provides direct geological, geophysical and geochemical support for ground based lunar science studies and spacecraft missions. It contributes to the definition of scientific objectives, mission objectives and rationale, and experiment design and definition, as well as data analysis and interpretation for experiments already conducted.

15. OPERATING PLAN

A. Objectives

The Geology and Mineralogy task (subtasks 1 through 5 listed above) is a coordinated program of experimental and theoretical research directed towards understanding the surface and subsurface properties of the Moon, evolutionary history of that body and the relation of its origin to that of the Earth and other terrestrial planets.

The objective of the Gamma Ray and X-Ray Spectroscopy task is to determine the abundance and distribution of important radioactive cosmic-ray excited isotopes on the lunar surface using gamma-ray spectroscopy in order to understand the origin of the Moon and the processes which have distinguished the areas of differing gamma ray response.

The objective of the Microwave Surface Properties task is to determine the relation between radar back scattered energy and sizes of scatterers on the lunar surface; then to correlate ALSE data to surface roughness and achieve a mapping of the Moon in terms of roughness characteristics.

A radar map at 7.5 m wavelength with resolution ten times better than those previously achieved at this wavelength is the objective of the Arecibo Data Reduction task.

Magnetic Resonance Studies of Geological Samples has as its objective the provision of new magnetic resonance data on both terrestrial and nonterrestrial samples, in order to further fundamental understanding of the nature of the nonterrestrial samples and their spectra.

B. Technical Approach

The Geology and Mineralogy task for FY 72 will consist of (1) analysis of lunar gravity and associated lunar structures, (2) analysis of electromagnetic techniques for lunar interior exploration, (3) thermal and thermoelastic histories of the body, based on previous investigations of lunar thermal history, (4) investigations of thermal deformation as a mechanism for modification of lunar surface features, and (5) studies of the reflectance and radiative properties of rocks and rock-forming minerals, and their use in interpretation of telescopic and spacecraft observations.

In the Gamma Ray and X-Ray Spectroscopy task the following efforts will be undertaken: (1) Activities will be resumed at the University of California's Bevatron. An experiment area with a much lower background than that for the original set of tests has been assigned for the experiment. The first steps will be to check equipment and system operation and determine the characteristics of the background. (2) A program of thick target irradiations will be undertaken using an NaI scintillation detector. Among the targets will be Fe and possibly also dunite, materials which have been employed in balloon altitude cosmic ray irradiations in which the gamma ray flux was measured. A source of lower energy protons will be sought to simulate the effective solar flare cosmic ray flux which is predominantly protons in the 20-100 MeV range. (3) A set of tests will be performed with a flight model of the Apollo gamma-ray spectrometer, possible with additional targets peculiar to lunar models. (4) The irradiation program will be repeated using an available solid-state detector with an energy resolution approximately 30 times better than the scintillation detector. Line to continuum ratios will be greatly improved. (5) Theoretical models, particularly the one under development at UCSD, will be evaluated in the light of the experimental data.

FY 72 effort in the Microwave Surface Properties task will be as follows: (1) Continue the theoretical description of the relation between the back scatter energy and a surface of scatterers with random sizes that has been partially developed under previous Microwave Surface Properties Studies. (2) Perform correlation on Lunar Sounder data and convert the relative signal strength to surface roughness. (3) Map the roughness units and compare with photographic data.

The Arecibo Data Reduction task will produce a radar map of the Moon at a wavelength of 7.5 m, the longest wavelength used in mapping lunar radar echoes. The task will reduce data already obtained from observations at Arecibo Observatory. Radar maps of the Moon at 7.5 m wavelength are produced by combining delay-Doppler mapping with interferometry (Thompson, 1970). The framework for this data reduction task is the programs that have been used in the previous mapping at 7.5 m. Some modifications will be needed because of the much better resolution of the unmapped data.

Under the task, Magnetic Resonance Studies of Geological Samples, studies will be carried out with electron spin resonance (ESR) and nuclear magnetic resonance (NMR) techniques of ferromagnetic phases (α-Fe_2O_3, $FeTiO_3$, and $FeSiO_3$) paramagnetic species (Ti^{3+}, Cr^{3+}, Mn^{2+}, and Fe^{3+}), diamagnetic species (^1H, ^{19}F, ^{27}Al, and ^{29}Si), radiation damage centers (free radicals) of appropriate geological samples. It is also proposed to further explore the use of ESR and NMR techniques in geological and mineralogical studies.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

Head, J. W., and A. F. H. Goetz, Descartes Region: Evidence for Copernican Age Volcanism. Jour. Geophys. Res. 77, 1368-1374(1972).

Phillips, R. J. The Lunar Conductivity Profile and the Uniqueness of Electromagnetic Data Inversion. In Press, Icarus(1972).

Blinn, J. C. III, J. E. Conel, and J. G. Quade. Microwave Emission from Geological Materials: Observations of Interference Effects. In Press, Jour. Geophys. Res.(1972).

Yost, E., A. F. H. Goetz, and R. Anderson. Isoluminous Additive Color Method for Detection of Small Spectral Reflectivity Differences. Submitted to Photo. Science and Engineering(1972).

Fanale, F. P., W. A. Cannon, and D. B. Nash. Surface Area of Lunar Fines and Terrestrial Rock Powders. Jour. Geophys. Res. 76, 6459-6461(1971).

Nash, D. B., J. E. Conel, and F. P. Fanale. Scientific Objectives of Unmanned Rover Exploration of the Moon. The Moon, 3, 221-230(1971).

Metzger, A. E., "Gamma-Ray Spectrometer Experiment," MSC Apollo 15 Preliminary Science Report, 1971.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	195-42-55	GEOLOGY AND MINERALOGY	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL	4.8	5.1	6.5		
DIRECT SUPPORT	0.9	0.9	1.5		
TOTAL DIRECT MAN YEARS	5.7	6.0	8.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	289	310	418		
TOTAL FUNDS	289	310	418		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	605-25501-0-8260	N/A	195-42-55-01-55

5. TITLE

GEOLOGY AND MINERALOGY (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: James E. Conel	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 -4516	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	196	
CURRENT FY 73(c)	187	
NEXT FY 74(c)	200	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 50-0-0-50-0

The Geology and Mineralogy study is a coordinated program of experimental and theoretical research directed towards understanding the surface and subsurface properties of the moon, the evolutionary history of that body, and the relation of its origin to that of the earth and other terrestrial planets. The tasks consist of (1) analysis of lunar gravity and associated lunar structures, (2) analysis of electromagnetic techniques for lunar interior exploration, (3) thermal and thermoelastic histories of the body, based on previous investigations of lunar thermal history, (4) investigations of thermal deformation as a mechanism for modification of lunar surface features, (5) studies of the reflectance and radiative properties of rocks and rock-forming minerals, and their use in interpretation of telescopic and spacecraft observations.

10. JUSTIFICATION (WHY)

This research provides direct geological, geophysical, and geochemical support for many types of lunar science missions and studies; it contributes to definition of scientific objectives, mission objectives, experiment design and to the data analysis and interpretation from a wide range of lunar science.

11. MAIN ACHIEVEMENTS

(1) All necessary soft-ware has been developed for direct analysis of orbital spacecraft tracking data in terms of "planetary" surface mass distributions. Analysis of Apollo 15 CSM data over Mare Serenitatis shows that only the "surface" mass distribution produces gravity effects like those observed. There is a striking correlation with wrinkle ridge patterns in the mare. A step-like basin fill model appears to fit the data best. (2) Analysis of techniques of electromagnetic data inversion currently in use has been made (R. J. Phillips, Icarus, in press). All estimates of lunar interior electrical conductivity are shown to be non-unique, except those for the two-shell model. All estimates of interior temperature properties of silicate rock glass prepared using a solar furnace in vacuum have been studied. Alkalai loss by volatilization may contribute significantly to darkening of (lunar) glass compared to other (closed system) glass preparation methods. (4) Thermal creep experiments with sand are again underway using carefully controlled containers. Aside from minor effects of compaction, thermal creep is shown to be a viable transport mechanism for certain geologic materials and slope conditions. (5) A study of microwave emission from layered silicates and associated interference phenomena has been submitted for publication in Journal of Geophysical Research.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	605-25611-0-8280	N/A	195-42-55-01-55

5. TITLE

GAMMA-RAY AND X-RAY SPECTROSCOPY (0)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Metzger, A. E.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 4017	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72 (c)	57	
CURRENT FY '73 (c)	35	
NEXT FY '74 (c)	50	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 20-0-20-40-20

The objective of this task is to develop and demonstrate the capability of gamma-ray spectroscopy to detect characteristic gamma radiation from long-lived radioactive decay as well as that induced by the interaction of high energy galactic and solar particle fluxes with the surface and/or atmospheres of lunar and planetary bodies. This will involve an understanding of the secondary production processes of neutron inelastic scattering, neutron capture, activation and direct nuclear reactions which lead to the gamma ray features.

High energy accelerator bombardments are planned to simulate the effects of cosmic rays in generating both line and continuum gamma radiation. The results will be compared with theoretical predictions of yields from the nuclear processes involved as well as balloon and spacecraft experimental data.

10. JUSTIFICATION (WHY)

Gamma-ray spectroscopy furnishes data on the elemental abundances of stellar, lunar and planetary surfaces and/or atmospheres by measuring the intensity and characteristic energy of radiation emitted between .05 and 10 MeV. The chemical composition of lunar and planetary surface layers is indicative of their bulk composition and thermal evolution and so bears directly on the origin and evolution of the solar system. The proposed program is designed to supplement the interpretation of Apollo 15 and 16 gamma-ray spectroscopy data by referencing observed yields to the known composition of target materials. A separate series of experiments will determine the improvement in sensitivity to be obtained from an experimental system having better energy resolution than that of the Apollo instrument.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Apollo 15 carried a successful gamma-ray spectroscopy experiment. The same instrument will be flown on Apollo 16. Additional experimental data is already available from two balloon flights with iron and dunite as the target materials as well as a preliminary accelerator bombardment. Reedy and Arnold of UCSD have developed a comprehensive theoretical model of induced gamma ray emission.

195

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	605-25504-0-8230	N/A	195-42-55-01-55

5. TITLE

Microwave Surface Properties (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Brown, W. E., Jr.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 2110	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	35	
CURRENT FY 73 (c)	35	
NEXT FY 74 (c)	100	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 57-00-43-00-00

A study of the relation between surface rock (or particulate) sizes and radar backscattered energy will be conducted. The Apollo Lunar Sounder Experiment (ALSE) is only concerned with the detection of subsurface layers or scatterers in the vertical profile mode of operation: there is no attempt to utilize the information about the surface areal response. The approach for this study will be to relate surface scatterer size to those ALSE signal amplitude characteristics that are measured as a byproduct in the Apollo Lunar Sounder Experiment (ALSE) data. Then the areal scatterer size distributions will be used to provide orthographic maps of the geological units so defined.

10. JUSTIFICATION (WHY)

The Lunar Sounder radar data will contain a significant amount of new and high resolution data about the distribution of fragment sizes at the surface and in the near surface (10 meter) zone. With the present ALSE data reduction plan, this information will be discarded so that subsurface layer data can be observed.

The relatively small effort described in this proposed RTOP coupled with the larger primary ALSE effort will convert the unused radar data into an improved understanding of the surface form or topography and provide for a more accurate geological categorization of the surface material.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Some theoretical work has been accomplished in the area of backscatter energy and distribution of particle sizes on previous task assignments for Microwave Surface Properties Studies. The results show that the procedures developed to date can be effective in making remote measurements of surface roughness or particulate sizes.

12. Technical Approach

1. Continue the theoretical description of the relation between the backscatter energy and a surface of scatterers with random sizes that has been partially developed under previous Microwave Surface Properties Studies.
2. Perform correlation on Lunar Sounder data and convert the relative signal strength to surface roughness.
3. Map the roughness units and compare with photographic data.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	605-	N/A	195-42-55-01-55

5. TITLE
MAGNETIC RESONANCE STUDIES OF GEOLOGICAL SAMPLES (N)

6. RESPONSIBLE NASA ORGANIZATION
NAME
JET PROPULSION LABORATORY
California Institute of Technology
ADDRESS
4800 Oak Grove Dr. / Pasadena, Calif. 91103
RESPONSIBLE INDIVIDUAL Cohen, E. A.
TELEPHONE 213 - 354 -2493

7. CONTRACTOR (IF APPLICABLE)
NAME
ADDRESS N/A
PRINCIPAL INVESTIGATOR
TELEPHONE

CONTRACT NO.
CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	18	
NEXT FY 74 (n)	50	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 2C-0-0-80-0

It is proposed to carry out studies with electron spin resonance (ESR) and nuclear magnetic resonance (NMR) techniques of ferromagnetic phases (α-Fe_2O_3, $FeTiO_3$, and $FeSiO_3$) paramagnetic species (Ti^{3+}, Cr^{3+}, Mn^{2+}, and Fe^{3+}), diamagnetic species (^1H, ^{19}F, ^{27}Al, and ^{29}Si), radiation damage centers (free radicals) of appropriate geological samples. The main objective is to provide new magnetic resonance data which will lead to fundamental understanding of the nature of non-terrestrial samples and their spectra. It is also proposed to further explore the use of ESR and NMR techniques in geological and mineralogical studies.

10. JUSTIFICATION (WHY) The presence of various ferromagnetic, paramagnetic, diamagnetic, and radiation damage centers and their chemical environments as well, which are the results of thermal, radiation, and meteoritic impact effects on the lunar surface, can all be studied in detail by ESR and NMR techniques. Therefore, the results of our proposed studies should provide new information concerning the nature of lunar and meteoritic samples and their thermal and radiation history.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

147

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72		N/A	195-42-55-XX-55

5. TITLE Arecibo Data Reduction (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL Thompson, T. W.

TELEPHONE 213 - 354 - 6934

7. CONTRACTOR (IF APPLICABLE)

NAME N/A

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72		
CURRENT FY 73 (n)	35	
NEXT FY 74 (f)	18	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 00-00-100-00-00

This task will produce a radar map of the moon at a wavelength of 7.5 m, the longest wavelength used in mapping lunar radar echoes. The task will reduce data already obtained from observations at Arecibo Observatory. This map produced will have a surface resolution ten times better than the existing map at this wavelength. Radar maps of the moon at 7.5 m wavelength are produced by combining delay-Doppler mapping with interferometry (Thompson, 1970). The framework for this data reduction task is the programs that have been used in the previous mapping at 7.5 m. Some modifications will be needed because of the much better resolution of the unmapped data.

10. JUSTIFICATION (WHY)

A radar map of the lunar surface at 7.5 m wavelength is important because it indicates near-surface conditions of the moon to depths of 50 to 100 m, the penetration depth of radar waves. This depth is well into the bedrock in the mare and may penetrate to bedrock in highland areas. This radar map at 7.5 m wavelength will compliment other data at 70 cm wavelengths and shorter. To date, comparison between the 7.5 m data and the other radar maps has not been possible, because the existing map at 7.5 m wavelength does not resolve anything smaller than the mares. It is important to continue lunar radar mapping to aid future studies of Mercury and Venus: only radar will map these planets in a global scale during the next decade. The interpretation of this planetary radar data will be aided by the multi-wavelength observations of the moon, where surface conditions are known to much greater accuracies.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

148

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		42,41	195-42-57

5. TITLE

PARTICLE TRACK COSMOCHRONOLOGY

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

N/A

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

006800,014000

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

This work is undertaken to expand our understanding of the mineralogic settings and differentiation histories of planetary heat sources. Improved understanding of these settings and histories will lead to clearer interpretation of isotopic chronology studies and will provide constraints for models of planetary evolution.

Planetary heat sources uranium and thorium are mapped on a microscopic scale by fission track mapping in lunar, meteoritic, and terrestrial materials. Sites of these species are studied geochemically and petrologically.

13. KEYWORDS

Uranium-bearing minerals, fission tracks

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. Justification

The study of uranium and thorium geochemical systems advances the understanding of planetary evolution in several ways. These species act as tracers for the movement of large amounts of material about a planet (laterally or radially); e.g., lunar KREEP. Study of the concentration sites improves the interpretation of U-Th-Pb chronologic studies. Perhaps most important is that U and Th provide most of the heat which drives geological processes and are thus directly responsible for much of planetary evolution.

Studies of chronology by particle tracks and the search for extinct nuclei in lunar materials are now supported by the Lunar Sample Office and are thus not a subject of this RTOP.

15. Operating Plan

A. Objectives

The objective of this work is to advance our understanding of the geochemistry and petrology of uranium and thorium. It is our goal, through these and studies on other trace and major elements, to understand the differentiation and evolution of the heat sources in the moon and earth.

B. Technical Approach

Fission track mapping is used to locate uranium- and thorium-rich environments and determine concentrations of these elements. The electron microprobe, ion microprobe, and optical microscope are used to study the environment as a guide to the processes of differentiation and concentration. Concentration, distribution, and partition of the elements are determined. Particle track studies are carried out where applicable to determine cosmic ray exposure age or fossil fission track age.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. Publications

1. E. L. Haines, A. L. Albee, A. A. Chodos, and G. J. Wasserburg, "The Uranium Bearing Minerals of Lunar Rock 12013," Earth and Planetary Science Letters 12, 145-154 (1971).

2. E. L. Haines, "Precise Coordinate Control in Fission Track Uranium Mapping," Nuclear Instruments and Methods 98, 183-184 (1972).

Publications (Cont.)

3. A. L. Albee, A. A. Chodos, A. J. Gancarz, E. L. Haines, et al., "Mineralogy, Petrology and Chemistry of a Luna 16 Basaltic Fragment, Sample B-1," Earth and Planetary Science Letters 13, 353-367 (1972).

4. E. L. Haines, A. J. Gancarz, A. L. Albee, and G. J. Wasserburg, "The Uranium Distribution in Lunar Soils and Rock 12013" (Presentation) Lunar Science III, Ed., C. Watkins, Lunar Science Institute Contribution No. 88, 350-351 (1972).

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	195-42-57	PARTICLE TRACK COSMOCHRONOLOGY		4 OF 5

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY QUARTER 1	2	3	4	FY QUARTER 1	2	3	4
Study lunar rock 12013																												
Study lunar soils																												
Study lunar rock 15455 (consortium)																												
Terrestrial mantle and crust																												
Other lunar materials (as they become available)																												

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	195-42-57	PARTICLE TRACK COSMOCHRONOLOGY	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY '75	FY '76
DIRECT PROFESSIONAL	1.0	0.5	1.0	1.0	1.0
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	1.0	0.5	1.0	1.0	1.0

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY '75	FY '76
R & D CONTRACTS					
IN-HOUSE SUPPORT	50	25	75	82	90
TOTAL FUNDS	50	25	75	82	90

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	605-26210-0-8280	N/A	195-42-57-01-55

5. TITLE

PARTICLE TRACK COSMOCHRONOLOGY (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Haines, Eldon L.

TELEPHONE: 213 - 354 - 2733

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72(c)	50	
CURRENT FY '73(c)	25	
NEXT FY '74(c)	75	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 25-0-25-25-25

The objective of this work is to advance our understanding of the geochemistry and petrology of uranium and thorium. It is our goal, through these and studies on other trace and major elements, to understand the differentiation and evolution of the heat sources in the moon and earth.

10. JUSTIFICATION (WHY)

The study of uranium and thorium geochemical systems advances the understanding of planetary evolution in several ways. These species act as tracers for the movement of large amounts of material about a planet (laterally and radially); e.g., lunar KREEP. Study of the concentration sites improves the interpretation of U-Th-Pb chronologic studies. Perhaps most important is that U and Th provide most of the heat which drives geological processes and are thus directly responsible for much of planetary evolution. Studies of chronology by particle tracks and the search for extinct nuclei in lunar materials are now supported by the Lunar Sample Office and are thus not a subject of this RTOP.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Advances have been made in fission track technology and duly published in open literature. Studies of Russian Luna 16 samples have been completed and similarly published. Studies of lunar soils from all lunar sites have been initiated and preliminary results were reported at the 3rd Lunar Science Conference.

154

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41	196-41-71

5. TITLE

GROUND BASED OPTICAL ASTRONOMY

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

196-41-74

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002000, 002200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The objective of this task is the comprehensive study of solar system bodies through ground-based telescope observations. Principal emphasis is devoted to high-resolution spectroscopic observation of Mars, Venus, Jupiter, Saturn and Uranus. The principal instrument used in this task is the high-dispersion coudé spectrograph and its ancillary equipment at the coudé focus of the Table Mountain Observatory 24-inch telescope.

Specific objectives for FY 73 include completion of the analysis of the Venus superior conjunction CO_2 data, completion of the analysis of the H_2 abundance on Saturn, analysis of CH_4 and NH_3 on Saturn through observation of the $3\nu_3$ and $3\nu_1$ bands at 1.1μ respectively, observation of CO_2 band strengths during Venus inferior conjunction, observation of the H_2 abundance on Uranus, compilation of a library of solar comparison spectra for Table Mountain, construction of an image tube scanning system for the coudé spectrograph, and construction of an image stabilizer and guidance system for the coudé spectrograph.

13. KEYWORDS Spectroscopic observations, atmospheres, Mars, Venus, Jupiter, Saturn, Uranus, telescopic observations.

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald P. Burcham ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. Justification

A comprehensive program of ground-based planetary astronomy has a vital role in the NASA Planetary Program. The information learned from such a program is as scientifically important as the information from space missions and is essential for the effective planning of space experiments and instruments.

The bulk of our present knowledge of planetary atmospheres has resulted from ground-based observation; however, a relatively small fraction of the astronomical activities throughout the world is devoted to planetary studies. Therefore, it is essential that NASA maintain a comprehensive planetary observing program devoted to meeting the immediate needs of future missions.

A number of observatories and universities have programs in planetary astronomy, in each case exploiting particular equipment and techniques available to them. The unique features of the program supported by this task are 1) a coudé spectrograph which will offer the highest achievable spectral resolution for extended sources in the spectral range from 0.6 to 1.2 microns, 2) an observatory exclusively devoted to the study of planets and their atmospheres and 3) a working environment in which optical astronomers, infrared astronomers, radio astronomers, spectroscopists and radiative transfer theorists are in daily contact one with the other, all working to a common objective — a deeper understanding of the physics and chemistry of the solar system.

15. Operating Plan

A. Objective

The general objective of this task is to obtain and analyze high-dispersion coudé spectra of planetary atmospheres. Specific objectives for FY 73 include completion of the analysis of the spectra of Venus taken at superior conjunction, completion of the analysis of the abundance of H_2 in the atmosphere of Saturn, reduction and analysis of the three plates taken in FY 72 of Saturn in the CH_4 $3\nu_3$ band at 1.1 microns, observation of Saturn in the NH_3 $3\nu_1$ band at 1.08 microns as well as further observation of CH_4 $3\nu_3$, studies of Jupiter in CH_4 $3\nu_3$ to detect spatial variations in latitude, observation of the band strengths of CO_2 in the spectrum of Venus when it passes through inferior conjunction in June 1972, observation and analysis of the H_2 abundance in the atmosphere of Uranus, and acquisition and compilation of a library of solar comparison spectra taken with the Table Mountain coudé spectrograph.

B. Technical Approach

An image-tube scanning system for the coudé spectrograph will be designed and constructed during FY 73. This system will incorporate a two-stage image intensifier tube (in hand) and an image dissector

tube (in hand) with a slit-shaped aperture. A planetary spectrum, intensified by the image tube, is scanned by the slit of the image dissector by magnetic field variation. An image stabilizing guider is under design and will be completed during FY 73. An initial version of a stabilizer attempted in FY 72 failed due to mechanical resonances which limited the system gain at frequencies below 5 Hz. To successfully compensate for image motion due to atmospheric seeing, a stabilizer should have measurable gain beyond 10 Hz. Such a guider system is crucial for the successful observation of weak absorption lines in the spectra of rapidly rotating planets. A two-stage electrostatic focus image intensifier tube will be purchased to extend the utility of the image tube scanner to 1.2 microns.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. Publications

Meetings and Symposia Papers

Newburn, R. L., "A Study of Missions to Comets and Asteroids, Key to Understanding of the Solar System," presented at the American Astronomical Society Division of Planetary Sciences meeting, Kailua-Kona, Hawaii, March 20-24, 1972.

Schorn, R. A., "Spectroscopic Observations of Venus at Superior Conjunction," presented at the American Astronomical Society Division of Planetary Sciences meeting, Kailua-Kona, Hawaii, March 20-24, 1972.

Young, L. G., "Spectroscopic Observations of Weather on Venus," presented at the American Astronomical Society Division of Planetary Sciences meeting, Kailua-Kona, Hawaii, March 20-24, 1972.

Journal Articles

Hunt, G. E. and Schorn, R. A. J., "Height Variations of Venusian Clouds," Nature Physical Science 233, 39-40, 1971.

Young, L. D. G. and Young, A. T., "On the Temperature Distribution in a Planetary Atmosphere,", Astrophys. J., in press.

Schorn, R. A. and Young, L. G., "Comments on 'the Venus Spectrum: New Evidence for Ice'," Icarus 15, 103-109, 1971.

Young, L. D. G., Schorn, R. A. J., Barker, E. S. and Woszczyk, A., "High Dispersion Spectroscopic Observations of Venus During 1968 and 1969. I. The Carbon Dioxide Bands at 7820 Å and 7883 Å, Acta Astronomica 21, No. 3, 329-363, 1971.

Margolis, J. S., Schorn, R. A. J. and Young, L. G., "High Dispersion Spectroscopic Studies of Mars. V. A Search for Oxygen in the Atmosphere of Mars," Icarus 15, 197-203, 1971.

Young, A. T. and Young, L. G., "Observing Venus Near the Sun," Sky and Telescope 43, 140-144, 1972.

Young, L. D. G., "Interpretation of High Resolution Spectra of Mars. II. Calculations of CO_2 Abundance, Rotational Temperature and Surface Pressure," JQSRT 11, 1075-1086, 1971.

Young, L. D. G., "Interpretation of High Resolution Spectra of Mars. III. Calculations of CO Abundance and Rotational Temperature," JQSRT 11, 385-300, 1971.

Young, L. D. G., "Observations of Venus Near Inferior Conjunction. I. The 7820 Å Band of CO_2," BAAS 3, 277, 1971.

Schorn, R. A. J., "Observations of Venus Near Inferior Conjunction. III. The CO_2 Bands at 10362 Å, 10488 Å and 10627 Å," BAAS 3, 278, 1971.

Books

Kaplan, L. D. and Young, L. D. G., "An Interpretation of the Mars Spectrum Taken by the Connes," in Planetary Atmospheres, Sagan, Owen and Smith, eds. p. 189-190, 1971.

Schorn, R. A., "The Spectroscopic Search for Water on Mars: A History," in Planetary Atmospheres, Sagan et al., eds., pp 223-236, 1971.

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15-04-72	196-41-71	GROUND BASED OPTICAL ASTRONOMY		5 OF 6

MAJOR MILESTONES	PRIOR FY ___ QUARTER 1	2	3	4	CURRENT FY ___ MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4
Working prints, Solar Atlas					▽																							
Image tube scanner, breadboard						▽																						
Image tube scanner, operational									▽																			
Image stabilizing guider										▽																		

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽(1) - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▽ ▭ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ ▭ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▭ ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

158

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 '72	196-41-'71	GROUND BASED OPTICAL ASTRONOMY	6 OF 6

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
DIRECT PROFESSIONAL	3.8	4.3	4.3		
DIRECT SUPPORT	1.0	1.5	1.5		
TOTAL DIRECT MAN YEARS	4.8	5.8	5.8		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	250K	270K	282K		
TOTAL FUNDS	250K	270K	282K		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 '72	602-47110-0-8250	N/A	196-41-71-01-55

5. TITLE

GROUND BASED OPTICAL ASTRONOMY (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Norton, R.H.

TELEPHONE: 213 - 354 - 5148

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	250	
CURRENT FY 73 (c)	270	
NEXT FY 74 (c)	282	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 20-20-20-35-5

A comprehensive study of planetary atmospheres is being conducted through ground-based telescopic observations. Analysis of high-dispersion coudé spectra yields information on the temperature, pressure, composition and secular and seasonal variations.

10. JUSTIFICATION (WHY)

A comprehensive program of ground-based planetary astronomy fulfills a vital role in the NASA planetary program in that 1) it provides planetary information at a small fraction of a mission cost; 2) such information is critical to the effective planning of space instruments and experiments; and 3) a relatively small fraction of the world's astronomical activities are devoted to planetary research.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A series of excellent spectra of Venus were obtained by A. and L. Young with the Table Mountain coudé spectrograph during superior conjunction. In collaboration with R. Schorn and G. Hunt, analysis of these spectra has yielded information on the atmospheric structure of Venus. Observations of the $3\nu_3$ band of Methane in the spectrum of Saturn were made by R. Newburn and R. Norton. The spectra are under analysis.

161

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		41	196-41-72

5. TITLE

GROUND-BASED INFRARED ASTRONOMY

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

196-41-74

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002000, 002200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START [X] EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The objective of this task is to obtain and analyze high resolution spectra of the planets at infrared wavelengths. The principal instrumentation employed is a Connes'-type Fourier spectrometer at the coude' focus of the 107" telescope, McDonald Observatory, University of Texas.

During FY'73, we plan to continue our observing program on Venus in order to elucidate the role of the clouds in the anomalous phase effects observed both in the continuum and in the HCl bands. We shall also continue our efforts to make a positive identification of the cloud material.

We also plan to continue our successful exploration of the spectrum of Jupiter and to commence observations on Saturn.

13. KEYWORDS

Spectroscopic observations, Mars, Venus, Jupiter, Saturn

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES [X] NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

The atmospheres of planets are dominated by molecular processes and, as is well-known, molecules exhibit their strongest absorptions in the infrared. It is therefore logical to employ the available atmospheric windows in order to study the physics and chemistry of planetary atmospheres.

Several atmospheric windows exist in the region 1.2-6 microns and we have the capability of working in any of them. Furthermore, we have clear evidence that as spectral resolution improves even some of the regions previously assumed to be unusable (in the 2.7μ water vapor band, for example) can be employed because of "micro-windows" within the band.

Most of our studies have been performed in the 3-6 micron region, to date. However, we have recently moved operations to the 1.4-2.7 micron region and we now feel that the interchange can be performed in a few hours.

15. OPERATING PLAN

A. Objectives

Our objective is to obtain the maximum possible information concerning the physical conditions existing in the planets using ground-based high-resolution infrared spectroscopy. The instrumentation we employ is virtually unique - a Connes'-type Fourier Interference spectrometer permanently attached to the 107″ telescope at McDonald Observatory, University of Texas.

A secondary objective of this task is to investigate alternative instrumentation when, for specific purposes, it may be better adapted for a particular problem than the interferometer. For example, a Fourier spectrometer is ill-adapted for the production of spatially-resolved planetary spectra. For mapping of a planet in a particular absorption band, other techniques may be superior.

B. Technical Approach

On some 90 days and nights a year, the interferometer is employed in planetary observations. Because of the weak signals and the high resolution required, many hours of useful observation are necessary in order to produce spectra with a satisfactory signal-to-noise ratio.

B. Technical Approach

Our principal planets for observation in the coming year will be Venus, Jupiter and Saturn. We shall also continue our collection of solar spectra for comparison purposes and we hope to begin studies on some of the gallilean satellites. We also have contingency plans for observation of any bright comets that may appear.

In particular, this year we hope to be able to determine the cause of the anomalies in the continuum and HCl line strengths in the atmosphere of Venus. We feel that the problem is intimately concerned with the cloud structure and the known variability of H_2O in the planet.

PROGRESS

A description of the instrumentation and the observing techniques has been published in the Review of Scientific Instruments (42, 1393, (1971)).

The results obtained from the 1969 Mars opposition, showing that C_3O_2 was not present on the planet to a limit of $3X10^{-7}$ of the surface area but that bound surface water was extensively present, was published in Icarus (15, 1, (1971)).

A 3-4 micron reflectivity curve of Venus and the suggestion that it might be due to R HCO_3 in the upper clouds, was published in the Astrophysical Journal Letters (168, L121, (1971)).

A paper announcing the discovery of CH_3D (mono-deuterated methane) in the atmosphere of Jupiter has been accepted by Science (in the press). This marks the first astronomical detection of deuterium by any technique.

A paper discussing the CH_3D abundance and the Jovian D/H ratio will be presented at the Division of Planetary Sciences meeting in Hawaii in March 1972. A more extensive analysis is in preparation for submittal to the Astrophysical Journal. Because of the profound cosmological significance of the D/H ratio, the discovery has excited considerable interest in the astronomical community.

New spectra of Mars and Venus at better than 0.1 cm^{-1} resolution have been obtained and are currently undergoing analysis.

A translation of a paper by P. & J. Connes discussing their latest interferometers, employing a revolutionary new control system, has been made and will appear as JPL Technical Memorandum 33-525 (1972).

PROGRESS (Cont'd)

Instrumentally, we have successfully made an interchange of wavelength regions in the interferometer (from the 3-6 micron region to the 1.4-2.7 micron region). We now feel that the interchange can be made, at will, within a few hours. A model of a new linear kinematic air-bearing for the moving element of the interferometer has been successfully tested and a new linear D.C. motor is in development.

Procurement has been initiated (AP 164) for a mini-computer to take over part of the interferometer system control. The new carriage, if successful, will extend our maximum available resolution to 0.02 cm^{-1} and the computer will enable us to improve our observing efficiency by 20-30% and permit one-man operation.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

Meetings and Symposia Papers

Beer, R., "Astronomical Infrared Spectroscopy with a Connes'-Type Interferometer: III. α Orionis, 2600 - 3450 cm^{-1}," presented at the 17th International Symposium on Astronomical Spectra in the Infrared and Microwave Regions, Liége, Belgium, June 28 - July 1, 1971.

Beer, R., "The Abundance of CH_3D and the Deuterium-Hydrogen Ratio in Jupiter," presented at the Division of Planetary Sciences Meeting, AAS, Kailua-Kona, Hawaii, March 20-24, 1972.

Journal Articles

Beer, R., Norton, R. H. and Martonchik, J. V., "Absorption by Venus in the 3-4 Micron Region," Astrophys. J. Letters, 168, L121, 1971.

Beer, R., Norton, R. H. and Seaman, C. H., "Astronomical Infrared Spectroscopy with a Connes'-Type Interferometer: I. Instrumental," Rev. Sci. Inst., 42, No. 10, 1393, October 1971.

Beer, R., Norton, R. H. and Martonchik, J. V., "Astronomical Infrared Spectroscopy with a Connes'-Type Interferometer: II. Mars, 2500-3500 cm^{-1}," Icarus, 15, 1-10, 1971.

Beer, R., Hutchison, R. B., Norton, R. H., Lambert, D., "Astronomical Infrared Spectroscopy with a Connes'-Type Interferometer: III. Alpha Orionis, 2500-3500 cm^{-1}," Ap. J., 172, 89, 1972.

Beer, R., Farmer, C. B., Norton, R. H., Martonchik, J. V., and Barnes, T. G., "Observation of Deuterated Methane in the Atmosphere of Jupiter," Science, in press.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	196-41-72	GROUND-BASED INFRARED ASTRONOMY	6 OF 6

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL	1.8	2.2	1.9		
DIRECT SUPPORT	1.8	1.7	1.7		
TOTAL DIRECT MAN YEARS	3.6	3.9	3.6		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	210 K	226 K	220 K		
TOTAL FUNDS	210 K	226 K	220 K		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	602-47210-0-3250	N/A	196-41-72-01-55

5. TITLE

GROUND-BASED INFRARED ASTRONOMY (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Beer, R.

TELEPHONE: 213 - 354 - 4748

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	210	
CURRENT FY 73 (c)	226	
NEXT FY 74 (c)	220	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-30-30-30-0

High resolution spectra of the planets are being obtained at infrared wavelengths with the JPL Connes'-type Fourier spectrometer at the 107-inch telescope, McDonald Observatory.

10. JUSTIFICATION (WHY)

Planetary atmospheres are dominated by molecular processes, and most fundamental molecular bands occur in the 1-5 micron spectral region. Therefore, we employ the available terrestrial atmospheric windows in a spectroscopic program of planetary investigation.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

The 1969 Mars data, the 1970 Venus data and an instrumental description have been published. Deuterium, in the form of CH_3D, has been discovered in Jupiter.

168

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		41	196-91-72 Addendum

5. TITLE
Ground Based IR Astronomy

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002000, 002200

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 -3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The objective of this task is to obtain emission spectra of the planets Venus and Jupiter, with approximately 1 cm^{-1} resolution, in the earth atmospheric window between 7.5μ and 14μ and to lay the ground work for extending the spectral range of spectroscopic astronomical observations outside the telluric windows. To this end a Michelson interferometer using liquid Helium cooled bolometer detectors has been adapted to a 60 cm diameter telescope on Mt. Wilson. The resulting measurements of spectral features and wavelength dependent brightness temperatures will yield information on atmospheric composition, and temperature structure and cloud properties.

13. KEYWORDS
Astronomy, Planets, Infrared Emission Spectra, Interferometer

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
ASSISTANT LABORATORY DIRECTOR			

14. JUSTIFICATION

The emission spectra of the planets Venus, Jupiter and Saturn contain information on the thermal structure and composition of their atmospheres. However, because of the intense absorption due to atmospheric CO_2 and H_2O, only the 7.5μ-14μ and 18-24μ regions of the infrared spectrum are accessible to observations with ground-based telescopes. Spectra of Venus and Jupiter between 7.5μ and 14μ with 20 cm^{-1} resolution (Stein, Gillet and Low (1969)) have already shown significant deviation from blackbody spectra. In the case of Jupiter, these deviations have been attributed to the ν_2 fundamental of NH_3. Observations with improved spectral resolution of approximately 1 cm^{-1} should allow the determination of gross temperature structure, using selected wavelengths between 7μ to 9μ of the ν_4 methane band and gross measurements of CH_4 and NH_3 abundances. In the case of Venus, observation with approximately 2 cm^{-1} resolution (Hanel et al.) have shown CO_2 bands at 9.4μ and 10.4μ and broad absorption-like features near 11μ. However, the interpretation of these measurements was complicated by the presence of a large amount of telluric emission in the spectra. Further observations with improved spectral resolution are needed to confirm the presence of these features; they also should put additional constraints on cloud composition. Spectral features near 8μ are postulated for hydrochloric acid cloud models. Clouds containing silicate or carbonate condensation nuclei should show spectral features between 9μ and 11μ. An additional objective of the proposed task is to lay the ground work for extending the spectral range of spectroscopic astronomical observations outside the telluric windows using airborne and spacecraft borne telescopes and to permit improved experiment definition using measured mean atmospheric parameters (i.e. low or no spatial resolution) for future planet orbiting or flyby spacecraft.

15. OPERATING PLAN

A. Objectives:

The long range objective of this task is to obtain emission spectra of astronomical sources with approximately 1 cm^{-1} resolution in the telluric windows between 7.5μ and 14μ and 18μ to 24μ and to lay the ground work for extending this spectral range to observation outside these telluric windows using airborne telescopes. The specific objective for FY 73 is to obtain spectra of Jupiter and Venus between 7.5μ and 14μ using a 60 cm diameter telescope on the Mt. Wilson. The observations will yield information on the gross composition, temperature structure and cloud properties of the planetary atmospheres. A spectral resolution of 1-2 cm^{-1} is required.

B. Technical Approach:

A Michelson interferometer has been modified, tested in the laboratory and adapted to the folded cassegrain focus of the 60 cm diameter Mt. Wilson telescope. The instrument is of the step and integrate variety with a minimum optical retardation per step of 2.5μ and a maximum stepping rate of

B. Technical Approach (Cont'd):

5 steps/second. The theoretical maximum resolution is 0.2 cm^{-1}. A germanium film deposited on an optically flat KBr plate acts as the beam splitter. Liquid Helium cooled bolometers with a noise equivalent power of $2X10^{-13}$ watt/$Hz^{\frac{1}{2}}$ are used as detectors. The detector outputs are amplified, phase detected and digitally stored on magnet tape. The radiation from the target is modulated by rapidly moving the telescope secondary mirror between two fixed positions at a rate of 30Hz. This is the first time a beam switching secondary is used with an interferometer system. This scheme allows the direct and optimum cancellation of the telluric background emission which exceeds the radiation emitted by Jupiter or Venus by several orders of magnitude. Based on reasonable assumptions regarding system efficiency and assuming detector noise limited performance, we estimate signal to noise ratios (between 7.5μ and 14μ) for 1 cm^{-1} resolution of 50, using a 10 minute total integration time on Venus; to achieve comparable signal to noise ratio on Jupiter requires the averaging approximately ten 10-minute interferograms.

C. RTOP Milestone Schedule:

Spectra of Venus, Jupiter and the Sun will be obtained and analyzed during FY 73. No detailed milestone schedule is attached. Providing satisfactory operation on the 60 cm telescope, system improvement such as corner cubes or multiple detectors and use of a large telescope (e.g. the 2.5 meter Mt. Wilson telescope) will be considered for FY 74 to improve the resolution or extend observations to fainter sources.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15-04-72	196-91-72 Addendum	Ground Based IR Astronomy	4 OF 4

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL		.30	.30		
DIRECT SUPPORT		.10	.10		
TOTAL DIRECT MAN YEARS		.4	.4		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT		23	26		
TOTAL FUNDS		23	26		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

172

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72		N/A	Addendum 196-91-72-05-55

5. TITLE

FAR INFRARED ASTRONOMY (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS: N/A
RESPONSIBLE INDIVIDUAL: Aumann, H. H.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 6615	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73(n)	23	
NEXT FY 74(c)	26	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 05-10-30-45-10

The objective of this task is to obtain emission spectra of the planets Venus and Jupiter, with approximately 1 cm^{-1} resolution, in the earth atmospheric window between 7.5μ and 14μ. A Michelson interferometer, using a liquid Helium cooled detector mounted at the cassegrain focus of the 60 cm diameter Mt. Wilson telescope, will be used for this purpose.

10. JUSTIFICATION (WHY)

The purpose of these measurements is to obtain gross atmospheric composition and temperature structures and to put additional new constraints on cloud models. An additional objective is to lay the ground work for extending the spectral range of astronomical observation to wavelengths outside the telluric windows using airborne telescopes.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A (new start)

173

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		41, 46	196-41-73

5. TITLE

RADIO AND RADAR PLANETARY STUDIES

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

N/A

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002000

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

RADIO ASTRONOMY

The objective of this task is to conduct a comprehensive program in ground based planetary radio and radar astronomy. Radio astronomical observations provide data on the properties of planetary atmospheres, magnetospheres, and surfaces. Radar astronomy provides data on the properties of the atmosphere, surfaces, and dynamical motions of the planets. A microwave radiometer development program is conducted to provide support for the observational radio astronomy program. The support objectives are to design, construct, test, and maintain advanced microwave radiometer systems for use at Table Mountain, Goldstone, and Owens Valley radio observatories.

Equipment used in the course of this task includes the facilities and test equipment of the Table Mountain Observatory and the Deep Space Network. The facilities include the 18-foot millimeter wave antenna at Table Mountain, and the 85-foot, and 210-foot antennas at the Goldstone Tracking Station. Observations at other observatories are carried out as required by the specific needs of the program.

13. KEYWORDS

Radio Astronomy, Radar Astronomy, Planets, Mars, Venus, Jupiter, Saturn, Uranus

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	4/3/72		

12. TECHNICAL SUMMARY, (Continued)

MICROWAVE RADIOMETER DEVELOPMENT

This effort is supportive of the above task. The objectives are to design, develop, construct, test and maintain advanced microwave radiometer systems for use at the Table Mountain, Goldstone, Owens Valley and other radiotelescope facilities. During FY'73, the specific objectives are to continue the upkeep of already existing equipments and to continue the development of low noise receivers and of the 8mm interferometer prototype. The technical approach will be as follows: the 8mm tunable system at Table Mountain and the 13mm tunable system at Owens Valley will be maintained and updated as required. The 8mm parametric amplifier development in a cooled configuration will be continued and installed at Table Mountain when complete. An 8mm interferometer utilizing the Table Mountain 18 foot antenna and the 10 foot antenna on the Nike pedestal, will be constructed.

DSIF RADAR ASTRONOMY

The objective of these tasks is to obtain radar data on the planets for determining properties of their surfaces and atmospheres, with Venus elevations and rotation vectors prime goals. This work employs the unique facilities of the DSIF, and exploitation of synthetic aperture techniques.

14. JUSTIFICATION

RADIO ASTRONOMY

The great value of ground-based radio and radar observations is that they afford a means of studying certain physical conditions of a planet which are not accessible to the classical techniques of optical and infrared astronomy. Nonthermal emission from the Jovian Van Allen radiation belt is easily detected at radio wavelengths, and observations of belts provide fundamental support to future spacecraft missions to Jupiter. Radio observations offer the possibility of measurement of radiation originating at and beneath the clouds of the major planets and Venus. The ability of long wavelength radiation to penetrate atmospheric clouds and dust and even to penetrate some distance into the solid planet is due to the wavelength dependence of the absorption coefficient of most materials. At radio wavelengths, the absorption coefficient generally decreases with increasing wavelengths, and the scattering from clouds and atmospheric particles of reasonable size is small.

A primary goal of this task is to detect microwave spectral lines in planetary atmospheres. There is no clear evidence that spectral features have ever been observed in the radio emissions from any planet, excluding the earth. However, spectral features are expected on theoretical grounds. Spectral lines of molecules resulting from their rotational or fine structure energy are predominately found at short centimeter (< 3cm) and millimeter wavelengths. These lines are expected to be vitally important in defining planetary microwave spectra, and provide a means of detecting molecular species in planetary atmospheres which might be undetected by other methods. If detected, these features would add a significant addition to our knowledge of the molecular and/or ionic species which populate planetary atmospheres.

A second goal of this task is to study the synchrotron emission which originates in the Van Allen radiation belts which surround Jupiter. As these belts have only been observed at radio wavelengths, radio observations are uniquely important to the understanding of the belts themselves.

A third goal of this task is the search for time dependence in the brightness in the radio emissions from the planets. Anomalies have been observed in the

14. JUSTIFICATION (continued)

infrared at 5 microns for both Jupiter and Venus. In neither case has an acceptable explanation been advanced. Additional observations in the radio region should contribute information needed to understand these anomalies. Temporal variations of spectral features should yield information about the variations in the abundance or spatial distribution of molecular species.

A fourth problem which can be investigated with radio-astronomical techniques is that of spatial features on the planets. Measurements made with pencil-beam radio telescopes simply yield an average disk temperature of the planet. Yet it is known that the temperature distribution over planetary disks is generally not uniform. At wavelengths where high resolution measurements have been made, spatial variations are seen. There are a number of possible reasons to expect such variations: polar cooling, nighttime-daytime differences, different thermal histories at different places on the planet, inhomogeneities in the distribution of different surface materials, polarized Brewster angle highlights, atmospheric inhomogeneities (such as clouds), and limb brightening or darkening in the atmospheres. These spatial variations are also subject to change with time and may show atmospheric circulation patterns.

MICROWAVE RADIOMETER DEVELOPMENT

There is a clear need for a companion microwave radiometer and instrumentation group in the Radio Astronomy Task. In addition to providing the primary support for maintaining the existing instrumentation, this group is required to build complementary instrumentation for certain scientific experiments and to provide state-of-the-art capability in all areas of instrumentation. The development of low-noise millimeter wave radiometers is of particular importance, since receiver noise is the limiting factor in nearly all the scientific experiments discussed in the Radio Astronomy Task.

DSIF RADAR ASTRONOMY

Radar contacts with objects in the Solar System are a very cost-effective method for determining parameters such as spin, ephemerides, radar brightness, elevations, etc.

15. TECHNICAL PLAN

A. Objectives

The objective of this RTOP is to conduct a broad program in planetary radio and radar astronomy by:

1. Defining basic questions about the Solar System which can be answered by radio and radar astronomical observations.
2. Conducting an observing program designed to answer these questions.
3. Developing theoretical models to explain the observations.
4. Providing basic data in support of flight projects.

B. Technical Approach

The program for the year will consist of the following activities:

15. TECHNICAL PLAN (continued)

RADIO ASTRONOMY

1. Prediction of spectral features likely to be present in radio region by theoretical calculations.
2. A search for spectral lines in Jovian 12-15 mm spectra utilizing a tunable radiometer and the 130-foot Owens Valley antenna.
3. A search for the time dependence in the brightness temperatures of Venus and Jupiter using the 18-foot Table Mountain antenna and an 8.5 mm radiometer.
4. A search for spectral lines using a tunable paramp and the 18-foot dish.
5. Measurement of the beaming of Jovian radio emission and the brightness temperature of Uranus and Saturn at 13 cm wavelength using the 210-foot and the 85-foot Goldstone antennae.
6. A search for spectral lines in planetary atmospheres using the new DSN-Ku band maser in combination with the 210-foot antenna.

MICROWAVE RADIOMETER DEVELOPMENT

1. The 8 mm and 13 mm tunable radiometers will be maintained and updated as required.
2. Development of a cooled, parametric amplifier will be continued and installed at the Table Mountain Observatory when complete.
3. An 8 mm interferometer, utilizing the Table Mountain 18-foot antenna and a 10-foot antenna on a Nike pedestal mount, will be constructed.

RADAR ASTRONOMY

The chief radar targets for FY'73 will be Mercury, Venus, Jupiter, and the Gallilean satellites. The Mercury data will be used to map the planet. Venus will be observed using interferometer techniques to study elevation differences and high resolution mapping. Jupiter and its moons will be studied in an attempt to determine their reflectivity and to improve on their ephemeris positions.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters' personnel will be conducted when requested.

17. PUBLICATIONS

Meetings and Symposia Papers

Klein, M., Gulkis, S. , Stelzried, C., and Sato, T. , "Jupiter: Secular Variations in Its Decimeter Flux," Bulletin of American Astronomical Society, 3, No. 4, Part 1, p 475, 1971, presented at the AAA Meeting held in San Juan Puerto Rico, Dec. 1971.

Gulkis, S., and Poynter, R., "Saturn: Interpretation of Its Microwave Spectrum," Bulletin of American Astronomical Society, 3, No. 4, Part 1, p 481, 1971, presented at the AAS Meeting held in San Juan Puerto Rico, Dec. 1971.

Gulkis, S., and R. Poynter, "Thermal Radio Emission from Jupiter and Saturn" Lunar Science Institute Conference on Physics of the Earth and Planetary Interiors, Houston, Texas March 1, 3, 1972.

Gulkis, S., "Radio Emission from the Major Planets - The Thermal Component" meeting of the American Astronautical Society Seattle, Washington, June 28-30 1971.

Poynter, R., and S. Gulkis, "Thermal Radio Emission from Jupiter and Saturn" presented at the AAS Division of Planetary Sciences meeting held in Kona, Hawaii, March 1972.

Klein, M. J., S. Gulkis and C. T. Stelzried, "Observations of the Beaming of Jupiter's Emission at 12.6 cm Wavelength" presented at the AAS Division of Planetary Sciences meeting held in Kona, Hawaii, March 1972.

Journal Articles

Gulkis, S., "Radio Emission from the Major Planets - The Thermal Component" American Astronautical Society, 29, Part 1, p 203, 1971.

Newburn, R. L. and S. Gulkis, "A Brief Survey of the Outer Planets Jupiter, Saturn, Uranus, Neptune, Pluto, and there Satellites," Space Science Reviews, (accepted for publication).

Gulkis, S., and R. Poynter, "Thermal Radio Emission from Jupiter and Saturn" Proceeding of Conference on Physics of the Earth and Planetary Interiors, to be published by North Holland Publishing Company, North Holland, Amsterdam, 1972.

Rosenkranz, P. W., F. T. Barath, J. C. Blinn, E. J. Johnston, W. B. Lenoir, D. H. Staelin, and J. W. Waters, "Microwave radiometric measurements of atmospheric temperature and water from an aircraft", submitted to J. Geophys. Res., 1972.

R. Goldstein, "Mars Radar Observations, a Preliminary Report", Science, Vol 174, Dec 71, Pp 1324-7. "Radar Obs. of Mercury", Astronomical Journal, Vol 76, #10, P1152

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15-04-72	196-41-73	MICROWAVE RADIOMETER DEVELOPMENT		6 OF 7

MAJOR MILESTONES	PRIOR FY 72				CURRENT FY 73												FY 74				FY				FY			
	QUARTER				MONTH												QUARTER				QUARTER				QUARTER			
	1	2	3	4	J	A	S	O	N	D	J	F	M	A	M	J	1	2	3	4	1	2	3	4	1	2	3	4
Table Mountain 8mm system maintenance																												
13mm system maintenance																												
8mm cooled paramp development																												
8mm cooled paramp installation																												
8mm interferometer development																												
8mm interferometer evaluation																												
Advanced paramp development																												
Table Mountain and Strawberry Peak Maintenance																												

NOTES

LEGEND (EXAMPLES)

- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

8/1

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15-04-72	196-41-73	RADIO AND RADAR PLANETARY STUDY	7 OF 7

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR FY 72	CURRENT FY 73	FISCAL YEAR FY 74	FY	FY
DIRECT PROFESSIONAL	5.9	6.4	7.4		
DIRECT SUPPORT	2.0	2.0	3.0		
TOTAL DIRECT MAN YEARS	7.9	8.4	10.4		

B. FACILITIES

C. R & D FUNDS

	PRIOR FY 72	CURRENT FY 73	FISCAL YEAR FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	381	417	476		
TOTAL FUNDS	381	417	476		

R & D CONTRACTS ($100K AND ABOVE) NONE

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR FY 72	CURRENT FY 73	FY 74	FY	FY
TOTAL MAN YEARS	1.0	2.0	1.0		

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	602-47310-0-8250	N/A	196-41-73-01-55

5. TITLE

RADIO ASTRONOMY (0)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: S. Gulkis	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 -5708	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	175	
CURRENT FY 73(c)	185	
NEXT FY 74(c)	200	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 25-15-10-45-5

This work unit uses the facilities and test equipment of the Table Mountain Radio Observatory and the Deep Space Network to conduct a comprehensive program in ground based planetary radio astronomy. Radio astronomy provides data on the properties of the atmospheres, surfaces, and magnetospheres of the planets. Programs to be conducted in FY'73 include a search for spectral lines in the Jovian and Venus mm spectra and a search for time dependence in the brightness temperatures of Venus and Jupiter at millimeter and centimeter wavelengths.

10. Justification (why)

The great value of ground based radio observations is that they afford a means of studying certain physical conditions of a planet which are not accessible to the classical techniques of optical and infrared astronomy. The radio signals detected with a radio telescope originate from a variety of different places in a planetary environment, ranging from the surface of Venus which lies beneath an extra ordinarily thick cloud blanket, to the tenuous regions in the magnetosphere of Jupiter. The ability of long wavelength radiation to penetrate atmospheric clouds and dust and even to penetrate some distance into the solid planet is due to the wavelength dependence of the absorption coefficient of most materials. At radio wavelengths, the absorption coefficient generally decreases with increasing wavelengths, and scattering from clouds and atmospheric particles of radiation originating at and beneath the clouds of the major planets and a start has been made in these studies. Nonthermal emission from the Jovian Van Allen radiation belt is easily detected at radio wavelengths, and observations of these belts provide fundamental support to future spacecraft missions on Jupiter.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

1. The brightness temperature of Venus and Jupiter was measured at 13 discrete frequencies within the frequency interval 20-24 GHz. The Jupiter observations support the model atmosphere in which ammonia is saturated in the uppermost adiabatic region, but are in disagreement with earlier radio measurements in which ammonia is required to be supersaturated.
2. Total flux data from Jupiter have been used to derive a magnetospheric rotation period of $09^h55^m29^s.75 \pm 0.10$, which is 0.38^s longer than the standard IAU System III (1957.0).
3. Long term variations in the total flux density from Jupiter have been detected at a wavelength of 13 cm.

181

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 4 72	602-47320-0-3310	N/A	196-41-73-02-55

5. TITLE

DSIF RADAR ASTRONOMY (0)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME JET PROPULSION LABORATORY, California Institute of Technology	NAME N/A
ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL Goldstein, Richard M.	PRINCIPAL INVESTIGATOR
TELEPHONE 213 - 354 - 3856	TELEPHONE 50-0-50-0-0

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	62	0
CURRENT FY 73 (c)	75	0
NEXT FY 74 (c)	79	0

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) This work unit uses the unique facilities of the DSIF to obtain radar data on the accessible planets, their satellites, and asteroids, for the purposes of determining properties of their surfaces and atmospheres. The chief targets for FY'73 are Venus, Mercury, and the Jovian satellites, with Venus elevations a prime new goal. The chief capabilities of the DSIF that make this radar program so attractive are the following: the 64m antenna at DSS 14, the world's highest gain steerable microwave antenna; low noise S-band reception capability; high-power transmitter capability; extremely precise and stable programmable exciters and receivers; and high resolution spectrum analyzers.

10. JUSTIFICATION (WHY) Radar contacts with objects in the Solar System are an extremely cost-effective method for determining key planetary properties. Scientific uses of data involve planetary ephemerides and spin parameters; radar brightness mapping; elevation finding; and cross-section and scattering law determination. In addition to the scientific uses made of the data, results of radar experiments are used to improve planetary ephemerides for flight project navigation, and to enhance the scientific value of planetary reconnaissance missions.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) In the past year, altitude mapping of Mars was conducted in the 1971 opposition using the overlapping range gate method. In addition to improving the Mars ephemeris for Mariner'71, the data produced altitude profiles around the planet in almost four complete scans in a narrow belt South of the Mars equator. Using the initial results of the Mariner'71 IRIS experiment temperature measurement, together with the altitude determination of the region near Nix Olympica called South Spot as being a Martian high point, it was conjectured that South Spot was a possible volcanic feature before video data was received which appeared to increase the plausibility of this conjecture. Methods were determined to fill in the gaps in ranging data caused by the monostatic mode of operation by looking at range gates not at the sub-Earth point and making an appropriate adjustment to transfer the range data to an equivalent sub-Earth range. In addition, the previously-devised method of obtaining radar brightness mapping of Mars (using the same data) with the North-South ambiguity removed by a vector projection technique was demonstrated with the Mars data. Completion of the brightness map is underway. Initial results of the altitude determination were published in Science in Dec. 1971. The Venus radar interferometer experiment for high resolution brightness mapping and elevation determination is well underway for the 1972 inferior conjunction. Plans for Mercury brightness mapping have been completed, with an experiment planned for Spring 1972. Analysis of the possibility of a Jupiter or Jovian moon bounce has been completed, with an experiment contemplated for the Summer of 1972. Saturn is another possible, but marginal, target.

182

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	602-47330-0-8230	N/A	196-41-73-03-55

5. TITLE

MICROWAVE RADIOMETER DEVELOPMENT (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Soltis, F.

TELEPHONE: 213 - 354 - 7169

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS:

PRINCIPAL INVESTIGATOR:

TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(c)	131	0
CURRENT FY 73(c)	135	0
NEXT FY 74(c)	175	0

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-50-5-10-25

This work is in support of the Radio Astronomy Task, Code 196-73-01. The objectives are to design, develop, construct, test and maintain advanced microwave radiometer systems for use at the Table Mountain, Goldstone, Owens Valley and other radio-telescope facilities. During FY'73, the specific objectives are to continue the upkeep of already existing equipments and to continue the development of low noise receivers and of the 8mm interferometer prototype. The technical approach will be as follows: the 8mm tunable system at Table Mountain and the 13mm tunable system at Owens Valley will be maintained and updated as required. The 8mm parametric amplifier development in a cooled configuration will be continued and installed at Table Mountain when complete. An 8mm interferometer utilizing the Table Mountain 18 foot antenna and the 10 foot antenna on the Nike pedestal, will be constructed.

10. JUSTIFICATION (WHY)

There is a clear need for a companion microwave radiometer and instrumentation group in the Radio Astronomy Task. In addition to providing the prim ary support for maintaining the existing instrumentation, this group is required to build complementary instrumentation for certain scientific experiments and to provide state-of-the-art capability in all areas of instrumentation. The development of low-noise millimeter wave radiometers is of particular importance, since receiver noise is the limiting factor in nearly all the scientific experiments discussed in the Radio Astronomy Task.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

During FY'72, the 8mm tunable system at Table Mountain, the tunable 13mm system at Owens Valley and the 13mm multichannel system at Goldstone, as well as the Table Mountain Radio telescope and the Strawberry Peak boresight facilities were maintained and updated as necessary. The operation of an uncooled parametric amplifier at 8mm has been demonstrated and installation of an operational cooled unit for Table Mountain initiated. The operation of a two element 8mm interferometer prototype system has been demonstrated in the laboratory and installation at Table Mountain initiated. Two temperature controlled standard gain horn antennas were developed for calibration of the 18 foot Table Mountain antenna at 8mm. A special multichannel filter bank for use with various radiometers was constructed and tested with the 13mm and 8mm radiometers.

183

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72	602-47321-0-8230	N/A	196-41-73-04-55

5. TITLE

DSIF Radar Astronomy Science Support (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Thompson, T. W.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 6934	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	13	
CURRENT FY 73 (c)	22	
NEXT FY 74 (c)	22	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

The direction and magnitude of the Venus rotation vector will be determined by correlating observed radar features as shown on maps obtained by the Goldstone radar during the 1969, 1970 and 1972 inferior conjunctions. Some of the computer programs for this task have been written and tested on data from the 1969 conjunction.

A system design for the application of synthetic aperture techniques to ground based radar astronomy will be generated. The 25 cm radar that has been used on the CV990 aircraft could be modified to operate at a higher frequency. The modified radar can be transported to a nearby radio telescope where antenna feeds already exist at the higher frequencies. First demonstrative tests will probably be made by observing the Moon, since lower powers and smaller antennas can be used. The objective is to design a system requiring a minimum amount of changes between the existing airborne 25 cm radar and existing radio telescopes.

10. JUSTIFICATION (WHY)

Radar mapping is the only practical technique for observing the Venusian surface. An important by-product of the maps is the determination of Venus' rotation vector. Although the maps obtained with the Goldstone radar since 1969 have a four-fold improvement in resolution over previous mappings, these new maps have not been studied to redetermine Venus' rotation vector.

An improved determination of the direction of Venus' spin direction may resolve whether core-mantle slippage or atmospheric-tide coupling has driven Venus' spin to its present state.

Future radar mapping of the planets may be improved by synthetic aperture techniques now applied in airborne side-looking radars. This technique may greatly reduce the digital processing now used in ground based radar astronomy; it may provide better resolution and/or greater signal-to-noise ratios.

11. MAIN ACHIEVEMENTS

Computer programs for spin vector determination have been written and tested on data from 1969 conjunction. Maps of radar echoes have been displayed on the IPL computer. Apparent spins have been computed from standard JPL ephemeris tapes.

184

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 '71		41	196-41-74

5. TITLE

INFRARED SPECTROSCOPY

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

196-41-71, 196-41-72

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002000, 012700

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The objective of this activity is to support astronomical and spaceflight studies of planetary atmospheres by obtaining spectra of gases under suitable conditions. There are two main functions, namely: (1) to furnish quantitative band or line data chiefly at infrared wavelengths, and (2) to provide direct aid in verifying identifications of features observed in planetary spectra.

The primary facility employed in this task is the Spectroscopy Laboratory which contains spectrometers covering the visible, near and middle infrared spectral regions and absorption tubes capable of providing path lengths of up to 1 kilometer at pressures up to 20 atmospheres.

13. KEYWORDS

Spectroscopy, infrared

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rea ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. Justification

As stated, the task supports two main functions:

a) A service function, in that the basic laboratory data (line positions, strengths etc.) needed for the reduction of the astronomical spectra obtained under the Infrared and Optical Astronomy tasks is often not available. Although a library of published spectra and molecular constants has been established and computer programs exist for the calculation of certain facets of molecular spectroscopy, in many instances it has been found necessary to resort to the empirical approach of obtaining a sample of the molecule in question and recording its spectrum.

b) A scientific function, in that many of the features of the spectra of simple molecules are not understood. In particular, this applies to H_2O, CO_2, CH_4, and NH_3, molecules of particular planetary interest. This function not only provides fundamental information on the properties of these molecules, but also has a direct bearing on planetary-scale problems (such as the radiative transfer in a planetary atmosphere) in which we have direct theoretical interest.

15. Technical Plan

A. Objectives

a) To provide such basic data as is dictated by the needs of the planetary astronomy programs, using the facilities of the Spectroscopy Laboratory.

b) To undertake the study of particular bands of specific molecules under conditions relevant to the investigation of planetary atmospheres.

B. Technical Approach

a) Precision spectral measurement of molecules of planetary interest will be continued. These include such common molecules as H_2O, CH_4, NH_3, and N_2O, and many others, such as the CH_3D recently discovered in Jupiter. The laboratory is also equipped to undertake rapid surveys of most gaseous species as the need arises.

b) The results of these spectral analyses will be applied to the solution of problems of planetary atmospheres. Although a number of such studies have been made in the past, the continuing advances both in ground-based and space-borne planetary instrumentation dictate an increase in both the quantity and quality of the supporting laboratory data.

c) Auxiliary spectral studies of liquids and solids of planetary interest will be conducted as appropriate.

15. C. FY 1972 Achievements

a) The analysis of several bands of N_2O has been completed and published in a series of papers by J. Margolis and R. Toth.

b) The analysis of the $2\nu_2$ band of CH_2O has been completed and is being prepared for publication by R. Toth.

c) The analysis of a number of NH_3 bands is in progress. Some intermediate results are being prepared for publication by J. Margolis.

d) A moderate resolution study of the ν_1 band of CH_3D under self- and hydrogen-broadening conditions has been conducted by R. Beer and F. Taylor in support of new interferometric spectra of Jupiter.

e) A study of the low-temperature transmission spectra of potential Venus cloud constituents is being conducted by R. Beer and J. Martonchik.

f) The results of the laboratory simulation of an absorbing and scattering atmosphere have been published by J. Margolis, D. McCleese, and G. Hunt.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. Publications

Meetings and Symposia Papers

Margolis, J. S., "On the Level of Formation of the Hydrogen Quadrupole Lines on Jupiter," presented at the Division of Planetary Sciences Meeting of the American Astronomical Society, Kailua-Kona, Hawaii, March 20-24, 1972.

Toth, R. A., "Self Broadened and N_2 Broadened Half-Widths of N_2O," presented at the Molecular Spectroscopy Symposium, Columbus, Ohio, June 14-18, 1971.

Toth, R. A., "High Resolution Determination of the Intensities of N_2O," presented at the Molecular Spectroscopy Symposium, Columbus, Ohio, June 14-18, 1971.

Journal Articles

Margolis, J. S., "Studies of Methane Absorption in the Jovian Atmosphere: III. The Reflecting Layer Model," Ap. J. 167, 553 (1971).

Margolis, J. S., Schorn, R. A. J., Young, L. D. G., "A Search for Oxygen in the Atmosphere of Mars," Icarus 15, 197 (1971).

McCleese, D. J., Margolis, J. S. and Hunt, G. E., "Absorption Spectra Formation in Cloudy Planetary Atmospheres: A Laboratory Simulation," Nature Physical Science 233, 102 (1971).

Margolis, J. S., McCleese, D. J. and Hunt, G. E., "Laboratory Simulation of Diffuse Reflectivity from a Cloudy Planetary Atmosphere," Applied Optics, in press.

Margolis, J. S., "Intensity and Half Width Measurements of the ($00^{0}2 - 00^{0}0$) Band of N_2O," JQSRT, in press.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 '71	196-41-74	INFRARED SPECTROSCOPY	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
DIRECT PROFESSIONAL	2.0	2.0	2.0		
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	2.0	2.0	2.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	100	97	112		
TOTAL FUNDS	100	97	112		

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

189

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 '71	602-47410-0-8250	N/A	196-41-'74-01-55

5. TITLE

SPECTROSCOPY OF SYNTHETIC ATMOSPHERES (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)	CONTRACT NO.
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A	CONTRACT START DATE
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS	
RESPONSIBLE INDIVIDUAL: Beer, R.	PRINCIPAL INVESTIGATOR	
TELEPHONE: 213 - 354 - 4748	TELEPHONE	

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	100	
CURRENT FY 73 (c)	97	
NEXT FY 74 (c)	112	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-10-35-35-10

Ground-based and space flight studies are supported by obtaining spectra of gases under suitable conditions. Quantitative band and line data are derived chiefly at unfrared wavelengths using the spectrometers and long path cells of the Spectroscopy Laboratory.

10. JUSTIFICATION (WHY)

Since planetary atmospheres are dominated by molecular and radiative processes, an understanding of those processes in a quantitative manner is vital for the interpretation of ground-based and space flight observations. Such understanding derives from, among other things, a quantitative analysis of molecular spectra in the laboratory.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

During FY '72 the analysis of several bands of N_2O has been completed and published; the analysis of the $2\nu_2$ band of CH_2O has been completed; a moderate resolution study of the ν_1 band of CH_2D under self-and hydrogen-broadening conditions has been conducted; and the results of the laboratory simulation of an absorbing and scattering atmosphere have been published.

190

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15-04-72		22,42,46	383-09-51

5. TITLE
Precision Lunar Ephemeris

6. RELATED SUBPROGRAMS (IF APPLICABLE)

7. RELATED RTOP'S (IF APPLICABLE)

8. CONSOLIDATION OF RTOP NO'S.

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
003000 Celestial Mechanics

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 1973

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

This RTOP, describing the prediction of laser range observations, lunar ephemeris and physical model improvement, and preliminary data analysis activities within the Apollo Laser Ranging Experiment, has four major objectives:

1) To support the observing program at McDonald and Haleakala Observatories with high precision range predictions and to conduct prediction accuracy studies.

2) To employ laser range and optical meridian transit and occultation observations in order to improve the lunar ephemeris. Numerical integration and correction procedures will be used.

3) To numerically integrate physical librations of the moon as a means of getting higher precision than is now obtainable.

4) To disseminate residuals from solutions made at JPL to other investigators in the experiment who are studying various geophysical and relativity effects.

This effort will satisfy the need for an accurate model of the lunar motion and will contribute towards understanding the rotational motions of the moon and earth.

13. KEYWORDS
Laser Ranging Experiment, Lunar Exploration
Lunar Ephemeris, Astronomical Constants

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rea ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

The Apollo Laser Ranging Experiment is dedicated to studying a variety of phenomena: polar motion, earth rotation, relativity effects, continental drift, solid body earth tides, and the orbit and orientation of the moon. Very high accuracy geodetic measurements become possible with this technique. Using the full accuracy of the ranging observations for measuring geophysical and relativity parameters requires that the lunar orbit and the orientation of the moon be known to a much higher level of accuracy than it is known at present. The needs of the experiment require that (1) a highly accurate lunar ephemeris be available for range predictions, (2) the range data be used to improve the ephemeris, (3) the new ephemeris and the residuals from the fit be distributed to other experimenters for their studies.

The combination of lunar laser and meridian transit observations with the observations of stellar occultations can be analyzed to advantage within the framework of a single data processing system such as that at JPL. The advantage arises because these data types have different systematic errors, so the combination can lead to an ephemeris freed from the biases due to any of their individual error sources. The stellar occultations, unlike meridian transit observations, can immediately refer the moon to a modern stellar coordinate system such as the FK 4. The occultation observations also have great strength for determining secular changes in the mean longitude of the moon such as those caused by tidal friction and the possible time variation of the gravitational constant.

15. TECHNICAL PLAN

A. Objectives

The objectives of the RTOP are (1) to support the observing program by supplying high precision range predictions computed from an accurate ephemeris, (2) to analyze the data for information on the orbits and masses of the earth and moon, the physical librations of the moon, observatory and reflector coordinates, UT1, polar motion, relativity parameters, tidal friction and other parameters which affect the ranging observable, (3) to improve the physical libration models using numerical integration techniques, (4) to exchange the residuals with LURE team members.

The objectives of the Occultation task for the immediate future are:

(1). To obtain the existing occultation data from the various sources and to convert all data to a standard format.

(2). To modify existing software to handle this data type.

Long range objectives include:

(1) Refining the calculation of the occultations to allow

15. TECHNICAL PLAN (continued)

for the irregularities of the lunar limb by employing the charts of the marginal zone of the moon of Watts in machine readable form.

(2) Combination of the occultation normal equation with the laser and meridian transit sets of normal equations in order to examine the questions of tidal friction and rate of change of the gravitational constant.

B. Technical Approach

RANGE PREDICTIONS

The prediction programs are in production status though changes and improvements need to be made occasionally. Range predictions for all retroreflectors will be routinely supplied during FY'73 to McDonald Observatory and to Haleakala Observatory at such time as it can do ranging. Predictions can be supplied to any other observatory if it is desired.

EPHEMERIS IMPROVEMENT

During FY'72 the system of computer programs (LSSDPS) has been upgraded to solve for the lunar orbit, libration parameters, the coordinates of McDonald Observatory and the lunar coordinates of the retroreflectors. Corrections are made to the computed range for UT1, polar motion, and atmospheric delay. In FY'73 changes to allow solving for the masses of the earth and moon, the orbit of the earth-moon barycenter, solid body earth tides, and relativity parameters should be included.

New numerical integrations of the moon's motion will be done whenever improved starting conditions are available. As has been the case in FY'72 new integrations would be made available for the starting conditions of other LURE experimenters too.

Ephemerides and residuals from solutions would be available to LURE team members and to nonmembers at the direction of the LURE team.

LIBRATIONS

During FY'72 a numerically integrated physical libration program was received from UCLA. This program is undergoing changes and improvements necessary to make it compatible with the LSSDPS system of programs. Since present analytical theories do not have sufficient accuracy for the ranging experiment, in FY'73 new integrations of the lunar orbit will be matched with new

LIBRATIONS (continued)

integrations of the physical librations. These would be distributed in the same way that lunar ephemerides are distributed.

STELLAR OCCULTATIONS

The software modifications for processing stellar occultations will be tested for a modern photoelectric occultation event for which the resulting immersion and emersion timings with respect to atomic time are well known. The iteration for the theoretical occultation timings should converge to the observed times.

The data will be obtained partly by searching the open literature and partly by communication with observatories such as the Royal Greenwich Observatory and the U. S. Naval Observatory

16. REVIEW AND REPORTING

Reporting to NASA is accomplished bi-monthly through progress reports to the Executive Secretary of the Experiment Team and written narrative reports submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. PUBLICATIONS

Williams, J. G., Sinclair, W. S., Holdridge, D. B. and Slade, M.A., "Making Solutions from Lunar Laser Ranging Data," American Astronomical Society, Division on Dynamical Astronomy, Annual Meeting, College Park, MD, 2-3 March 1972

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15-04-72	383- 09-51	Precision Lunar Ephemeris		5 OF 6

MAJOR MILESTONES	PRIOR FY '72 QUARTER 1	2	3	4	CURRENT FY '73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY '74 QUARTER 1	2	3	4	FY '75 QUARTER 1	2	3	4	FY '76 QUARTER 1	2	3	4
Software development for observation application		▼																										
Provide range predictions to participants																												
Develop libration correction model			▽																									
Provide numerically integrated librations																												
Develop tidal dissipation in integrator			▽																									
Investigate differential correction techniques				▽																								
Improve lunar ephemeris with laser data		▽						▽						▽				▽		▽		▽		▽		▽		▽
Investigate earth's rotation													▽															
Collection of occultation data										▽																		
Analyze occultation data																		▽										

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▭▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▭▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15-04-72	383-09-51	Precision Lunar Ephemeris	6 OF 6

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY '75	FY '76
DIRECT PROFESSIONAL	2.0	2.5	3.0		
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	2.0	2.5	3.0		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY '72	FY '73	FY '74	FY '75	FY '76
R & D CONTRACTS					
IN-HOUSE SUPPORT	85	150	150		
TOTAL FUNDS	85	150	150		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

196

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15-04-72		383-09-51	383-09-51-01-55

5. TITLE

Precision Lunar Ephemeris (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Williams, J. G.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 6466	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72 (c)	85	
CURRENT FY '73 (c)	125	
NEXT FY '74 (c)	125	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10-0-70-10-10

1) Routine range predictions for McDonald and Haleakala Observatories
2) Improve solutions to lunar orbit with laser ranging and optical data.
3) Extend modelling to allow solving for orbit of earth, masses of earth and moon, relativity parameters, and rate of change of gravitational constant. Include tidal friction effects.
4) Continue working on numerically integrated librations.

10. JUSTIFICATION (WHY)

1) Range predictions needed to support laser ranging program.
2) The laser ranging data cannot be used to get geodetic, geophysical, and relativity results without also solving for the orbits and masses of the earth and moon and other sensitive quantities.
3) The presently used series for libration is less accurate than the laser data. A numerical integration can improve the libration modelling.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

1) Routine predictions for ranging four reflectors from McDonald Observatory
2) Addition of ability to solve for observatory coordinates, reflector coordinates, and libration parameters to ability to solve for the orbit. Corrections now made for UT1, polar motion, and atmosphere.
3) Solutions made from laser data and new ephemerides generated.
4) Modification of UCLA program for numerically integrating the lunar librations
5) Extension of lunar state partial derivatives tape.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 - 4 - 72			383-09-51-05-55

5. TITLE

Stellar Occultations by the Moon (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Slade, M.A.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 -2841	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72	--	--
CURRENT FY 73 (n)	25K	--
NEXT FY 74 (c)	25K	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 10 - 0 - 60 - 25 - 5

Occultations of stars by the moon provide a data type which is very sensitive to the angular position of the moon in its orbit. For example, photoelectric timings of the occultation have a precision of ~ ± 0.002 seconds, or ± 0".001. A visual observation is typically ~ 100 times less precise.

Existing software at JPL can be modified to treat this data. Obtaining the data from other institutions such as the U. S. Naval Observatory, and conversion to a standard format will be a significant part of this task. Processing this data will lead to a credible estimate of the quadratic term in the moon's mean longitude, currently uncertain by ~ 50%.

10. JUSTIFICATION (WHY)

An accurate knowledge of the quadratic term in the mean longitude has strong implications for the understanding of tidal friction in the earth-moon system. (The major effect is a torque on the moon due to frictionally delayed tides on the earth.) The mean longitude is the observable which is most sensitive to tidal frictions, since the effect amounts to the equivalent of ~ 40 kilometers in a century according to current estimates. The change in mean semi-major axis, to which the laser ranging experiment is primarily sensitive, amounts only to 3 meters per century. Knowledge of tidal friction is crucial however, if a scientific goal of the Lunar Ranging Experiment (LURE) - the determination of the time variation in the gravitational constant G-is to succeed. Tidal friction also is important in understanding the dissipation of energy in the earth's mantle, as represented by the quality factor Q.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

New Task

198

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		42-28	383-09-55

5. TITLE

INTERPRETATION OF APOLLO RESULTS

6. RELATED SUBPROGRAMS (IF APPLICABLE)
195-42

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
006800

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 -3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The results of the analysis of returned lunar samples and other geophysical data are yielding a quantitative model of the lunar thermal history. Deciphering the moon's thermal history appears at present the best means of unravelling its origin and evolution of that body, and perhaps by analogy obtaining clues to the history of the terrestrial planets as well. This thermal-history approach provides models making specific testable predictions about the present physical state of the lunar interior, surface heat flow and past chronology of igneous activity. This effort will extend past theory by the incorporation of results from the Apollo missions.

Additionally one man-year is provided to support ad hoc NASA assignments for review and interpretation of Apollo scientific data and providing of science oriented written material for NASA use.

13. KEYWORDS
Lunar Sample Analysis, Thermal History

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald P. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

This study will produce a better understanding of the origin and thermal evolution of the moon, together with suggestions for future experiments to test the models developed. Understanding the origin and evolution of the moon requires a coherent model which accounts for known facts about lunar history. Such a model should be capable of providing specific testable predictions for each possible mode of lunar origin, in addition to accounting for known facts about past and present state. The testing of such predictions can form the basis of a continuing program of lunar exploration. The purpose here is (1) to the extent possible provide a picture of lunar origin and evolution consistent with what we have thus far learned from Apollo returned sample analysis; (2) to provide the relevant theory (thermal calculations); (3) provide inputs on relevant laboratory research; and (4) offer suggestions where possible on what further lunar measurements should be made.

15. OPERATING PLAN

A. Objectives

Through the collection of scientific data and by the exercise of the scientific method it is anticipated that the moon's thermal history may be elucidated. Any model of the thermal and physical state of the interior of the moon which might result will be tested by experiment and observation.

B. Technical Approach

Geochronological and petrological results from all Apollo missions will be a major part of the scientific data needed to carry out this study. A continuous literature search will be made and discussions with principal investigators and the scientific community will be held. Thermal computations will be carried out and relevant small-scale laboratory research will be undertaken. The results will be reported both in the scientific literature and in JPL reports.

In addition to the Apollo results, the principal data presently available include: (a) the chronology of igneous activity in early lunar history, (b) the K/U systematics of lunar material, (c) information on the bulk lunar U abundance, (d) present estimates of the lithology of the near-surface stratigraphic column, (e) the present thermal state of the lunar interior, to the extent that this may be deduced by analysis of the interaction of solar wind electromagnetic fields with the moon, and by interpretation of lunar seismic activity, (f) the apparent global character of lunar thermal remnant magnetism, (g) the generally low level of near-surface radioactive elements in highland regions. Parameters less well constrained are: (a) the initial temperature profile, and (b) the physical nature of the boundary conditions in such models.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

Work in this program has resulted in a report (JPL 900-522) "Physical Constraints on Lunar Thermal History: An Analysis of Results from Investigation of Lunar Samples and Geophysical Data" prepared in January. This is currently being revised and extended for journal publication. A paper by consultant Prof. R. A. Lyttleton, "On the Formation of Planets from the Solar Nebula" was prepared for publication. This work deals with accretion of planetary objects, and provides new insights into this difficult, but crucial subject. The work can eventually be used to establish approximate initial lunar temperature profiles for accretion models.

17. PUBLICATIONS

A. Journal Articles

1. Lyttleton, R. A., On the Formation of Planets from a Solar Nebula, Monthly Notices, Royal Astron. Soc. In Press.

B. Meetings and Symposia

1. Goetz, A. F. H., Description of an Anomalous Region in the Lunar Highlands from Ground Based and Orbital Measurements, Am. Astronomical Soc., Kona, Hawaii, March 1972.

2. Phillips, R. J. and J. E. Conel, Least Squares Inversion of Lunar Gravity Data, Fall Meeting of Am. Geophysical Union, December 1971.

3. Phillips, R. J., Radar Experiments for Outer Planets Missions, URSI-PGAP, Radio Propagation Meeting, UCLA, 23 September 1971.

C. JPL Reports

1. Conel, J. E., F. P. Fanale, and R. J. Phillips, Physical Constraints on Lunar Thermal History: An Analysis of Results from Investigation of Lunar Samples and Geophysical Data, JPL Technical Report 900-522, January 1972.

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	383-09-55	INTERPRETATION OF APOLLO RESULTS	4 OF 4

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY	FY	FY
DIRECT PROFESSIONAL		1.8			
DIRECT SUPPORT		-			
TOTAL DIRECT MAN YEARS		1.8			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT		100			
TOTAL FUNDS		100			

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	608-55510-0-8260	N/A	383-09-55-01-55

5. TITLE

INTERPRETATION OF APOLLO RESULTS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Conel, James E.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 -4516	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	38	
CURRENT FY 73 (c)	50	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 50-0-0-50-0

This task is a continuing attempt at interpretation of the results of lunar sample analysis and other geophysical data to yield a quantitative model of lunar thermal history. Deciphering the moon's thermal history appears at present the best means of unravelling its origin and evolution of that body, and perhaps by analogy obtaining clues to the history of the terrestrial planets as well. A thermal-history approach, while by no means free of difficulties, provides models making specific testable predictions about the present physical state of the lunar interior, surface heat flow and past chronology of igneous activity. Past work along these lines needs to be revised both by extension of the theory and most importantly by incorporation of results from other Apollo missions.

10. JUSTIFICATION (WHY)

Understanding the origin and evolution of the moon requires a coherent model which accounts for known facts about lunar history. Such a model should be capable of providing specific testable predictions for each possible mode of lunar origin, in addition to accounting for known facts about past and present state. The testing of such predictions can form the basis of a continuing program of lunar exploration. The purpose here is (1) to the extent possible provide a picture of lunar origin and evolution consistent with what we have thusfar learned from Apollo returned sample analysis; (2) to provide the relevant theory (thermal calculations); (3) provide inputs on relevant laboratory research, and (4) offer suggestions where possible on what further lunar measurements should be made.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

During calendar year 1971, thermal models were constructed based largely on geochronologic and petrologic results of Apollo 11, 12, and 14 sample analyses and upon various geophysical data including ALSEP results and gravity measurements from lunar orbiters. The presence and/or absence of a thermally insulating outer surface layer in the early thermal history emerged as a crucial constraint. A report (JPL 900-522) "Physical Constraints on Lunar Thermal History: An Analysis of Results from Investigation of Lunar Samples and Geophysical Data" was prepared in January. This is currently being revised and extended for journal publication. A paper by consultant Prof. R. A. Lyttleton, "On the Formation of Planets from the Solar Nebula" was prepared for publication. This work deals with accretion of planetary objects, and provides new insights into this difficult, but crucial subject. The work can eventually be used to establish approximate initial lunar temperature profiles for accretion models

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15/04/72	608-55513-0-1300	383-09-55-03-55	383-09-55-03-55

5. TITLE
Lunar Science Studies

6. RESPONSIBLE NASA ORGANIZATION
NAME
JET PROPULSION LABORATORY
California Institute of Technology
ADDRESS
4800 Oak Grove Dr. / Pasadena, Calif. 91103
RESPONSIBLE INDIVIDUAL Brereton, R. G.
TELEPHONE 213 - 354 - 4257

7. CONTRACTOR (IF APPLICABLE)
NAME
ADDRESS
PRINCIPAL INVESTIGATOR
TELEPHONE

CONTRACT NO.
CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72	42	
CURRENT FY '73	50	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

To provide document entitled "Lunar Exploration 1972, Our Present Knowledge of the Moon." It is expected that, on NASA ad hoc assignments in FY'73, approximately 90 percent of effort will go towards providing documents on interpretation of Apollo results and 10 percent on lunar science planning.

10. JUSTIFICATION (WHY)

This work is an outgrowth of NASA Headquarters need for current lunar scientific information and for documentation of Apollo results in response to ad hoc requests.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

1. Provided end of year resume of Apollo scientific results/2. Provided technical review of third Lunar Science Conference/3. Published Apollo Science Review in QTR 2-1 1972/4. Assistance given in preparation of congressional material/5. Provided science documentation support as required.

204

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41	384-50-71

5. TITLE
PLANETOLOGY DATA ANALYSIS

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
007100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The objective of this task is to delineate the major crustal provinces of Mars and, by analogy with geologic features of the Earth and the Moon, to infer (1) the physical processes which act, now or in the past, at the surface of Mars, (2) the nature of the surface materials, and (3) the sequence of events, i.e., geologic history, which led to the present surface.

The primary source of data will be Mariner 9 pictures. Cooperation and coordination with the MM'71 investigators in all disciplines will be emphasized.

13. KEYWORDS
Mars, Surface Geology, Photo Interpretation

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION

A geologic map of the entire planet is useful for formulating and directing further analysis of the Mariner 9 data. From such a map many testable models can be developed and pursued. For example, the geologic map can aid in the selection of areas to be studied in detail for representative crater density studies or lineament studies. The geologic map can also serve as a point of departure or at least provide a common ground for discussion of map units among the geologists who will compile the 1:5 million scale maps of the planet. Finally, the geologic map of the entire planet is useful as a base for other types of data: gravity, albedo, meteorologic variable features, topography, UV spectrometer, IR interferometer-spectrometer, etc. In the interpretation of the findings, geologic similarities and differences in the development of the Earth, Moon, and Mars will be emphasized.

15. OPERATING PLAN

A. Objectives

A 1:25 million scale structural map and map of geologic provinces of Mars will be compiled from all data sources (primarily MM'71). A 1:5 million scale map will be initiated during this period as part of the Mars systematic geologic mapping program.

B. Technical Approach

The following techniques and data types will be integrated into the final maps.

1. Photo interpretation of MM'71 pictures using lunar and terrestrial analogues where appropriate, or for purposes of clarification of geologic models.
2. Crater diameter distribution in selected areas.
3. Crater morphology.
4. Elevation data.
5. Radar RMS shape and roughness.
6. Color and albedo
7. Lineament and fault patterns.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	384-50-71	PLANETOLOGY DATA ANALYSIS	3 OF 3

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
DIRECT PROFESSIONAL	1.0	0.8	0.8		
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	1.0	0.8	0.8		

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	50	40	40		
TOTAL FUNDS	50	40	40		

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

207

jpl → RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	609-57110-0-8260	N/A	384-50-71-01-55

5. TITLE
MARS PHOTOGEOLOGY INTERPRETATION (N)

6. RESPONSIBLE NASA ORGANIZATION
NAME
JET PROPULSION LABORATORY
California Institute of Technology
ADDRESS
4800 Oak Grove Dr. / Pasadena, Calif. 91103
RESPONSIBLE INDIVIDUAL Saunders, R. S.
TELEPHONE 213 - 354 - 3815

7. CONTRACTOR (IF APPLICABLE)
NAME
ADDRESS
PRINCIPAL INVESTIGATOR
TELEPHONE
CONTRACT NO.
CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	50	
CURRENT FY 73 (c)	40	
NEXT FY 74 (c)	40	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 20-0-50-30-0

(1) Compilation of 1:25 million scale structural map and map of geologic provinces of Mars as contribution to MM'71 TV experiment final report and eventually as more complete separate publication.

(2) Comparative analysis of structural style of various regions of Mars. Classification and interpretation of surface features.

10. JUSTIFICATION (WHY)

The geologic map of the entire planet helps to direct further studies of particular interest and provides the geologic framework for topical studies. By discussions among participating geologists of geologic units on a planetwide scale, the 1:5 million systematic geologic mapping can be better coordinated. Regional geologic patterns can aid in interpretation of gravity data obtained from tracking the MM'71 spacecraft.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A preliminary map of Mars' geologic provinces has been compiled from MM'71 pictures. Programs have been developed for direct analysis of MM'71 pictures using a digitizer. These programs allow rapid and accurate determination of structural patterns and crater distributions.

208

RESEARCH AND TECHNOLOGY OPERATING PLAN

Addendum

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		10, 41	384-50-71 Addendum 1

5. TITLE
Planetology Data Analysis

6. RELATED SUBPROGRAMS (IF APPLICABLE)
185-50

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
007100

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

The mysteries of Mars are abundant in the data acquired by Mariner Mars '71. The unraveling of the processes that have brought Mars to its present state, the comparison of models with Earth and lunar physics to derive implications applicable to solar system evolution requires interdisciplinary analysis. Sophisticated software for deriving mass distribution from tracking data; and for storing, cataloging, indexing, sorting and retrieving data have been developed in the MM'71 and other programs. Geologic interpretation and documentation from analysis of MM'71 pictures has been initiated. The objectives of the proposed tasks are to utilize the developed software to provide level of effort support to non-MM'71 investigators for image processing, to retrieve supporting data and results, to extend geologic interpretation of gravity data to Mars, and to evaluate the depth of the regolith. Throughout, extensive cooperation and coordination with the MM'71 investigators in all disciplines will be emphasized.

13. KEYWORDS
Mars, Surface Geology, Photo Interpretation, Management Information Systems

PROPRIETARY INFORMATION CONTAINED IN RTOP ☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Roe ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. JUSTIFICATION

Each image, each spectrum acquired by the MM'71 instrument payload has associated with it a list of navigation and engineering parameters. These parameters relate to where on the planet the measurement was made, attendant viewing geometry and other data critical to interpretation of the measurement unit. Automated cataloging, indexing, searching, and retrieval software has been developed and is called the MM'71 LIBSET-MARK IV system. Non-MM'71 investigators analyzing MM'71 data will find accessing these supporting files essential to their selection and interpretation of interesting MM'71 data.

The gravity field of Mars, like that of the Moon and the Earth gives an indication of inequalities of material distribution within the body. An inequality of mass per unit area, i.e., an indication of non-isostasy, is an indication that special conditions of material strength or other means of supporting anomalous loads exist in the planetary interior. On the other hand, it is important to establish whether isostatic conditions prevail both locally and on a regional basis. The first step in understanding the "geologic" significance of lumps in the Martian gravity field is to demonstrate their existence and character, their correlations if any with topographic features, and then attempt to locate and define the geometry of the anomalous bodies. Once this is accomplished we may proceed to investigate their significance for Martian history.

Better understanding of the depth and nature of the regolith will help in understanding the processes that have shaped the surface of Mars. It should help in distinguishing effects of atmospheric and external processes from those of internal processes. Further, it should be helpful in planning future missions and experiments. This applies particularly to the possibility of reaching bedrock, which is of great geological importance.

15. OPERATING PLAN

A. Objectives

Non-MM'71 investigator analysis will be supported by Science Ground Data Handling. Documentation and liaison will appraise users of the capabilities available from the LIBSET-MARK IV System.

Radio tracking data from MM'71 will be used to study the Martian gravity field and to correlate the obtained information with planetary shape and surface structure.

The depth and nature of the regolith will be evaluated from the imagery.

B. Technical Approach

The specific tasks included are:

1. Level of effort support will be provided by Science Ground Data Handling personnel trained in usage of the MM'71 developed LIBSET-MARK IV software. Comparable computer time will be available to service user requests.

2. Gravity data analysis will employ methods exactly analogous to those developed by Muller and Sjogren (1968) and Phillips and Conel (1971) for obtaining gravity effects from Doppler data and analyzing these in terms of "anomalous" mas distributions.

3. To determine regolith depth and nature, sharpness of small craters in MM'71 and previous imagery will be compared quantitatively with pictures of laboratory craters with known amounts of overlay and mass-wasting. This technique was successfully used for the Moon with Ranger pictures (Jaffe, 1965, 1966). More recent work on crater shapes will help improve the technique.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

211

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	Addendum 1 384-50-71	Planetology Data Analysis	4 OF 4

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY	FY	FY
DIRECT PROFESSIONAL		2.7			
DIRECT SUPPORT		0.1			
TOTAL DIRECT MAN YEARS		2.8			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY 73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT		183			
TOTAL FUNDS		183			

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY 73	FY	FY	FY
TOTAL MAN YEARS		1.5			

212

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	Addendum 1 384-50-71-WW

5. TITLE
MARS REGOLITH (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Jaffe, L. D.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 -3725	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	16	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

To determine regolith depth and nature, the sharpness of craters in MM'71 and earlier pictures will be compared quantitatively with that in pictures of laboratory crater models with known amounts of overlay. This technique was successfully used to determine regolith depth on the moon before the first lunar landings (L. D. Jaffe, J.G.R. 70, 6129 (1965); 71, 1095 (1966); Icarus, 5, 545 (1966)); the results were confirmed by subsequent landings. More recent work on lunar and martian crater shapes will help in improving the technique. Mass-wasting will be modeled experimentally as well as overlay. The resolution of available pictures appears adequate. Pictures of bowl-shaped craters 0.3-5 km in diameter in cratered terrain will be examined first, then pictures of larger flat-bottomed craters and of other terrain types. Other types of information, such as reflection and thermal emission data, including IRR, will be considered as supplementary.

20-0-30-50-0

10. JUSTIFICATION (WHY)

Better understanding of the depth and nature of the Mars regolith will help in understanding the processes that have shaped the surface of Mars. It should help in distinguishing effects of atmospheric and external processes from those of internal processes. Further, it should be helpful in planning future missions and experiments. This applies particularly to the possibility of reaching bedrock, which is of great geological importance.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72			Addendum 1 384-50-71-XX

5. TITLE

IPL PROCESSING AND ANALYSIS SUPPORT (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Green, W. B.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 5016	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	63	
NEXT FY 74 (c)	210	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

The full software capability of the Image Processing Laboratory and analyst support will be made available to non-MM'71 television experiment investigators to support scientific analysis of the MM'71 television data. Capabilities to be made available include contrast enhancement, special filtering, image differencing, picture element listings and plots, mapping projections, contouring, color ratio and reconstruction, and limited software development. Due to the existing commitment of IPL 360/44 time in FY 73, sufficient funding to allow utilization of other computer facilities has been included in the cost of this task.

10. JUSTIFICATION (WHY)

The large quantity of available MM'71 data makes possible detection and analysis of details of the Martian environment. Many of the planetary and atmospheric characteristics manifest themselves subtly in the raw or recalibrated image data and require significant computer processing to be fully understood. This task makes available the required tools for detailed qualitative and quantitative analysis of the MM'71 data for use by scientists outside the MM'71 television experiment team.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72			Addendum 1 389-50-71-YY

5. TITLE

MARINER '71 INFORMATION SYSTEM (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Sander, M. J.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 4703	TELEPHONE:

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	55	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW)

The MM'71 developed LIBSER-MARK IV system will be available to support MM'71 data analysis by non-MM'71 investigators. Level of effort support by personnel trained in usage of the LIBSET-MARK IV software will be provided to service user requests. A document appraising users of the system capability and file content will be written and distributed. Additionally, tables and other displays that index data and analyzed results will be provided.

10. JUSTIFICATION (WHY)

Each image, each spectrum acquired by the MM'71 instrument payload has associated with it a list of navigation and engineering parameters. These parameters relate to where on the planet the measurement was made, attendant viewing geometry and other data critical to interpretation of the measurement unit. Automated cataloging, indexing, searching, and retrieval software has been developed and is called the MM'71 LIBSET-MARK IV system. Non-MM'71 investigators analyzing MM'71 data will find accessing these supporting files essential to their selection and interpretation of interesting MM'71 data.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

The MM'71 developed LIBSET-MARK IV system has enabled MM'71 investigators to access a file of measurement unit supporting data structured according to user need rather than solely from file construction constraints. The flexibility of file content, indexing, and display provides analysis support of new dimensions.

215

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	Addendum 1 389-50-71-ZZ

5. TITLE
MARS GRAVITY ANALYSIS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME JET PROPULSION LABORATORY California Institute of Technology	NAME CONTRACT NO. CONTRACT START DATE
ADDRESS 4800 Oak Grove Dr., Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL Phillips, R. J.	PRINCIPAL INVESTIGATOR
TELEPHONE 213 - 354-4973	TELEPHONE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY		
CURRENT FY 73 (n)	49	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 50-0-0-50-0

Radio tracking data from MM'71 will be used to study the Martian gravity field and correlate the results so obtained with planetary shape, surface morphology and geology. The methods employed for analysis of gravity data will be analogous to those developed by Muller and Sjogren (1968) and Phillips and Conel (1971) for obtaining gravitational fields from Doppler data, and analyzing these fields in terms of the mass distribution on a planet. Such approaches require inversion of the Doppler data to construct geophysical models. Such models are tested for uniqueness, resolution, and variance before being correlated with other observables. The work proposed will be a joint effort of the Planetology Group, J. Conel, R. Phillips, S. Saunders, and members of the Tracking and Orbit Determination Section associated with the MM'71 Celestial Mechanics Team - J. Lorell, W. Sjogren, and J. Anderson. In particular, the coordinated effort will allow a blend of geophysical and geological experience with the experience of deriving gravitational fields from spacecraft Doppler measurements.

10. JUSTIFICATION (WHY)

The gravity field of Mars, like that of the Moon and the Earth gives an indication of inequalities of material distribution within the body. An inequality of mass per unit area, i.e., an indication of non-isostasy, is an indication that special conditions of material strength or other means of supporting anomalous loads exist in the planetary interior. On the other hand, it is important to establish whether isostatic conditions prevail both locally and on a regional basis. The first step in understanding the "geologic" significance of variations in the Martian gravity field is to demonstrate their correlations if any with topographic features, and then attempt to locate and define the geometry of the anomalous masses. Mass anomalies can be indicative of mechanisms and rates of mass transport, interior convection, tectonic and volcanic activity.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Analysis of MM'71 tracking data and its interpretation in terms of actual geologic structure is a new task. However, all of the necessary software for establishing unique surface mass distributions directly from Doppler data has been developed for an analogous program carried out for lunar mascons. In this latter program it has been possible to locate unique surface mass distribution satisfying the geophysical and morphological data, and to eliminate several proposed models of mascon geometry and formation. It is to be expected that a similar analysis of Martian data would lead to useful results and eliminate many of the pitfalls and false paths followed in similar analyses and interpretations of the lunar gravitational data.

216

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41	384-50-71 Addendum 2

5. TITLE

Planetology Data Analysis

6. RELATED SUBPROGRAMS (IF APPLICABLE)

N/A

7. RELATED RTOP'S (IF APPLICABLE)

N/A

8. CONSOLIDATION OF RTOP NO'S.

N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

002000 (Astronomy), 002200 (Atmospheric Physics) 007100 (Geology)

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL

NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

OBJECTIVES: The objectives of this task are (a) to develop, test and document computer programs to perform cartographic projections of images to be returned from the MVM73 mission and (b) to specify requirements for the MVM73 Television Supplementary Experiment Data Record data content and accuracy that are imposed by the projection software requirements.

APPROACH: The Image Processing Laboratory will provide programming and analysis support and the required computer time and facility support to achieve the task objectives. A major activity will be the conversion of MM71 projection programs to be operable on data to be returned by MVM73. Other activities will include development of a computer algorithm for projection of the MVM73 quarter-frame format and the definition of an acceptable frame format for projected images with the Imaging Experiment Team.

13. KEYWORDS

VENUS, MERCURY, IMAGE PROCESSING, CARTOGRAPHIC

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION:

The MVM73 Imaging Team has projected their requirements for mosaicking of Venus and Mercury images, and it is estimated that computer cartographic projection of approximately 200 Venus frames and approximately 680 frames from Mercury will be required to prepare the final mosaics of both planets to be constructed. The long focal length of the camera systems and the quarter frame strip image format present new demands on the accuracy required for computer projection of the images. It is thus necessary to have an early effect on the design of the overall mission data processing procedures to insure that the data required for computer cartographic projections will be included in the Television Supplementary Experiment Data Record (TV SEDR); it is particularly important that those data quantities specifically required to generate the parameters required to perform the computer geometric transformations be included in the TV SEDR and that they meet the stringent accuracy requirements of the MVM73 mission.

Once an acceptable TV SEDR data content has been established, the projection software written for MM71 by the Image Processing Laboratory will be modified and simulation runs can then be made to assist the experiment team in their planning of mosaicking activities that are based on utilizing MVM73 data.

15. OPERATING PLAN:

The following specific tasks are proposed for this work unit:

1. Specification of data quantities to be provided in the MVM73 Television Supplementary Experimenter Data Record (TV SEDR) that are required for accurate computer projection of individual frames. This task will consist of:

   (a) Analysis to determine required data and sequence modelling to determine probable distribution of pictures for mosaicking.
   (b) Generation of document specifying the quantities required, the accuracy requirements, and the number of significant digits required for each variable

   (c) Test of mapping projection software using simulated TV SEDR data

2. Modification of MM71 software to perform the following projections: (a) Orthographic, (b) Mercator, (c) Polar Stereographic, (d) Lambert Conformal. This task will consist of:

   (a) Write, checkout and document subroutine to read MVM73 TV SEDR quantities as specified in task 1, and generate Geometric Transformation Parameters

   (b) With the MVM73 Imaging Team, arrive at an acceptable image format (including labelling) for projected images and modify MM71 software accordingly

   (c) Demonstration of each projection utilizing MVM73 simulated TV SEDR data or (if TV SEDR is not available) equivalent input data

3. Design of computer algorithm to utilize TV SEDR data for projection of MVM73 quarter-frame image format.

Current estimates of FY73 support requirements include:

0.6 MY: Programming and Analysis

0.2 MY: Support of TV Experiment Representative for interaction with Imaging Team members

0.2 MY: Task Coordination

0.2 Contractor MY: Computer and film recorder operations support

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	Addendum 2 384-50-71	Planetology Data Analysis		4 OF 5

MAJOR MILESTONES	PRIOR FY ____ QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	NEXT FY ____ QUARTER 1	2	3	4
Analysis to determine required SEDR data																				
Requirements document for TV SEDR issued																				
Modify MM71 software																				
Define Labelling with TV Team																				
Receive Simulated SEDR Data																				
Demonstrate software with simulated data																				
Design Algorithm for Quarter frame format																				
Program and checkout quarter frame algorithm																				
Demonstrate quarter frame algorithm																				
Final Report & Software Documentation released																				
Support Imaging Team Mosaicking Simulation																				

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEUDLE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

219

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	Addendum 2 384-50-71	Planetology Data Analysis	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR FY 72	CURRENT FY 73	FISCAL YEAR FY	FY	FY
DIRECT PROFESSIONAL		1.0			
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS		1.0			

B. FACILITIES

C. R & D FUNDS

	PRIOR FY 72	CURRENT FY 73	FISCAL YEAR FY	FY	FY
R & D CONTRACTS	0	0			
IN-HOUSE SUPPORT	0	45			
TOTAL FUNDS	0	45			

R & D CONTRACTS ($100K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR FY 0	CURRENT FY 0.2	FY	FY	FY
TOTAL MAN YEARS					

221

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72		N/A	Addendum 2 384-50-71-AA

5. TITLE

COMPUTER CARTOGRAPHIC PROJECTIONS FOR PLANETARY MOSAICS (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME: N/A
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS:
RESPONSIBLE INDIVIDUAL: Green, W.B.	PRINCIPAL INVESTIGATOR:
TELEPHONE: 213 - 354 - 5016	TELEPHONE: 60-0-30-0-10

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72	0	0
CURRENT FY 73 (n)	45	0
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) The objectives of this task are (a) to develop, test and document computer programs to perform cartographic projections of images to be returned from the MVM73 mission and (b) to specify requirements for the MVM73 Television Supplementary Experiment Data Record data content and accuracy that are imposed by the projection software requirements.

The Image Processing Laboratory will provide programming and analysis support and the required computer time and facility support to achieve the task objectives. A major activity will be the conversion of MM71 projection programs to be operable on data to be returned by MVM73. Other activities will include development of a computer algorithm for projection of the MVM73 quarter-frame format and the definition of an acceptable frame format for projected images with the Imaging Experiment Team.

10. JUSTIFICATION (WHY) The MVM73 Imaging Team has projected their requirements for mosaicking of Venus and Mercury images, and it is estimated that computer cartographic projection of approximately 200 Venus frames and approximately 680 frames from Mercury will be required to prepare the final mosaics of both planets to be constructed. The long focal length of the camera systems and the quarter frame strip image format present new demands on the accuracy required for computer projection of the images. It is thus necessary to have an early effect on the design of the overall mission data processing procedures to insure that the data required for computer cartographic projections will be included in the Television Supplementary Experiment Data Record (TV SEDR); it is particularly important that those data quantities specifically required to generate the parameters required to perform the computer geometric transformations be included in the TV SEDR and that they meet the stringent accuracy requirements of the MVM73 mission.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

N/A

R & AD WORK UNIT SCHEDULE

NASA Code 384-50-71-AA JPL Code: _____ Resp. Indiv. W. B. Green Ext: 5016

Title: COMPUTER CARTOGRAPHIC PROJECTIONS FOR PLANETARY MOSAICS Date: 15 04 72

Revision No:

Major Milestones	Prior FY Quarter 1	2	3	4	Present Fiscal Year 73 Month J	A	S	O	N	D	J	F	M	A	M	J	Next FY Quarter 1	2	3	4
Analysis to determine required SEDR data																				
Requirements document for TV SEDR issued																				
Modify MM71 software																				
Define Labelling with TV Team																				
Receive Simulated SEDR Data																				
Demonstrate software with simulated data																				
Design Algorithm for Quarter frame format																				
Program and checkout quarter frame algorithm																				
Demonstrate quarter frame algorithm																				
Final Report & Software Documentation released																				
Support Imaging Team Mosaicking Simulation																				

Notes:

222

JPL T 10035 (2-68)

223

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		41,47	385-36-00

5. TITLE
Magnetospheric Physics Data Analysis

6. RELATED SUBPROGRAMS (IF APPLICABLE)
N/A

7. RELATED RTOP'S (IF APPLICABLE)
N/A

8. CONSOLIDATION OF RTOP NO'S.
N/A

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002100, 016600, 013000

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

This task provides for further reduction, analysis, and interpretation of scientific data obtained by the OGO search coil magnetometers, the Mariner vector helium magnetometer, and the OGO 5 plasma spectrometers.

In the magnetic field area, this task includes the investigation of several species of plasma waves: 1) persistent plasmaspheric hiss (OGO-5), 2) intense magnetotail emissions generated sporadically during substorms (OGO-5), 3) intense emissions ("Lion Roars") generated within the magnetosheath (OGO-5), 4) persistent, low altitude hiss with and without a sharp low frequency cutoff (OGO-6). The analysis of the OGO-6 data includes a study of simultaneous electric field measurements carried out by a UCB experiment on another polar-orbiting satellite. The Mariner 5 magnetometer and plasma data are being used in conjunction with Explorer 33, 35 plasma and magnetic field data to analyze sector boundaries in the interplanetary magnetic field.

The OGO 5 plasma data are used 1) to study the internal structure of the earth's bow shock, of the earth's magnetopause, and of discontinuities in the solar wind, 2) to provide near-earth baseline data for comparison with simultaneous solar wind data from Pioneer 9 and the ALSEPs, 3) to correlate with other OGO 5 experiments to understand the many field-particle interactions occurring in the interaction of the solar wind with the earth's magnetic field, 4) to extend power spectral analysis of the interplanetary medium to the frequency regime of radio scintillation measurements, and 5) to study the relative variations of protons and alpha particles in the solar wind.

The work will be performed at JPL in collaboration with university coinvestigators. The task will provide material for the NSSDC and publishable scientific results.

13. KEYWORDS Solar wind, interplanetary magnetic fields, OGO plasma/magnetic field data, wave-particle interactions, magnetospheric emissions

PROPRIETARY INFORMATION CONTAINED IN RTOP ☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	4/3/72		

14. Justification

It has been NASA policy to have the cognizant center fund the initial analysis of scientific data obtained by satellites and space probes. This task continues the analysis and interpretation of space data beyond the period of financial support by the project.

In particular, the program of basic research in space plasma physics and auroral and magnetospheric phenomena is continued and extended. For the magnetometer experiments, the reduced data are now all available in a form suitable for analysis and physical interpretation. Computer programs are operational, e.g., those which use the triaxial waveforms to compute the polarization and direction of propagation of the waves. These capabilities should now be exploited to bring the scientific investigations to fruition.

As of March 1, 1972, approximately 60% of the OGO 5 solar wind positive ion data have been reduced to an easily usable form. This task will continue this reduction and produce a similar reduction of the electron data. The payoff of this task lies in the scientific analysis of these reduced data, which are unique with respect to their high time resolution and the opportunity for correlation with data from a large number of other highly sophisticated fields and particles experiments on the same satellite.

15. Operating Plan

A. Objectives

1) To continue the reduction, analysis, and interpretation of data obtained by search coil magnetometer experiments in the frequency range .01 to 1000 Hz on OGO 1-6. To continue the analysis and interpretation of magnetic field data from Mariner 5. 2) To correlate the magnetometer data with simultaneous charged particle and field measurements on the OGOs, Mariners, and other spacecraft (Pioneer, etc.) 3) To determine the essential properties of naturally-occurring, extremely-low-frequency (ELF) waves, their origin, mode of propagation and relation to thermal and superthermal charged particles. 4) To study the average spectra of sferics, hiss and chorus to determine their intensity, peak frequency and bandwidth, and dependence on magnetic latitude, local time and magnetic activity. 5) To determine the direction of propagation and polarization of hiss, chorus and sferics. 6) To seek inter-satellite correlations between emissions measured at low altitude on OGO-6 and simultaneous observations by a nearly identical instrument on OGO-5 at large geocentric distances. 7) To seek correlations between OGO data and simultaneous measurements on the same and other satellites of fields, particles and auroral phenomena. 8) To continue OGO-ALSEP correlations of solar wind data, with special emphasis on ALSEP sunset and sunrise times to search for limb shocks and other effects. 9) To continue to OGO/Pioneer correlations to study the dependence of solar wind variations on distance from the sun. 10) To study high frequency fluctuations in the interplanetary plasma. 11) To study the internal structure of the earth's magnetopause. 12) To study the relative variations of helium and hydrogen ions in the solar wind. 13) To prepare and deliver magnetic tapes and other appropriate material to the National Space Science Data Center. 14) To report the results of the data analysis to the scientific community by publication and oral presentation.

B. Technical Approach

The OGO magnetometer data analysis will be continued as a collaboration with R. E. Holzer of UCLA (who is to be funded separately by NASA). OGO data have been reduced and merged with trajectory parameters and the various regions of space (magnetosphere, magnetosheath, etc.) have been identified. Some of the digital data will be analyzed at JPL under the direction of E. J. Smith. Analog, special purpose telemetry data will be analyzed at JPL to supplement the reduction and analysis being carried out at UCLA. The data to be analyzed and the nature of the analysis are coordinated with UCLA in order to enhance mutuality of interest, prevent unnecessary redundancy of effort, etc. Several of the investigations are done in collaboration with UCLA. A theorist (R. M. Thorne, UCLA) hired as a consultant assists in interpreting the data.

The Mariner magnetometer data analysis is a continuing collaboration with L. Davis, Jr., of Caltech, P. J. Coleman, Jr., of UCLA, and D. E. Jones of BYU. Scientific areas for which JPL will assume primary responsibility are identified by agreement with the co-investigators. The magnetic field data will be combined with simultaneous plasma and field measurements on Mariner 4, 5 and other spacecraft. Correlations with simultaneous particle measurements will be studied in collaboration with the appropriate investigators.

The further reduction of positive ion spectra from OGO 5 to the form of velocity, temperature, and density vs. time will continue. Computer programs to produce visual displays (plots) of these reduced data will be developed. These data, the plots, and related documentation will be submitted to NSSDC.

Positive-ion data from the Faraday cup on OGO 5 are being compared with simultaneous data from the OGO 5 fluxgate and search coil magnetometers to determine the structure and stability of the earth's magnetopause and the field-particle interactions occurring within it.

Comparisons are being made between the OGO 5 and Pioneer 9 plasma data when the two spacecraft are close to the same streamline but at different radial distances from the sun.

Power spectra of the solar wind flux are being computed from OGO 5 data for frequencies up to 14 Hz. Density and velocity fluctuation spectra will be computed up to 0.1 Hz. Eventually, cross spectra will also be computed. Comparisons will be made with spectra obtained at different distances from the sun (Pioneer 9) and on the lunar surface (ALSEP).

The positive-ion solar wind data are being analyzed to search for the source of variations in the ratios of alpha to proton densities, temperatures, and velocities.

16. Review and Reporting

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in the open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested. Activities and progress at UCLA will be reported elsewhere.

17. Publications

K. W. Chan, R. K. Burton, R. E. Holzer, and E. J. Smith, "Measurement of the Wave Normal Vector of Proton Whistlers: OGO-6," J. Geophys. Res., 1971.

J. T. Gosling, V. Pizzo, C. W. Snyder, and M. Neugebauer, "27-Day Recurrences in the Solar Wind: Mariner 2," J. Geophysical Res. (submitted).

R. W. Fredericks, F. L. Scarf, C. T. Russell, and M. Neugebauer, "Detection of Solar Wind Electron Plasma Frequency Fluctuations in an Oblique Nonlinear MHD Wave," J. Geophys. Res., 1972.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
02 03 72	385-36-00	Magnetospheric Physics Data Analysis (Plasma)		5 OF 6

MAJOR MILESTONES	PRIOR FY 72 QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY 74 QUARTER 1	2	3	4	FY 75 QUARTER 1	2	3	4	FY 76 QUARTER 1	2	3	4
Completion of computer code to fit ion spectra	▼																											
Reduction of solar wind data to usable form																												
March-April 1968			▼																									
Nov-Dec 1968		▼																										
Jan-Feb 1969					▽																							
Mar-Apr 1969								▽																				
Nov-Dec 1969				▽																								
Jan-Feb 1970			▼																									
March-April 1970			▼																									
Nov-Dec 1970			▼																									
Jan-Feb 1971											▽																	
Mar-Apr 1971														▽														
Electron data processed																				▽								

NOTES

LEGEND (EXAMPLES)
- ▽ - SCHEDULED COMPLETION DATE
- ▽1 - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

227

jpl → RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	385-36-00	Magnetospheric Physics Data Analysis	6 OF 6

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY 75	FY
DIRECT PROFESSIONAL	6.4	1.5	3.0	1.5	
DIRECT SUPPORT	4.0	1.5	2.1	.7	
TOTAL DIRECT MAN YEARS	10.4	3.0	5.1	2.2	

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY 74	FY 75	FY
R & D CONTRACTS	65				
IN-HOUSE SUPPORT	238	150	182	97	
TOTAL FUNDS	303	150	182	97	

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY 72	FY 73	FY 74	FY 75	FY
TOTAL MAN YEARS	1.4	1.4	1.4	1.4	

229

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	-30010- 610-40110-0-8280 -40120-	-36-00-01-55 385-50-01-15-55 -50-01-38-55	385-36-00-01-55

5. TITLE

MAGNETOMETER DATA ANALYSIS (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Smith, E. J.

TELEPHONE: 213 - 354 - 2248

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (c)	168	65
CURRENT FY 73 (c)	100	0
NEXT FY 74 (c)	97	0

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 25-0-75-0-0

Scientific data from search coil magnetometers on OGO 1-6 and vector helium magnetometer data from Mariner 5 are being reduced, analyzed and interpreted. The results are disseminated through scientific talks and publications. Data on magnetic tapes and films are being prepared and delivered to NSSDC. The work is performed in collaboration with university co-investigators.

10. JUSTIFICATION (WHY)

This is a program in basic research in space plasma physics. This work unit continues the scientific analysis of magnetometer data after termination of project support. The continuation of this work will bring the scientific investigations to fruition, provide data to NSSDC and allow publication of the scientific results.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Mariner. 1. Discontinuities in the interplanetary field have been classified on the basis of the existence or absence of a field component normal to the plane of the discontinuity. Rotational discontinuities have been unambiguously identified and shown to occur approximately as often as tangential discontinuities. 2. The orientation of the normals to tangential and rotational discontinuities have been shown to be different (tending along the ortho spiral and radial directions, respectively). 3. The propagation time of interplanetary sector boundaries is significantly affected by the heliographic latitude of the source region and interactions between adjacent solar wind streams.

OGO. 1. OGO-5 data show that the plasmasphere contains persistent ELF hiss and represents a naturally-occurring example of a fully turbulent plasma. The hiss appears to be generated in the outer plasmasphere near the magneto equator by an electron cyclotron resonance (pitch angle instability). The observed properties of the waves are strongly influenced by magnetospheric reflection and collisionless damping (probably a Landau resonance interaction with ring current protons). 2. Hiss observed above the ionosphere by OGO-6 appears to be downcoming plasmaspheric hiss. The substantial abundance of ions at low altitudes allows coupling between modes of propagation and results in a sharp low frequency cutoff of the hiss. The existence of the cutoff is strongly dependent on magnetic latitude. 3. Intense emissions (Lion Roars) are observed by OGO-5 everywhere in the magnetosheath and are found to be propagating nearly parallel to the ambient magnetic field. They are triggered at frequencies less than one-half the electron gyro-frequency by a reduction in magnitude of the local magnetic field and appear to result from a basic anisotropy in the temperature of the magnetosheath electrons.

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	610-40130-0-8280	385-50-01-16-55	385-36-00-03-55

5. TITLE

OGO PLASMA DATA ANALYSIS (N)

6. RESPONSIBLE NASA ORGANIZATION

NAME: JET PROPULSION LABORATORY, California Institute of Technology

ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103

RESPONSIBLE INDIVIDUAL: Neugebauer, M.

TELEPHONE: 213 - 354 - 5182

7. CONTRACTOR (IF APPLICABLE)

NAME: N/A

ADDRESS

PRINCIPAL INVESTIGATOR

TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72 (n)	70	
CURRENT FY 73 (c)	50	
NEXT FY 74 (c)	85	

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 25-0-75-0-0

Scientific data obtained by the OGO-5 plasma spectrometers are being reduced, analyzed, and interpreted. Positive-ion solar-wind spectra are being translated into estimates of proton and alpha-particle velocity, density, and temperature, with the results made available to NSSDC and other users on magnetic tape and 35-mm film plots. More detailed calculations are performed on the data for selected time intervals to obtain information about electrons, high-frequency fluctuations, and the properties of non-solar-wind positive ions. Scientific results are being prepared for publication and oral presentations.

10. JUSTIFICATION (WHY)

This task will complete the reduction of plasma spectra to a form usable by other scientists (i.e., velocity, temperature, and density as a function of time). This task is also a program of basic research in space plasma physics based on the OGO-5 plasma data, which are unique with respect to their high time resolution and the chance for correlation with data from a large number of other highly sophisticated fields and particles experiments on the same satellite.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

A computer program has been completed which can economically compute the ion density, velocity, and temperature from the measured spectra. As of March 1, 1972, approximately 60% of the solar wind data have been processed by this program.

The analysis of the OGO-5 plasma data has led to important discoveries in several areas of research: (1) the internal structure of the earth's bow shock, (2) the identification of wave-particle interactions just upstream of the earth's bow shock, (3) dissipation mechanisms in tangential discontinuities in the solar wind, (4) the identification of the earth's polar cusp and its dependence on the direction of the interplanetary field, (5) the redistribution of the velocity profile of solar wind streams with distance from the sun (from OGO 5 – Pioneer 9 comparisons), and (6) the power spectrum of fluctuations in the interplanetary plasma at frequencies up to and including those in the radio scintillation regime.

231

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		44	385-41-XX

5. TITLE
General Relativity Data Analysis

6. RELATED SUBPROGRAMS (IF APPLICABLE)
Not Applicable

7. RELATED RTOP'S (IF APPLICABLE)
Not Applicable

8. CONSOLIDATION OF RTOP NO'S.
Not Applicable

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)
002100; 003000

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL NAME Burcham, Donald P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY '73

☒ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

Data from the superior conjunctions of Mariner 6 and 7 will be analyzed in order to reduce the uncertainty in the time delay test from the present level of ± 4% to a level in the neighborhood of ± 2%. This will be accomplished by combining the data from both spacecraft into a single solution and by applying a sequential estimation algorithm. In addition data from other space missions, particularly Mariner 4 and 5, and radar bounce data to the inner planets will be combined with the Mariner 6 and 7 data to obtain new determinations of the relativity parameters (β, γ) and the solar quadrupole moment (J_2). Realistic error bars will be assigned to each parameter.

It is important to pursue this work so that an evaluation can be made of the relativity information contained in existing data. This will result in a clearer understanding of the contribution of future space experiments to the field of experimental relativity.

If JPL is requested by Marshall Space Flight Center to perform error analyses on particular space missions, then up to 10% of this effort will be devoted to answering such requests.

13. KEYWORDS
Relativity Experiments; Spacecraft Tracking; Planetary Ranging.

PROPRIETARY INFORMATION CONTAINED IN RTOP
☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Ra ASSISTANT LABORATORY DIRECTOR	3/27/72		

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	385-41-XX	General Relativity Data Analysis	2 OF 5

14. JUSTIFICATION Because of the termination of support from the MM'69 Extended Mission Project on January 1, 1972, the analysis of the Mariner 6 and 7 data has come to a stop. Although the primary relativistic information has been obtained from those data, a further analysis will result in a refinement of the time delay test and a worthwhile reduction in the uncertainty of the experiment. In addition there is no other source of funding to analyze either past spacecraft data or radar data for purposes of relativity tests. It is important to analyze all the significant existing data at this time in order to arrive at a clear position on the degree to which a particular theory of gravity can either be verified or discarded. It will then be easier to understand the significance of future tests of relativity, for example tests with drag free solar probes or with orbiting gyroscopes.

15. OPERATING PLAN

A. Objective

The long term objective of the effort is to analyze all relevant spacecraft and planetary data in order to obtain new and significantly more accurate values of the two Eddington-Robertson relativity parameters (β, γ) and the solar quadrupole moment J_2. During FY'73, the Mariner 6 and 7 tracking data will be analyzed to reduce the uncertainty in the time delay test from the current level of ±4% to a level of about ±2%. Spacecraft data will be combined with planetary radar data to obtain at least preliminary values of all three parameters (β, γ, J_2). An error analysis will be performed on the result.

B. Technical Approach

The proposed method of attack is to use existing JPL software for both the analysis of the spacecraft and radar data. No appreciable software development is required. The uncertainty in the Mariner 6 and 7 relativity experiment will be reduced by combining data from both spacecraft into a single solution and by applying a sequential estimation algorithm to minimize the error contribution from random varying nongravitational forces. The combination of the spacecraft data with the planetary radar data will be accomplished with the system of computer programs used to generate planetary ephemerides for the flight projects. Any response to requests from Marshall Space Flight Center to perform error analyses on future mission will be accomplished by a subset of the same system of programs.

This effort will involve only data analysis that is not supported by flight projects. However, all results will be coordinated with relativity experiments that are receiving project support (MM'71, MVM'73, Helios, Viking). When it is appropriate to combine the past spacecraft data and the radar data with data from a current flight project, for example MM'71, this will be done. The flight project will support the reduction of the current spacecraft data and the generation of least squares normal equations for those data. The normal equations for the radar data and the past spacecraft data will be a necessary output of the work described in this RTOP. The combination of the normal equations from various sources into one least squares solution can be accomplished with project funding.

16. REVIEW AND REPORTING Written narrative reports will be prepared and submitted to NASA Headquarters as required by the sponsoring Headquarters Program Office. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, articles in the JPL Quarterly Technical Review, contractor reports, and publications in to open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

17. Publications

Anderson, J. D., Espositio, P. B., Martin, W. L., Muhleman, D. O., "A Measurement of the General Relativistic Time Delay with Data from Mariners 6 and 7," in Proceedings of the Conference on Experimental Tests of Gravitational Theories, JPL TM 33-499, Nov. 1, 1971.

Muhleman, D. O., Anderson, J. D., Esposito, P. B., Martin, W. L., "Radio Propagation Measurements of the Solar Corona and Gravitational Field: Applications to Mariners 6 and 7," in Proceedings of the Conference on Experimental Tests of Gravitational Theories, JPL TM 33-499, Nov. 1, 1971.

Anderson, J. D., Esposito, P. B., Martin, W., Muhleman, D. O., "Determination of Astrodynamic Constants and a Test of the General Relativistic Time Delay with S-Band Range and Doppler Data from Mariners 6 and 7," in Space Research XI, Adademie Verlag, Berlin, 1971, pp. 105-112; Paper No. 2.14, XIVth Plenary Meeting of COSPAR.

Esposito, P. B., Thornton, C. L., Anderson, J. D., Muhleman, D. O., "Classical Least Squares and Sequential Estimation Techniques as Applied to the Analysis of the Mariner VI and VII Tracking Data," AAS Paper No. 71-384, presented at the Astrodynamics Specialist Conference, Fort Lauderdale, Florida, August 17-19, 1971.

jpl → **RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE**

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 04 72	385-41-XX	General Relativity Data Analysis.		4 OF 5

MAJOR MILESTONES	PRIOR FY___ QUARTER 1	2	3	4	CURRENT FY '73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY '74 QUARTER 1	2	3	4	FY '75 QUARTER 1	2	3	4	FY '76 QUARTER 1	2	3	4
Time delay test to ±2% from Mariner 6 & 7 (γ to ±4%)													▽															
Reduction of past spacecraft data for relativity purposes									▽																			
Reduction of important radar and optical data									▽																			
Generation of publishable combined solution for β, γ and J_2														▽														
Two publications of 1. Mariner 6 & 7 results alone and 2. combined solution for β γ and J_2																▽												
Determination of β to < ±3%, γ to < ±1%, and J_2 to < $\pm 10^{-5}$																				▽								
Determination of β to < ±1% and J_2 to < $\pm 5 \times 10^{-6}$																												▽

NOTES

At the conclusion of the FY'73 work, the milestones for future improvements in β, γ and J_2 will be defined more clearly.

The listed upper bounds on the uncertainties are probably conservative.

LEGEND (EXAMPLES)

- ▽ - SCHEDULED COMPLETION DATE
- ▽(1) - RESCHEDULED COMPLETION DATE (REVISION 1)
- ▼ - ACTUAL COMPLETION DATE
- ▽ — — ▽ - ACTIVITY WITH SCHEDULED BEGINNING AND END
- ▽ - DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- ▽ - SCHEDULED COMPLETION DELAYED (REVISION 1)

234

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 04 72	385-41-XX	General Relativity Data Analysis.	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY '73	FY '74	FY '75	FY '76
DIRECT PROFESSIONAL		1.0	1.0	1.0	1.0
DIRECT SUPPORT		0.2	0.2	0.2	0.2
TOTAL DIRECT MAN YEARS		1.2	1.2	1.2	1.2

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY	FY '73	FY '74	FY '75	FY '76
R & D CONTRACTS					
IN-HOUSE SUPPORT		60	60	60	60
TOTAL FUNDS		60	60	60	60

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY '73	FY '74	FY '75	FY '76
TOTAL MAN YEARS		0	0	0	0

236

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72			385-41-XX-YY

5. TITLE

General Relativity Data Analysis (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Anderson, John D.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 3956	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY '72	0	0
CURRENT FY '73 (n)	60	0
NEXT FY '74(c)	60	0

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) 0-0-100-0-0 Data from the superior conjunctions of Mariner 6 and 7 will be analyzed in order to reduce the uncertainty in the time delay test from the present level of ±4% to a level in the neighborhood of ±2%. This will be accomplished by combining the data from both spacecraft into a single solution and by applying a sequential estimation algorithm. In addition data from other space missions, particularly Mariner 4 and 5, and radar bounce data to the inner planets will be combined with the Mariner 6 and 7 data to obtain new determinations of the relativity parameters (β, γ) and the solar quadrupole moment (J_2). Realistic error bars will be assigned to each parameter.

10. JUSTIFICATION (WHY) Because of the termination of support from the MM'69 Extended Mission Project on January 1, 1972, the analysis of the Mariner 6 and 7 data has come to a stop. Although the primary relativistic information has been obtained from those data, a further analysis will result in a refinement of the time delay test and a worthwile reduction in the uncertainty of the experiment. In addition there is no other source of funding to analyze either past spacecraft data or radar data for purposes of relativity tests. It is important to analyze all the significant existing data at this time in order to arrive at a clear position on the degree to which a particular theory of gravity can either be verified or discarded. It will then be easier to understand the significance of future tests of relativity.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS) Although this is a new task for FY'73, past funding for data analyses has produced some significant progress which will form a basis for the proposed effort. This includes:

1. Radar observations of Mercury, Venus and Mars from 1964-68, together with meridian circle observations of the Sun and four inner planets from 1911-67 and observations of the minor planet (1566) Icarus from 1949-68, were analyzed for relativity information and for a value of the solar quadrupole moment by J. H. Lieske and G. W. Null in late 1969 (AJ. 74, 297).

2. Tracking data from the Mariner 5 spacecraft were combined with radar and optical observations of the inner planets in the Summer of 1970 by J. H. Lieske et. al. (Cel. Mech., 4, 233).

3. General Relativity was tested to the level of ±4%, the most accurate test to date, by means of range data taken during the superior conjunctions of Mariner 6 and 7 (Proceedings of the Conference on Experimental Tests of Gravitation Theories, JPL TM 33-499, Nov. 1, 1971; Space Research XI - Akademie - Verlog, Berlin 1971, pp 105 - 112; Paper No. 2.14 XIVth Plenary Meeting of COSPAR; AAS Paper No. 71-384, Astrodynamics Specialists Conference, Fort Lauderdale, Aug. 17-19, 1971).

237

RESEARCH AND TECHNOLOGY OPERATING PLAN

1. DATE PREPARED	2. AGENCY ACCESSION NO.	3. RELEVANCE CODE	4. CURRENT NUMBER/CODE
15 04 72		21	975-50-01

5. TITLE

Space Shuttle Instrument Development Studies

6. RELATED SUBPROGRAMS (IF APPLICABLE)

7. RELATED RTOP'S (IF APPLICABLE)

8. CONSOLIDATION OF RTOP NO'S.

9. SCIENTIFIC AND TECHNICAL AREAS (COSATI)

004600

10. RESPONSIBLE NASA ORGANIZATION

NAME JET PROPULSION LABORATORY
California Institute of Technology

ADDRESS *4800 Oak Grove Dr. / Pasadena, Calif. 91103*

RESPONSIBLE INDIVIDUAL

NAME Burcham, D. P.

TELEPHONE 213 - 354 - 3028

11. STATUS OF THIS RTOP

PLANNING PROPOSAL FOR FY _____

☐ NEW START ☐ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

FIRM PROPOSAL FOR FY 73

☐ NEW START ☒ EXTENSION ☐ CHANGE IN SCOPE OF EXISTING ACTIVITIES

PROPOSED CHANGE IN APPROVED PROGRAM PLAN-CURRENT FY _____

☐ CHANGE IN SCOPE ☐ TERMINATION OF ACTIVITIES

12. BRIEF TECHNICAL SUMMARY/ABSTRACT (OBJECTIVES AND APPROACH)

Out present work on this task indicates that significant cost savings can result from applying certain guidelines to the development of Space Shuttle Instruments. One of these guidelines establishes a requirement for defining a modular approach to instrument supporting subsystems design which will allow significant portions of an experiment to be reused on a new experiment at a later time, as well as provide many standard designs for certain common types of subsystem hardware, such as power conditioning units, amplifiers, analog-to-digital data processors, data systems and data display devices. Another significant cost savings guideline developed in our present study eliminates the need for rigorous qualification testing of the instrument sensor by defining the sensor/spacecraft interface in such a way as to allow in-flight adjustments to be made on the sensor without requiring it to be a part of the crew compartment pressure seal.

The objective of this study is to carry out the recommendations as defined in our present guidelines by performing the conceptual design of several candidate Shuttle Instrument sensor and supporting subsystems. The approach for accommodating these experiments on a Shuttle payload will be formulated. The worth of the proposed approach will be established by performing a preliminary systems design of the selected instruments in a way which utilizes Shuttle interface options in a cost effective manner. Specific recommendations will be made regarding both sensor and supporting subsystems configurations, as well as recommendations concerning the Shuttle interface.

13. KEYWORDS

Space Shuttle Instrument, Cost Effectivity

PROPRIETARY INFORMATION CONTAINED IN RTOP

☐ YES ☒ NO

SIGNATURE AND TITLE	DATE	SIGNATURE AND TITLE	DATE
Donald S. Rice ASSISTANT LABORATORY DIRECTOR	3/27/72		

14. JUSTIFICATION (WHY)

The Gemini spacecraft was in a considerably advanced state of design even prior to the time that proposals for scientific instruments were solicited for this series of missions. At the time of epxeriment selection, the Gemini prototype spacecraft had already been completed. Since the spacecraft was in such an advanced state of design, NASA was faced with the prospect of substantially reducing the scope and increasing the cost of several proposed investigations in order to make them flyable.

The NASA Office of Manned Space Science learned from the Gemini experience, and attempted to impact the design of the Apollo spacecraft in mid-1964 to make it more suitable for flying science instruments. Little progress was made within the Command Module, but a location was secured in the LM for the Lunar Surface Experiment Package. The most significant payload accommodations were secured in the Service Module, where JPL flew a Gamma Ray Spectrometer on Apollo 15/16.

Even though a seven-year leadtime existed between the flight and planning dates for the Apollo science instrument payload, the integration of that payload turned out to be quite difficult. Experiment packages were more or less forced to be designed to the Apollo constaints, rather than having it the other way around. Severe weight, volume and vibration environment constraints resulted in a significant reduction in the scope and increase in cost of several science instruments.

Since the Apollo vehicle was not originally designed to accommodate science instruments in the service module, vibration levels in that location were extremely high. Severe vibration levels, coupled with tight packaging requirements, were substantial factors contributing to the cost ($3.4 M), schedule (2.5 years) and manpower (35 MY) requirements for the development of the JPL Apollo 15/16 Gamma Ray Spectrometer.

It presently costs a few hundred thousand dollars to fly an instrument on an air-borne or balloon mission, and at least ten times that much to fly an instrument on an unmanned or manned spacecraft. If substantial savings in instrument development costs are to be realized for Shuttle, then the developmental approach must be similar to that used for balloon and airborne flights. This approach must represent a significant departure from present trends in flight instrument cost which seem to be constantly increasing. In order to realize significant cost savings, it is apparent that Shuttle accommodations must be significantly more favorable to instrument integration than those found on Apollo.

The Gemini and Apollo instrument integration problem serves to illustrate what can happen if science payload planning occurs late in a manned mission. By conducting thorough instrument payload planning activities well in advance of the time and spacecraft hardware design is firm, one can achieve trulysignificant results. Shortcomings of the spacecraft/instrument interface can be revealed early enough to allow significant changes to be made to the spacecraft without incurring excessive costs. By performing detailed instrument planning early in the developmental cycle, it will be possible to arrive at common instrument developmental philosophies and construction techniques, as well as realizing subsystem commonality (signal and power level compatibility). Once these goals are accomplished, then the non-recurring RTD&E cost incurred subsequent to that time, may be substantially reduced. The same rationale is used to justify the cost-effectivity of the reusable Shuttle launch vehicle.

15. OPERATING PLAN

A. Objectives

Perform a conceptual design study on several candidate Shuttle Instrument sensor and supporting systems.

B. Technical Approach

During FY'73 we propose to study the sensor and supporting subsystem configuration for several space instruments that are being developed for unmanned missions. Our approach is to select instruments which represent a wide range of requirements. It would be desirable to include some of the instruments being proposed by the European space agencies to broaden the scope of the study. A conceptual systems design will be completed for each instrument with the objective of making detailed recommendations regarding cost-effective instrument configuration as well as Shuttle interface (electronic subsystems, scientific airlocks, small telescopes, etc.) configuration.

16. REVIEW AND REPORTING

Written narrative reports will be prepared and submitted to NASA Headquarters on an annual basis. In addition, formal publications such as JPL Technical Reports, Technical Memoranda, contractor reports, and publications in open literature will be prepared as appropriate. Oral briefings and presentations for Headquarters personnel will be conducted when requested.

RESEARCH AND TECHNOLOGY OPERATING PLAN MILESTONE SCHEDULE

DATE PREPARED	CURRENT NO./CODE	TITLE	REVISION NO.	PAGE
15 4 72	975-50-01	Space Shuttle Instrument Development Studies		4 OF 5

MAJOR MILESTONES	PRIOR FY ___ QUARTER 1	2	3	4	CURRENT FY 73 MONTH J	A	S	O	N	D	J	F	M	A	M	J	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4	FY ___ QUARTER 1	2	3	4
Study Instruments Flown on Unmanned Missions																												
Sensor Studies for Shuttle Missions																												
Supporting Subsystem Studies for Shuttle Missions																												
Interface Studies for Shuttle Missions																												
Interim Report																												
Summary Report																												

NOTES

LEGEND (EXAMPLES)
- SCHEDULED COMPLETION DATE
- RESCHEDULED COMPLETION DATE (REVISION 1)
- ACTUAL COMPLETION DATE
- ACTIVITY WITH SCHEDULED BEGINNING AND END
- DELAYED INITIATION (COMPARED TO PRIOR SCHEDULE)
- SCHEDULED COMPLETION DELAYED (REVISION 1)

280

RESEARCH AND TECHNOLOGY OPERATING PLAN (CONTINUATION)

DATE PREPARED	CURRENT NO./CODE	TITLE	PAGE
15 4 72	975-50-01	Space Shuttle Instrument Development Studies	5 OF 5

17. RESOURCES REQUIREMENTS

A. MANPOWER (MAN YEARS)

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
DIRECT PROFESSIONAL	1.1	1.2			
DIRECT SUPPORT					
TOTAL DIRECT MAN YEARS	1.1	1.2			

B. FACILITIES

C. R & D FUNDS

	PRIOR	CURRENT	FISCAL YEAR		
	FY 72	FY 73	FY	FY	FY
R & D CONTRACTS					
IN-HOUSE SUPPORT	50	54			
TOTAL FUNDS	50	54			

R & D CONTRACTS ($ 25K AND ABOVE)

(a) ACTIVE

CONTRACT NO.	START DATE	CONTRACTOR	AMOUNT

(b) PLANNED

ITEM/SUBJECT	START DATE	AMOUNT

D. CONTRACTOR SUPPORT MANPOWER (MAN YEARS)

	PRIOR	CURRENT			
	FY	FY	FY	FY	FY
TOTAL MAN YEARS					

242

RESEARCH AND TECHNOLOGY WORK UNIT RESUME

1. DATE PREPARED	2. JPL JOB NUMBER	3. PRIOR NUMBER/CODE	4. CURRENT NUMBER/CODE
15 04 72	615-50101-0-8230		975-50-01-01- 55

5. TITLE

Space Shuttle Instrument Development Studies (N)

6. RESPONSIBLE NASA ORGANIZATION	7. CONTRACTOR (IF APPLICABLE)
NAME: JET PROPULSION LABORATORY, California Institute of Technology	NAME
ADDRESS: 4800 Oak Grove Dr. / Pasadena, Calif. 91103	ADDRESS
RESPONSIBLE INDIVIDUAL: Lewyn, Lanny L.	PRINCIPAL INVESTIGATOR
TELEPHONE: 213 - 354 - 6937	TELEPHONE

CONTRACT NO.

CONTRACT START DATE

8. FUNDING ($ K)	IN-HOUSE	CONTRACT
PRIOR FY 72(n)	50	
CURRENT FY 73 (c)	54	
NEXT FY		

9. BRIEF DESCRIPTION (WHAT IS BEING DONE, HOW) (0-100-0-0-0)

Several instruments flown on unmanned missions will be studied with regard to simplifying instrument/spacecraft interfaces and substantially reducing development costs for Space Shuttle missions.

Specific recommendations will be made regarding sensor integration approaches and supporting subsystem detailed design considerations including modular packaging, interface commonality, hardware utilization on CV 990 flights, materials section and safety criteria.

10. JUSTIFICATION (WHY)

By performing detailed instrument planning early in the developmental cycle, it will be possible to arrive at common instrument developmental philosophies and construction techniques, as well as realizing subsystem commonality (signal and power level compatibility). Once these goals are accomplished, then the non-recurring RTD&E cost incurred subsequent to that time, may be substantially reduced. The same rationale is used to justify the cost-effectivity of the reusable Shuttle launch vehicle.

11. MAIN ACHIEVEMENTS (SIGNIFICANT PROGRESS)

Our present task has identified several areas for significantly reducing the development costs of space instruments developed for Shuttle. Substantial (70% to 80%) savings may be realized by the use of a common approach to supporting subsystems development. We also have completed a detailed assessment of selected instrument development costs for balloon flight, CV 990, Nimbus E, and Apollo spacecraft. This assessment identifies cost elements such as design, R&QA, fabrication, documentation, management and PI support.