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OCTOBER 1973

GEORGE C. MARSHALL SPACE FLIGHT CENTER

RESEARCH AND TECHNOLOGY PROGRESS REPORTS

FOR THE PERIOD APRIL 1, 1973 THROUGH SEPTEMBER 30, 1973

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PREFACE

This issue of MSFC's Research and Technology Progress Reports has been prepared in accordance with instructions for reporting Research and Technology from the Office of Aeronautics and Space Technology. A format is used, which provides only a narrative summary report at the RTOP level. Milestone Schedule Charts and Financial Status Charts are no longer required as elements of each progress report. However, as both charts provide useful information to individuals and groups within NASA having a program management function, they are available separately, in a supplementary volume, to those having a special need for them.

Issues of these reports are published twice a year, with reporting dates conforming to the OAST requirements of April 1 and October 1.

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NOTE

The sequence of the contents of this report is indicated by the number at the center of the top margin of each page. Entries on the form completing the "Page_____of____" block should be ignored. Their only purpose is to indicate the number of report pages (including charts) submitted on a particular unit of work and the relative location of a particular page within that group.

To insure positive identification of text with charts, a Cross-Reference Table has been provided in the supplement.

To facilitate identification of certain research which was reported with codes differing from those assigned by NASA Headquarters, a Table of Corresponding Codes has also been included. All reports in this document are identified by Headquarters assigned codes.

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TABLE OF CORRESPONDING CODES

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908-51-87	MANUFACTURING & INSPECTION	908-51-21
908-51-98	MANUFACTURING & INSPECTION	908-51-21
908-52-25	CONTROL SYSTEM TECHNOLOGY FOR SHUTTLE VEHICLES	908-52-08
908-52-70	AEROTHERMODYNAMICS	908-52-39
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909-54-60	RELIABILITY & TRADE-OFF STUDY OF AERO-MANEUVERING ORBIT-TO-ORBIT SHUTTLE (AMOOS)	909-54-22
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		CURRENT NO.:	PRIOR NO.:
Marshall Space Flight Center	01 04 73 - 30 09 73	113-31-12	128-31-63

4. TITLE:

MAIN PROPULSION FOR SPACE SHUTTLE VEHICLES

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
T. W. Winstead	453-3854	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Rapid Start of LH_2 Turbopumps

CONTRACT: NAS8-27608, Rockwell International/Rocketdyne

OBJECTIVES: To develop data on the rapid start of LH_2 turbopumps under conditions applicable to the Space Shuttle APS turbopumps, with emphasis on insulation coatings to reduce prechill requirements, and on deadhead starts.

APPROACH: Using data from contracts NAS8-20167 and NAS8-20324 as baseline:

(1) Perform analyses to select optimum coatings for the various feedline components and evaluate turbopump starting relationships.

(2) Conduct laboratory tests to determine thermophysical properties of candidate coating materials.

(3) Conduct tests on both uncoated and coated RL-10 turbopumps using various applicable starting modes.

STATUS: Technical Progress: The comparative testing has been completed and demonstrated that 30% reductions in chilldown time and mass are practically achievable. The data indicated that 60% reductions are probable, but this was not demonstrated due to sequencing peculiar to the test facility.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
ASR 71-311	First Quarterly Progress Report	G. S. Wong	October 1971
ASR 72-6	Second Quarterly Progress Report	G. S. Wong	January 1972
ASR 72-93	Third Quarterly Progress Report	G. S. Wong	April 1972
ASR 72-146	Fourth Quarterly Progress Report	G. S. Wong	July 1972
ASR 72-239	Fifth Quarterly Progress Report	G. S. Wong	October 1972
ASR 73-5	Sixth Quarterly Progress Report	G. S. Wong	January 1973

FIRST BENEFITING PROJECT: SPACE SHUTTLE

Post-test inspection of the feed system indicated excellent coating adhesion after 12 cryogenic cycles totaling 680 seconds exposure.

The coating on the RL-10 turbopump was Kel-F with microballoons. A thickness of .020" was selected for the heavy housing components to retard heat flow and .005" for the rotating components to accelerate chilldown. Temperature and pressure fluctuations were minimal during chilldown of the insulated pump, as the coating surface rapidly cools to below the metastable boiling regime.

Management Progress: The final report draft has been submitted for approval, and a final briefing scheduled for October 4, 1973.

Conclusions: Laboratory tests provided significant data on the use of coatings to enhance cooldown of turbomachinery for LH_2, LN_2, and LOX. Limited testing demonstrated the feasibility of deadhead starts and coated turbopumps. A 30% reduction in chilldown requirements was demonstrated, and a 60% reduction indicated but not demonstrated due to facility-peculiar sequencing limitations.

Problems: Erosion of coating at tip of impeller blade.

Cause of Problem: Possibly due to deep cavitation during partial chilldowns where pump performance could not be developed.

Problem Solution: Reduced flow velocity profile by considering coating during initial design.

Forecast: Applications development testing can proceed on LH_2, LN_2, or LOX coated turbomachinery with low risks, based on the data established under this program. Preliminary data indicates significant weight and cost savings are possible for altitude-restart applications.

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Marshall Space Flight Center	01 04 73 - 30 09 73	113-31-12	128-31-80

4. TITLE:

PROPELLANT PROPERTIES AND PERFORMANCE

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
T. W. Winstead	3-3854	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Thermal Stratification and Destratification Scaling Concepts (The Development Of)

CONTRACT: NAS8-24747, McDonnell Douglas/Western Division

OBJECTIVES: Develop stratification scaling procedures for fluids in normal and low gravity to provide "vehicle" for relating available stratification data from various tank/propellant/environment combinations.

APPROACH: Develop scaling parameters for thermal stratification, considering

- High-G, two-phase, single component
- Low-G, two-phase, single component
- High-G, two-phase, two component
- High-G, three-phase, single component

Develop normalized differential-equation matrix

Perform selected tests for correlations

- Tank Size - 6", 12", 18"; L/D = 2
- Fluid Height - 50% and 87.5%
- Acceleration - 1 to 27 G's

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final:			
Volume I	Definition of Thermal Stratification Scaling Parameters & Experimental Investigations	T. M. Lovrich, S. H. Schwartz	July 1973
Volume II	Stratification, Experimental Data	T. M. Lovrich S. H. Schwartz	July 1973

FIRST BENEFITING PROJECT: SPACE SHUTTLE

- Heating Rate - 0 to 2000 Btu/hr.ft^2
- Fluid - Water & Freon 113

STATUS: The final report has been distributed and validates the scaling approach with only minor data disagreement for some of the tests. The data is reported in broad detail in Volume II for 37 scalable tests. These data indicate that bulk temperature and tank pressure can be scaled with modified Grashof number, Fourier number, and an Interface number. Some deviation was noted and further data evaluation is indicated.

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	113-31-14	

4. TITLE:

Shuttle Main Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMT William B. White	453-5619	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Fast Response High Temperature Sensor
NAS8-28952, Kollsman, Syosset, NY
NAS8-28953, International Harvester, San Diego, CA
H-96516A, Barnes Engineering, Stamford, CT

OBJECTIVE(S): The control Shuttle APU and APS Turbine Temperature will require a reliable sensor capable of continuous operation in a hot gas environment of 1000-1400 degrees celsius at pressures up to 8000 psi while providing a time response characteristic and reliability requirements are not compatible utilizing conventional temperature measuring techniques such as thermacouples or resistance elements. Therefore, technology development is needed to arrive at a satisfactory solution.

APPROACH: A literature and market survey will be conducted to determine the most feasible approach of non-contacting, fast response temperature sensors. Representative samples will be obtained for testing and evaluation based on preliminary requirements of engine operating characteristics. The most feasible approach will then be developed into a prototype flight sensor system.

STATUS: Technical Progress - Hardware has been received from contracts NAS8-28952 and H-96516A. Preliminary operational checks have been made on these two systems, however, intensive performance tests have been delayed until delivery of the

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
	Final Report, System for Measuring Turbine Blade Temperatures, Contract NAS8-28952	J. Micaliand M. Wengryn	Dec. 1972

FIRST BENEFITTING PROJECT: Space Shuttle

third system, NAS8-28953, is complete.
Management Progress - Contracts NAS8-28952 and H-96516A are complete.
Conclusions - None
Problems - The "hold" that was placed on NAS8-28953 during FY 73 has resulted in longer than anticipated delivery. Hardware delivery is now expected during October 1973.
Cause of Problems - FY 73 budget limitations
Suggested Solutions - Delay of evaluation tests
Forecast - Complete delivery under NAS8-28953 and conduct detailed evaluation tests on the three types of temperature sensing systems.

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4. TITLE:

Shuttle Main Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMF J. Goldstein	453-5622	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Cryogenic Facility Mass Flowmeter
H-87466A, NBS, Boulder, CO

OBJECTIVE(S): To develop a cryogenic mass flowmeter capable of measuring mass flow with an accuracy of 0.5% over the flow range of the Space Shuttle engine. Dynamic response will also be considered for use in POGO effect testing.

APPROACH: The NBS Cryogenic Flow Facility will be modified to generate known dynamic flow conditions of 10% modulation of steady flow rate at frequencies up to 100 Hertz. The dynamic flow is generated by means of hydraulic modulating value for the frequency range of 0-40 Hertz and an oscillating test section for the frequency range of 25-100 Hertz.

STATUS: The NBS facility modification has been completed. Preliminary checkout indicates that the system meets the objective.
Management Progress - NBS Flow Facility modifications has been completed. Two each 2" Ramapo Flowmeters have been calibrated and are being used for flowmeter evaluation at the MSFC Pogo Facility.
Problems - Some problems have been encountered in the calibration of an orifice system. Work is presently in progress to determine the cause of the problems. Funds of $10,000 have been requested to complete this work.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly and Quarterly Reports			

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (CONCLUDED): Conclusions - Facility modification appears to meet objectives.

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4. TITLE:

Shuttle Main Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMP H. Harman	453-5620	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: 035, Pressure Transducer for Active Pogo Control
H-92100A, NBS, Washington, D. C. and Boulder, CO

OBJECTIVE(S): A very high resolution, responsive pressure transducer, is required to measure pressure oscillations of 8 to 10 psi in an 8000 psi liquid oxygen or hydrogen line with an accuracy of 1% in amplitude and phase and the pressure oscillations in the combustion chambers. The main problems requiring development are transducer stability and sensitivity in such a hostile environment.

APPROACH: A development program to test, evaluate, modify, and retest various types of pressure transducers will be initiated to produce a pressure transducer meeting the described objective.

STATUS: Technical Progress - NBS Boulder has stopped work due to a lack of funds. Requested funds have not been granted to continue the cryogenic testing. NBS, Washington, D. C. is continuing with the hot gas portion of the contract. Sensors being evaluated are: Kaman Sciences, Sensotec, Sensometrics, PCB, Inc. and Entran, Inc.
Management Progress - none
Forecast - Development will result in productivity of a prototype transducer for testing and flight qualification.

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FIRST BENEFITTING PROJECT: Space Shuttle

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MSFC	01 04 73 to 30 09 73	114-03-05	124-09-21

4. TITLE:

SPACE RADIATION SHIELDING AND DOSIMETRY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. O. Burrell, S&E-SSL-NR	453-5130	R. Decher, S&E-SSL-N

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Radiation Shielding and Dosimetry

H-3828A Atomic Energy Commission

NAS8-26753 Science Applications, Inc.

OBJECTIVE(S): The Space Radiation Shielding and Dosimetry Program is primarily concerned with the generation of basic data and development of theoretical and computational methods for treating the effects of high energy charged particles and the shielding against these radiations. These particles originate from solar flares, cosmic rays, and trapped radiation belts and pose a hazard to all space flight.

APPROACH: (1) To continue efforts by Oak Ridge National Laboratory (ORNL) to develop basic data (cross sections) and improve methods for realistic charged particle radiation calculations in space vehicles. (2) To continue ORNL efforts in high energy (cosmic ray), heavy charged particle cross sections, with emphasis on secondary cascades and residual nuclei. (3) To continue the in-house effort to apply all new methods and data to real engineering problems for ongoing NASA programs.

STATUS: This program was transferred to MSFC from NASA Headquarters in August 1967. At that time the theoretical aspects were separated from the experimental verifications program, which was carried on by NASA at Langley Research Center. MSFC has been responsible for the theoretical aspects of this program. The program has received no funding since October 1971 (FY'72). Last December (1972) the ORNL effort was reduced

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
Approximations for Neutron Emission Spectra from Proton Collisions between 20 and 500MeV on Nuclei of A ≥ 12, NASA TN D-7386	M. O. Burrell	Aug 1973
Methods of Treating Complex Space Vehicle Geometry for Charged Particle Radiation Transport	C. W. Hill	Aug 1973
Shielding of Manned Space Vehicles Against Galactic Cosmic-Ray Protons and Alpha Particles	R. T. Sanotro K. C. Chandler R. G. Alsmille	Apr 1973

Since 1967 - over 50 publications

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STATUS: Continued

to a minimum in order to keep the NASA FY'73 spending down. The effort has recently been extended for an additional year to December 1974. This effort by Science Applications, Inc. was finished in August 1973, resulting in the final phase of a handbook titled "Methods of Treating Complex Space Vehicle Geometry for Charged Particle Radiation Transport".

Management Progress - The work effort at ORNL has been reduced in this quarter to a minimum in order to stretch out contract for one year. Activity will not pick up until third quarter of 1973.

Problems - No problems of any consequence except for in-house effort being curtailed by computer restraints at MSFC.

Forecast - This research will make it possible for man to spend long periods of time in space safely and will minimize new technology requirements for space studies.

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MSFC	01 04 73 to 30 09 73	114-03-25	129-03-25

4. TITLE:

EXTRATERRESTRIAL MATERIALS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. R. Miller, S&E-SSL-TE	453-3103	E R Miller for W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Extraterrestrial Materials

NAS8-26579 Auburn University

OBJECTIVE(S): To investigate the thermal and physical properties of simulated lunar and planetary materials to gain basic knowledge of their behavior under their respective environmental conditions. Measurements will include: Spectral emission, absorption, and reflection properties throughout the infrared and into the millimeter region; the angular distribution of emitted radiation; and thermal conductivity of particulate and heterogeneous mixtures in simulated vacuum conditions. The result will be the beginning of a catalog of data, a thermophysical model of the surface and subsurfac with all parameters and quantities taken into account, and conclusions and recommendations as regarding the surface material and the utilization of the resources. The product will be data published in technical reports in these areas.

APPROACH: (1) Thermal conductivity measurements will be made using the differentiated line heat source method. Measurements will be made in vacuum and in simulated planetary environments. Temperature ranges will also be simulated. The various properties will be studied as a function of atmospheric pressure, constituency sample condition (such as solid, particulate, or mixture) and sample mineralogical makeup. (2) Spectral infrared measurements will be continued using several spectrophotometers which are in use in this lab. Examples are the grating instruments, interferometer and circular variable filter spectrophotometers. The instruments use liquid helium cooled infrared detectors. The angular radiation properties will be studied using a unique bidirectional measuring device which will allow the sample to be illuminated with a solar simulator

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Density Depth Model for the Lunar Outermost Layer "Journal of Geophysical Research"	Billy P. Jones	Jan 1968
	Thermal Conductivity of Particulate Basalt as a Function of Density in Simulated Lunar & Martian Environments, "Journal of Geophysical Research"	J. A. Fountain E. A. West	July 1970
	Predicting Lunar Temperatures, "Progress in Astronautics and Aeronautics"	Billy P. Jones	Oct 1968
	Lunar Surface Mining: A review of some Major Environment Constraints, NASA TMX-64530 A comparison of Two Transient Methods of Measuring Thermal Conductivity of Particulate Materials, NASA TMX-64559	Reynold Q. Shotts Stanley A. Fields	July 1970

FIRST BENEFITTING PROJECT: APOLLO

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APPROACH: Continued

from any angle over almost two steradians and measurements to be made from a similar set of angles. (3) All of the properties and measurements will be used in theoretical models of the various extraterrestrial bodies and compared with observation data.

STATUS: Technical Progress - Conductivities have been measured of basalt powder as a function of density. For a fixed temperature in the range between 150°K and 400°K the thermal conductivity increases with density, except in the extreme lower range of density. The reasons for the behavior at low densities are not known, but are related to the relative radiative and conductive modes of heat transfer. Further refinements in the method of measurement are continuing using glass beads as samples. An angular radiation device is being developed to allow measurements of IR radiation intensity vs. source angle. Experimental work has been completed for friction and adhesion studies. Theoretical work on the thermal conductivity of heterogeneous mixtures has developed along three principal lines of investigation. One method is based upon heat flow lines and parallel isotherms; this method is based upon a proposal by Wiener and Tsad but extended to include a more representative geometrical arrangement of the solid particles, and for the first time, a packing theory has been incorporated into the basic geometrical model. Comparison of the calculated results with the experimental data shows correlations that are a significant improvement over previous formulations. A second method utilizes a stochastic approach and is an extension of a proposal by Baxley and Couper for suspensions and emulsions. This model is extended to include the effect of contact areas between particles, the dependence of gas conductivity on pressure at low pressures, and radiation heat transfer. The model is applicable to granular materials over a wide range of pressures and temperatures. When compared with experimental data, the model has generated low conductivity values, and this is attributed to low calculated values for the contact conductivity. Another method, based upon non-linear heat flow, takes account of particle size, porosity, depth below the lunar surface, and solid particle mechanical thermal properties, including radiation between particles. This model gives effective conductivity values that compare favorably with the experimental data from lunar surface samples obtained on Apollo 11 and 12 missions. This work has culminated in papers and reports either published or in the process of being published (see reports list).

Management Progress - Purchase orders and report editing are in process. Contract NAS8-26579 was signed with Research Foundation, Auburn University. This contract will expire October 23, 1973.

Conclusions - Thermal conductivity of basalt varies with density in vacuum, less so in CO_2 (Martian) environment. Conclusions from the theoretical models are being formulated (see "technical progress").

Problems - None

Forecast - The objectives for the theoretical conductivity of heterogenous mixtures will be met. The angular radiation device has undergone extensive repair and rewiring and will be made operational by the contract expiration.

7. REPORTS: Continued

Thermal Properties of Granulated Materials, to be published in AIAA Progress Series Volume	Alfred E. Wechsler Peter E. Glaser James A. Fountain	Mar 1973
Thermal Conductivity Model for the Lunar Surface presented at 12th International Conference on Thermal Conductivity, Birmingham, Ala. September 1972	M. S.Khader R. I. Vachon	Sept 1972
A Theoretical Model for Lunar Surface Material Thermal Conductivity, ASME Paper	M. S. Khader R. I. Vachon	Feb 1973
Thermal Conductivity of Heterogeneous Mixtures and Lunar Soils, Final Report (Draft), Contract NAS8-26579		Oct 1973
Thermal Conductivity of Heterogeneous Mixtures, Ph. D. Dissertation, 1973	Athansios George Prakouras	1973
Thermal Conductivity of Randomly Packed Granular Materials, Ph. D. Dissertation, 1973	Roger Alan Crane	1973

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MSFC	01 04 73 - 30 09 73	CURRENT NO.: 114-03-33	PRIOR NO.:

4. TITLE:

Structural Composite Materials For Space Shuttle

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
F. P. LaIacona	205-453-5516	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of a Method for Fabricating Metallic Material Composite Shapes By A Continuous Process. NAS8-27010 Commonwealth Scientific Corporation

OBJECTIVE: To develop a method for automatically fabricating a metallic composite utilizing automatic mechanical winding techniques and consolidating the cladded filament by heat and pressure into a structural shape. The materials shall be aluminum for the matrix, boron and graphite for the reinforcement. The structural shapes to be fabricated shall be tube, "I" beam, and hat section of "Z" section.

APPROACH: A study shall be made of the necessary die design required to produce structural shapes of boron-aluminum and graphite-aluminum composites by a continuous process. Various parameters such as differences in thermal expansion of die material, dwell time at temperature, reaction between filament and matrix, and matrix-filament mechanical properties of the resultant composites shall be evaluated.

STATUS: Technical Progress: The effort to produce larger diameter .050 m (2.00") B/Al tubes has necessitated significant modifications from the fabrication of smaller tubes. These modifications were; preform preparation, heating and sheath removal, acrylic binder removal, and die convergance changes including drawing speeds. Also, another approach is being explored using a triangular orifice which permits passage of a pyramidal array of clad coated boron ends with a perfectly aligned bundle prior to die introduction. Resistance heating is the prime source of heating the preform; however, induction heating is still the most efficient. An induction heating unit is on order and should be available momentarily. Several problems remain to attain complete consolidation, wall thickness uniformity, and sheath and core removal. Steps are being taken to alleviate these problems.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

FIRST BENEFITTING PROJECT: Sortie Lab

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STATUS (CONCLUDED): Efforts in the G/Al composite program has largely concentrated toward improving the resistance heating process. However, another approach is being explored which consists of passing a clad G/Al bundle through an electron beam. This approach appears to have promise, since the beam vaporizes the aluminum and forces it all around the graphite fibers. Consideration is being given to the automation of this process.

Management Progress: This program has been extended to March 1, 1974.

Conclusions: None to report at this time.

Problem: None

Forecast: None

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4. TITLE:

Structural Composite Materials For Space Shuttle

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
F. P. LaIacona	205-453-5516	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Evaluation of Boron/Aluminum Structural Components for Space Shuttle NAS8-27738 General Dynamics/Convair

OBJECTIVE: The objective of this program is to evaluate the properties of boron-aluminum structures and at the same time to establish and facilitate processing techniques, design analysis, and fabrication characteristics of boron-aluminum composites.

APPROACH: Boron-Aluminum properties will be evaluated by testing the composite in tension, fatigue, and shear from -320°F to +800°F. Structural assemblies will be designed involving the following structures: (1) Compression panel, (2) Thrust structure truss beam, and (3) Thrust structure shear web beam. In addition, a manufacturing process development task is to be conducted, which shall include studies in machining, joining, chemical treatment, and tooling requirements. Finally, boron-aluminum components selected from the design analysis, will be fabricated and these components subjected to structural tests.

STATUS: Technical Progress: Four phases initially planned for this program, Material Evaluation, Design and Analysis of Thrust Structure Components, Process Development, and Shear Beam Fabrication have been completed. The structural test for the shear beam component was completed with the structure sustaining 102% of design ultimate load before failing. The test, therefore, was considered a success. Work on the design and fabrication of a 0.74 by 2.03 m (29 x 80 in) B/Al compression panel has been completed and the component has been delivered to this Center for test to a temperature of 589°K (600°F). In addition, the contract has been extended for another eight months to include methods of repairing B/Al structures experimentally and in the field.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
GDCA-OBG73-006	Design, Mfg. Dev. Test, and Evaluation of Boron/ Aluminum Structural Components for Space Shuttle Vol 1: Design and Analysis Vol 11: Materials & Processing	M. F. Miller J. L. Christian W. F. Wenmhold	August 1973

FIRST BENEFITTING PROJECT: Space Shuttle

STATUS (CONCLUDED):

Management Progress: The contract has been extended for an additional 8 months to May 31, 1974.

Conclusions: It has been established that B/Al composites can be successfully fabricated into useful structural components, such as, a shear beam with properties exceeding that of aluminum at both room temperature and at 600°F. Also, resistance welding and mechanical joining methods were found to be well within the state-of-the-art.

Problem: None

Forecast: None

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MSFC	01 04 73 - 30 09 73	114-03-34	

4. TITLE:

Design Properties of Materials (Evaluation of Softgoods)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN T. E. Wood	3-1231	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Evaluation of Rubber Soft Goods, NAS8-29060, General Dynamics/Convair, San Diego, CA.

OBJECTIVE(S): This program is to study the performance of rubber soft goods which will be used for seals, bladders, O-rings, diaphragms, gaskets, and related applications as affected by extreme cyclic variations in the Shuttle vehicle flight environment, coupled with the reusability, reliability and quick turn-around requirements.

APPROACH: Candidate rubber materials in both typical and use configuration and standard test configurations will be exposed to cyclic thermal and pressure environments comparable to anticipated Shuttle environments. Various parameters will be monitored. These parameters will include tensile strength, elongation compression set, stress relaxation, aging behavior, hardening, embrittlement, reversion and other attributes which dictated the suitability and selection of the materials for the given application. Current state-of-the-art rubbers and seal materials will be used in the program. These materials shall be fully identified and the formulations and cure schedules shall be documented.

STATUS: Technical Progress--Cyclic load deflection measurements have been completed on all Phase I (Hydraulic) seal candidates (Vitons) at room temperature and 300°F. No viton has shown any compression set under any condition employed to date. The white viton stock was found superior to either of the black viton stocks .

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Ten Progress reports have been issued.

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (CONCLUDED): Only two of the six potential seal candidates for the Main Propulsion System, cross linked Halar and AF-E-124, meet the impact requirements for service in liquid oxygen.

Only one of the four Orbital Maneuvering System seal candidates, the phosphazine fluoroelastomer, shows signs of degradation after six months immersion in monomethyl hydrazine.

Conclusions--Results to date indicate that there are two or more compounds suitable for use in each of the following Space Shuttle vehicle systems: (1) hydraulic, (2) main propellants and (3) auxiliary.

Problem--None

Causes of Problem--N/A

Suggested Solution--N/A

Forecast--N/A

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4. TITLE:

Materials Compatibility Evaluation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. B. McPherson	205-453-5509	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Influence of Gaseous Hydrogen on Metals - NAS8-25579 Rocketdyne, Canoga Park, CA.

OBJECTIVE: To determine the effects of gaseous hydrogen on the engineering properties of various metal alloys that have potential use in pressure vessels, pressurization components, engine components, and fuel cells necessary to re-usable space shuttle propulsion and life support systems. Design data and safe operating parameters will be established based on results of this investigation.

APPROACH: Tests will be made to determine the fracture toughness, K_{IC}, threshold stress intensity, K_{TH}, and cyclic flaw growth rates, da/dN vs K_{IC}, for A302-B Mod. steel in 103.4 MN/m^2 (15000 psi) hydrogen at room temperature. The variation of fracture mechanics behavior for Inconel 718 in GH_2 will be determined as a function of pressure to measure the equilibrium crack extension.

STATUS: Technical Progress: Tensile, fracture toughness (K_{IC}), threshold stress intensity for sustained-load crack growth (K_{TH}), and cyclic and sustained load crack growth rate measurements were performed on a number of alloys in high-pressure hydrogen and helium environments. The results of tensile tests performed in 34.5 MN/m^2 (5000 psi) hydrogen indicated that Inconel 625 was considerably embrittled at ambient temperature but was not embrittled at 144 K (-200F). The tensile properties of AISI 321 stainless steel were slightly reduced at ambient temperature and 144 K (-200 F). The tensile properties of Ti-5Al-2.5 Sn ELI were essentially unaffected by hydrogen at 144 K (-200 F). OFHC copper was not embrittled by hydrogen at ambient temperature or at 144 K (-200 F).

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
R-8719	Influence of Gaseous Hydrogen on Metals	R. J. Walter H. G. Hayes W. T. Chandler	May 24, 1971
	Influence of Gaseous Hydrogen on Metals	R. J. Walter A. J. Jacobs W. T. Chandler	June 28, 1972
	Influence of Gaseous Hydrogen on Metals Final Report	R. J. Walter W. T. Chandler	October 1973

FIRST BENEFITTING PROJECT: Space Shuttle Main Engine

STATUS (CONCLUDED):

Threshold stress intensity (K_{TH}) measurements were performed on Inconel 718 (in two heat treatment conditions), Inconel 625, AISI 321 stainless steel, A-286 stainless steel, Ti-5Al-2.5 Sn ELI, 2219-T87 Al alloy, and OFHC copper. The tests were performed at ambient temperature and 144 K (-200 F) in 34.5 MN/m^2 (5000 psi) hydrogen and helium environments and were monitored by acoustic emission. Sustained load, hydrogen-induced crack growth occurred in Inconel 718, Ti-5Al-2.5 Sn ELI and in A-286 stainless steel. No influence of hydrogen was noted on crack propagation in 2219-T87 aluminum and in OFHC copper.

Embrittlement of notched Inconel 718 tensile specimens by 34.5 MN/m^2 (5000 psi) hydrogen at ambient temperature was found to vary considerably with condition. Reduction of notch tensile properties was least for Inconel 718 with a very fine grain size, moderate for a coarse-grained material after a 1325, 1033-922 K (1925, 1400-1200 F) heat treatment and most severe for a coarse-grained material after a 1214, 991-894 K (1725, 1325-1150 F) heat treatment. Embrittlement appeared to correlate with grain size and the presence of a nearly continuous precipitate identified as Ni_3Cb. The cyclic crack growth rate in Inconel 718 increased with increasing hydrogen pressure, and was a complex function of cyclic rate. The influence of hydrogen on the cyclic crack growth rate of Inconel 718 decreased appreciably from ambient to 200 K (-100 F). The ambient temperature cyclic crack growth rates of HY100 and ASTM A-533-B steels were approximately 20 times greater in hydrogen than in helium over a wide range of stress intensities at pressures of 51.7 MN/m^2 (7500 psi) for HY100 and 103.4 MN/m^2 (15,000 psi) for ASTM A-533-B.

K_{TH} was measured as a function of hydrogen pressure for AISI 4340 steel and Inconel 718 to determine whether hydrogen-environment embrittlement is caused by adsorbed or absorbed hydrogen. The small effect of hydrogen pressure on K_{TH} of both alloys indicates that hydrogen-environment embrittlement results from a hydrogen adsorption dependency mechanism.

Management Progress: This program has been completed.

Conclusion: See Technical Progress

Problem: None

Forecast: None

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4. TITLE:

Materials Compatibility Evaluation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. G. Williamson	205-453-4355	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: The Corrosion and Stress Corrosion of Several High Temperature Alloys, NAS8-27270 McDonnell Douglas Astronautics Company-East, St. Louis, Mo.

OBJECTIVE: To determine the corrosion resistance and the stress corrosion susceptibility of several high temperature alloys.

APPROACH: Two alloys that are candidates for the Shuttle Solid Booster case were tested under simulated service conditions to define subcritical flaw growth behavior under both sustained and cyclic loading conditions. The materials evaluated were D6AC and 18 Ni maraging steel, both heat treated to a nominal yield strength of 1380 MN/m^2 (200 ksi).

STATUS: Technical Progress: The experimental portion of this program has been completed and a draft of the final report prepared.

Management Progress: This program has been completed.

Conclusions: The sustained load tests were conducted by exposing stressed specimens of both alloys to alternate immersion in synthetic sea water. It was found that the corrosion and stress corrosion resistance of the 18 Ni maraging steel was superior to that of the D6AC steel. It was also found that austenitizing temperature had little influence on the threshold stress intensity of the latter alloy. The cyclic tests were conducted by subjecting surface-flawed specimens of both alloys to load/temperature cycles that simulated expected mission conditions. The crack propagation rate of 18 Ni maraging steel was unaffected by these simulated mission cycles relative to the baseline (load cycling only) condition. A slight acceleration in crack growth rate was observed for this alloy when cycled in the presence of synthetic sea water. The crack propagation rate for D6AC steel, however, was found to be affected by mission cycling relative to the baseline condition.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MDC E0609	"Corrosion and Stress Corrosion Susceptibility of Several High Temperature Materials"	J. W. Davis L. J. Pionke	Aug. 31, 1972
	"Evaluation of Shuttle Solid Rocket Booster Case Materials	L. J. Pionke K. C. Garland	Oct. 31, 1973

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6. Accomplishments (Continued)

Problems: None

Forecast: None

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4. TITLE:

Materials Compatibility Evaluation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. B. McPherson	205-453-5509	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Influence of Elevated Temperature on Metals in Gaseous Hydrogen NAS8-26191 Pratt & Whitney, West Palm Beach, Florida

OBJECTIVE: To determine the effects of gaseous hydrogen on the engineering properties of various metal alloys that have potential use in pressure vessels, pressurization components, engine components, and fuel cells necessary to re-usable space shuttle propulsion and life support systems. Design data and safe operating parameters will be established based on results of this investigation.

APPROACH: Tensile, low and high cycle fatigue, and creep tests will be made on MAR-M200DS and Astrology nickel alloys, A-286 stainless steel and Haynes 188 cobalt alloy. To simulate flight hardware environments, tests will be made in hydrogen, hydrogen-water and ammonia at 3.45 MN/m^2 (500 psi) (ammonia) and 34.5 MN/m^2 (5000 psi) and temperatures of 298K (77F), 951K (1250F), and 144K (1600F).

STATUS: Technical Progress: The nickel-base alloys as a class were the most susceptible to hydrogen environment degradation. With two exceptions, the low-cycle and high-cycle fatigue life, both strain-controlled and tension-tension load-controlled, was degraded for all nickel-base alloys tested in 34.5-MN/m^2 (5000-psig) hydrogen. The fracture toughness, K_{IE} or K_{IC} was degraded for only one material, WASPALOY. The rupture life, on a stress for specific life basis, was degraded only by the pure hydrogen environment, with Inconel 718 (both heat treatments) and Inconel 625 being severely degraded, and WASPALOY, IN-100 and MAR M-200 DS slightly degraded (less than 25%). Materials tested in the hydrogen and water vapor and dissociated hydrazine environments were not degraded by those environments. Tensile property degradation was more evident at room temperature with ductility being most affected.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
PWA-FR-4566	Properties of Materials in High Pressure Hydrogen at Cryogenic, Room and Elevated Temperatures	J. A. Harris, Jr. M. C. Van Wanderham	June 30, 1971
PWA-FR-5129	Properties of Materials in High Pressure Hydrogen at Room and Elevated Temperatures	J.A. Harris, Jr.	June 30, 1972
PWA-FR-5768	Properties of Materials in High Pressure Hydrogen at Cryogenic, Room and Elevated Temperatures	J.A. Harris, Jr.	July 31, 1973

FIRST BENEFITTING PROJECT: Space Shuttle Main Engine

STATUS (CONCLUDED): Elongation and reduction of area were quite degraded, with IN-100 the most degraded, followed by MAR M-200 DS, Inconel 718 (1227°K solution), Inconel 625, Inconel 718 welded (1313°K solution), and Inconel 718 (1313°K solution) in that order.

Two iron-base alloys were tested, A-286 and AISI347. These alloys as a class exhibited the least severe degradation of all materials tested. In fact, AISI 347 had negligible property degradation for all tests and conditions investigated during this program. A-286 exhibited negligible property degradation at 300°K (80°F). The elevated temperature (951°K [1250°F]) creep-rupture and smooth tensile properties only were degraded at 34.5 MN/m^2 (5000-psig) pressure.

The two titanium alloys tested, 6A1-4V and A-110, did not exhibit significant degradation in any property at room temperature except tensile properties. The smooth tensile ductilities and notch tensile strength were degraded to severely degraded. At a temperature of 366°K (200°F) the low-cycle fatigue life and tensile properties of both alloys were degraded, with A-110 more severely affected. There was also evidence of the formation of surface hydrides on specimens tested at 366°K (200°F).

Haynes 188 was tested in three hydrogen containing environments. The only property evaluated that was degraded was low-cycle fatigue life at 951°K and 34.5 MN/m^2 (1250°F and 5000-psig) pressure, which was severely degraded.

Management Progress: This program has been completed.

Conclusions: This program was established to determine specific material properties and to enable general observations in regard to the susceptibility of a particular material to hydrogen degradation. The experience of this program has been that creep-rupture and low-cycle fatigue, both of which involve relatively long exposures to the environment at high strain/stress levels, are the most severe tests ot a material for hydrogen degradation, followed by high-cycle fatigue, tensile, and fracture toughness tests, in that order.

Problem: None

Forecast: None

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MSFC	01 04 73 - 30 09 73	114-08-04	

4. TITLE:

Space Shuttle Composites for Primary Structure

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. E. Engler	453-4050	G. A. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Boron/Epoxy Truss Beam

OBJECTIVE(S): To indicate areas of growth potential for the Space Shuttle vehicle through the use of advanced filamentary composite materials which would provide maximum strength to weight capabilities and result in increased payload; and to develop thrust structure concepts, including major structural components, applicable for various engine arrangements by number and size. Existing technology composite systems will be utilized to obtain minimum weight structure.

APPROACH: Technology investigations in the areas of structural design and analysis, materials evaluation, fabrication, quality assurance, and testing will be conducted. Representative requirements for Space Shuttle thrust structure beams will be utilized for the design, fabrication, and test of a truss type beam assembly utilizing boron/epoxy. The potential for weight savings with this type structure will be evaluated.

STATUS: The contractor (Grumman Aerospace Corp.) successfully tested individual elements of the beam assembly which utilized boron/epoxy tubes with titanium end fittings. The nine tube beam assembly was subsequently fabricated and delivered to MSFC for testing per the contractual requirement. The test fixture was fabricated by MSFC, but testing has not been accomplished due to program priorities.

Management Progress: None
Problems: Inability to test beam at MSFC.
Reports: Monthly progress reports issued under contract NAS8-26675

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Monthly Progress Report		

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4. TITLE:

Space Shuttle Composites for Primary Structure

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. E. Engler, S&E-ASTN-ES	453-4050	G. A. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Boron/Epoxy Shear Web Beam and Components

OBJECTIVE(S): To evaluate the potential for reduced structural weight of shear web beams utilizing boron/epoxy. The considerations will include representative production joining methods.

APPROACH: Representative requirements for Space Shuttle thrust structure beams will be used for the design, fabrication, and test of structural components and assemblies. The program will be phased such that testing of subelements will precede fabrication of related assemblies. The weight saving potential with this type structure will be evaluated. The program is in-house at MSFC.

STATUS: Subelement beam caps and bolted joint specimens were fabricated and tested. Revised specimens were designed and fabricated based on test results. A beam assembly (simple shear beam) representing a portion of the beam was fabricated in conjunction with bonded web closeout specimens. The specimens have not been tested due to program priorities. Plans to fabricate the complete beam assembly were cancelled due to the expense involved and the lack of priority.

MANAGEMENT PROGRESS - None
Problems - Testing at MSFC

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None			

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4. TITLE:

Space Shuttle Composites for Primary Structure

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. E. Engler, S&E-ASTN-ES	453-4050	G. A. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Graphite/Epoxy Compression Panel

OBJECTIVE(S): To evaluate the potential for reduced structural weight by the use of graphite/epoxy in primary structure compression panels.

APPROACH: A representative structural loading intensity for the Space Shuttle was chosen, and test panels designed, fabricated, and tested. This fabrication was preceded by materials processing, analysis, and test of subelements of the panel. Load introduction fittings were incorporated for evaluation.

STATUS: Two panels (29" x 80") were successfully tested at MSFC. Both panels exceeded requirements. Program is complete. The program was conducted by Martin Marietta under contract NAS8-26242.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MCR-73-40	Graphite/Epoxy Compression Panels	John R. Lager	Feb. 1973

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4. TITLE:

Space Shuttle Composites for Primary Structure

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. E. Engler, S&E-ASTN-ES	453-4050	G. A. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Boron/Epoxy Compression Panel and Stringers

OBJECTIVE(S): To evaluate the potential for reduced structural weight by the use of boron/epoxy in primary structure compression panels.

APPROACH: A representative structural loading intensity for the Space Shuttle was chosen, and a test panel and related stringer subelements designed and fabricated. The stringers were tested prior to panel fabrication for verification of load capability. Load introduction fittings were incorporated for evaluation. The program was conducted in-house at MSFC.

STATUS: Stringer elements were successfully tested, and a 29" x 80" panel was fabricated. The panel has not been tested due to program priorities.

Management Progress - None
Problems - Testing of panel

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
None			

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 115-17-04	PRIOR NO.: 115-17-04

4. TITLE:
Shuttle Guidance

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-GG R. R. Burrows	205-453-0445	Clyde D. Baker

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Uniform Shuttle Guidance
NAS8-28425, International Business Machines
18100 Frederick Pike
Gaithersburg, MD 20760

OBJECTIVE(S): Due to a current decline in interest as regards a unified shuttle guidance system and an increase in interest in guidance for the space tug and because of the relative ease with which the algorithms of this and associated contractual efforts can be revised for tug application, the scope of this contract has been expanded to include tug related activities. Thus, the objectives of this effort are now two-fold.
(1) An algorithm for real-time reentry guidance of shuttle vehicles to meet terminal and inflight constraints and to maximize some measure of performance will be developed. The trajectories generated will be feasible but not necessarily optimal. The algorithm will be compatible with and similar in structure to the ascent and orbital maneuver programs (specifically, GUIDE 71/6) already developed under separate contracts.
(2) The space tug is to be a versatile tool for exoatmospheric transportation, able to complete complicated orbital maneuvers without either on-board or ground based human intervention. As a result, the requirement for reliable automatic guidance and control is especially stringent. This effort will be directed towards the adaptation of the GUIDE algorithm (developed under NAS8-24018 for optimal space shuttle ascent and orbital guidance studies) for real-time optimal guidance of the space tug in applications such as transfer from low earth orbit to rendezvous with a synchronous equatorial satellite.

APPROACH: In order to develop a method of controlling a re-entering shuttle vehicle meeting specific landing location, peak-heating and g-loading constraints, a

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FIRST BENEFITTING PROJECT: Space Shuttle

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APPROACH (CONCLUDED): quantitatively measured performance index will be developed. This reduces the problem, therefore, to one of maximizing this index. Objective (2) above will be met by adapting currently existing algorithms to tug real-time optimal guidance applications. A Bolza formulation with terminal constraints will be used with tuning of the matrix to achieve a suitable compromise between the constraints and fuel cost for a variety of missions. Complete simulation of missions using two or three burns separated by coast arcs will be conducted. The developed algorithm will be checked for efficiency in a real-time feedback guidance mode and in an on-board targeting mode. Finally, the algorithm will be documented and a FORTRAN implementation delivered to MSFC.

STATUS: Technical Progress: Work on objective (1) has been completed and a report issued to cognizant MSFC personnel as part of the regular progress report for June 1973. The problem of maximizing the performance index as outlined in the approach section was met in the unconstrained case with a straightforward application of a routine developed by M. J. D. Powell. The trajectories thus generated proved to be only slightly less than optimal. As it turned out, these unconstrained solutions also satisfied the maximum g-force constraint. Further work in this area was therefore unnecessary. After various other methods were studied, a nonlinear programming approach to temperature control was finally implemented and proved satisfactory. The airport flyover constraint was at least partially solved by use of a quadratic search procedure. Although many refinements could be made in the final algorithm here outlined, no further work is now planned. Instead, future efforts will be directed towards meeting objective (2).

Management Progress: A formal agreement between IBM and MSFC on the expansion of the objectives of this contractual effort is due to be completed in a short time. The contractor is, however, proceding on the expanded work without formal agreement.

Conclusions: A suitable reentry algorithm for shuttle onboard guidance has been developed.

Problems: None

Causes of Problems: None

Suggested Solutions: None

Forecast: A space tug real-time optimal guidance algorithm will be developed on schedule.

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Marshall Space Flight Center	01 04 73 - 30 09 73	CURRENT NO.: 124-08-16	PRIOR NO.: 124-08-08

4. TITLE:

CRYOGENIC STORAGE

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Eric H. Hyde	453-3852	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Investigation of High Performance Insulation Problems

CONTRACT: NAS8-21400, McDonnell Douglas/Western Division

OBJECTIVES: To develop technology for the design and fabrication of thermal protection systems with a "ρk" product less than 5×10^{-5} Btu-lb/hr-ft^4-$^\circ$F for long term space storage of cryo-propellants (primarily LH_2) in large propulsion stages for mission duration from 30 to 300 days under earth orbital, lunar, and interplanetary environments.

APPROACH: Work will be performed through evaluation of material composites, calorimeter tests of selected composites, evaluation and selection of attachment and design concepts, thermal analyses, thermal and structural component tests, and application of the selected concepts to a typical flight-type tank. The test tank will then be tested in the MSFC 15-foot diameter vacuum chamber.

STATUS: Technical Progress: The technical and contractual efforts related to this program are complete. A materials screening program was initiated that provided for selection of a MLI composite made of double aluminized Mylar and B4A Dacron net spacer material. An electrical screening technique was developed that quickly and inexpensively screened out candidate spacer materials. A systematic method of defining the minimum practical layer density of any MLI composite was defined and developed. Thermal performance repeatability depends on repeatable fabrication between two different fabricators. A fabrication method with required tooling to achieve this goal of

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
DAC-63250	First Quarterly Report Jan 20 - Apr 20, 1969	G. O. Fredrickson	
MDC-G1152	Second Quarterly Report Apr 20 - July 20, 1969	G. O. Fredrickson	
MDC-G1238	Third Quarterly Report July 20 - Oct 20, 1969	G. O. Fredrickson	
DAC-63264	Special Report No. 1	G. O. Fredrickson	
MDC-G0275	Fourth Quarterly Progress Report, Oct 20 - Jan 1970	G. O. Fredrickson	
MDC-G2135	Interim Progress Report February 1971	G. O. Fredrickson	
	Combined Insulation Report Feb 20 - Sep 1, 1971	G. O. Fredrickson	
MDC-G4722	Final Report August 1973	G. O. Fredrickson	

FIRST BENEFITING PROJECT: SPACE TUG

repeatable and predictable thermal performance was defined and demonstrated. Fabrication and application of MLI panels to vessels 10 meters in diameter, 20 meters long was demonstrated. Component thermal performance tests were performed to define the basic composite heat flux, thermal effects of seams and perforations. Component (face sheet, fasteners) structural tests were performed for design sizing. Mylar and face sheet expansion coefficients were experimentally measured. These tests showed that the panel load-carrying members will remain loaded after tank-propellant-loading induced chilling. Panel structural integrity in a Saturn acoustic environment was demonstrated down to -285°F. The panels fluffed up after acoustic tests suggesting that improved thermal performance can be expected after an MLI system is launched. The results of all component tests were combined into a flightworthy MLI system design which was fabricated and installed on a 2.67-meter diameter MSFC furnished tank. A purge gas system was defined and purge gas requirements for pre-launch, groundhold, and ascent were calculated. A purge jacket was defined, designed, and fabricated by Goodyear Aerospace Corporation and applied to the 2.67-meter tank. The MLI system was installed and tested in the MSFC 4.56-meter vacuum chamber. The B4A Dacron net composite test yielded the lowest applied heat flux of 4.16 w/m^2 (0.13 $Btu/hr\text{-}ft^2$) to date. If a 3.05-meter tank containing 1050 Kg of LH_2 were insulated with the B4A, the resulting boiloff would be about 0.22%/day or it would take 455 days for all of the LH_2 to evaporate.

Management Progress: The program was completed within budget with no cost overrun.

Conclusions: Fabricating and installing purge type high performance MLI system for one-shot large vehicle stages is now possible with minimal applied thermal degradation.

Problems: There were several problems during the program. The most significant was the sealing of the purge jacket around penetrations and the shift in thermal performance between tests where the MLI was initially evacuated and purged with gaseous helium.

Cause of Problem: The leaking purge jacket was a result of sharp edges and poor sealing near the penetration. The shift in MLI thermal performance was theorized to be residual gas conduction.

Problem Solution: Eliminate sharp sealing edges around penetration by using fairing near the purge jacket termination. A positive method of eliminating gas conduction is unknown. Preconditioning the MLI composite may be one solution.

Forecast: The final report was prepared and distributed August 1973. A certificate of performance has been issued to the contractor, MDAC/WD.

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MSFC	01 04 73 - 30 09 73	124-08-37	

4. TITLE:

Space Shuttle Advanced Composites for Primary Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN L. M. Thompson	3-1223	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: "Development of Design Data for Graphite and Boron Reinforced Epoxy and Polyimide Composites" NAS8-26198, General Dynamics/Convair Division

OBJECTIVE(S): To develop reliable design data for graphite fiber reinforced epoxy and polyimide composites for structural application on advanced space vehicles. Strength data shall be developed over the maximum useful temperature range for each composite. Data will also be developed on thicker sections of these composites than are normally tested. The results shall be incorporated into material and process specifications for both composites types. Hat sections graphite/polyimide stringers shall be designed, fabricated, and tested to specified criteria. Boron and high modulus graphite fiber/polyimide laminates shall be studied, and design data developed for high modulus graphite/polyimide laminates.

APPROACH: From the survey-available materials and test data, four candidate prepregs for both the epoxy and polyimide systems shall be selected for further study. Of the four candidate prepregs, at least one shall be made of high modulus graphite fibers and another of high strength graphite fibers. Based on test data from laminates made from the prepregs, one candidate representing each resin system shall be selected to develop design data. Tests shall be run to optimize cures for each system using vacuum bag, press, and autoclave cures. Other tests as needed will be obtained on the laminates over a temperature range of -423°F to +350°F for the epoxy laminate and -423 to 600°F for the polyimide material to develop design allowables. Based upon the data developed, 15-inch and 40-inch long hat section stringer assemblies will be designed and fabricated from high strength graphite fibers and polyimide

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
REPORT NO.			
Sampe Paper	Development on Graphite/ Polyimide Composites	Dr. J. M.Stuckey W. G. Scheck	Oct. 1971
Sampe Paper	Development and Evaluation of Graphite and Boron Polyimide Composites	Dr. J. M. Stuckey W. G. Scheck	Oct. 1972

FIRST BENEFITTING PROJECT: Space Shuttle

MSFC - Form 360 (March 1973)

PROGRESS REPORT
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CURRENT NO./CODE: 124-08-37

APPROACH(CONCLUDED): resin, and will be tested to specified criteria. Laminates of various high modulus graphite fiber/polyimide resin combinations will be studied, and one laminate will be selected to develop design data. Boron fiber/polyimide resin laminates will also be evaluated.

STATUS: Technical Progress--All program objectives have been achieved. All design data has been reduced and drafts of final reports have been received and are under evaluation.

Management Progress--None

Conclusions--This program is complete with all objectives met. No further reports will be issued.

Problems--None

Causes of Problems--None

Suggested Solutions--None

Forecast--This program was sucessfully completed.

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4. TITLE:

Space Shuttle Advanced Composites for Primary Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN J. M. Stuckey	3-1222	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: In House Effort on Evaluation of Graphite Composites

OBJECTIVE(S): To evaluate and optimize curing and processing conditions for graphite prepreg materials through fabrication of test specimens and to develop realistic design information for composite materials. Recently to qualify graphite/epoxy laminates as the material for the optical bench of the Large Space Telescope (LST).

APPROACH: Initial efforts are concentrated upon available high modulus and high tensile graphite-epoxy prepreg materials. Test pieces are being fabricated, and the physical and mechanical properties obtained for finished products over a wide temperature range are correlated with processing and curing history. Optimization of cure procedures using a dielectric monitor will be studied. In addition, polyimide specimens provided under Contract NAS8-26198 will be tested at -423°F, and cure procedures developed under that program will be checked for reproducibility. Based on available data four commercially available high modulus graphite/epoxy prepreg were selected for qualification to the unique requirements of the LST.

STATUS: Technical Progress--Efforts on the report on the evaluation of 0/90 bidirectional graphite/epoxy-phenolic laminates obtained from General Electric have been delayed. Emphasis is being placed on high modulus graphite/epoxy laminates for LST. Laminates are being fabricated from three candidate epoxy prepregs and test specimens are being prepared for thermal expansion, thermal conductivity, outgassing, environmental

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENETITTING PROJECT: LST

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STATUS (CONCLUDED): exposure, moisture sorption, and mechanical property tests. Data on mechanical properties as fabricated are being obtained at 75°F and -100°F. Moisture sorption tests have been initiated.

Management Progress--Emphasis shifted to qualifying high modulus graphite/epoxy laminates for LST.

Conclusions--Data shows a problem with graphite and boron/epoxy laminates from moisture sorption; polyimide laminates are not encountering the same difficulty. Tests on the pyrone resin/graphite laminate show that more development effort is required before commercial application.

Problem--Tensile testing at -423°F (temporarily postponed) has resulted in specimen failures in the reinforced area rather than the test area. One prepreg eliminated from program due to inability of the prepreg suppliers to obtain the basic epoxy resin which was discontinued by the manufacturer. Another prepreg has been ordered as a replacement.

Cause of Problems--Differences in thermal expansion of adhesive and reinforcement add to the thermal stresses introduced by the test temperature.

Suggested Solutions--Reduce mismatch in thermal expansion by using a filled adhesive to bond reinforcement and use reinforcements of glass or graphite laminates.

Forecast--The program in progress should establish that graphite/epoxy can be used for LST. Thermal expansion, outgassing, and moisture sorption-disorption data should indicate the more desirable laminates for LST application.

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MSFC	01 04 73 - 30 09 73	129-03-33	

4. TITLE:

Materials Compatibility Evaluation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN Dale M. Kornfeld	3-1220	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of LOX-Compatible Structural Adhesive, NAS8-27087, Whittaker Corp., Narmco R&D Division, San Diego, CA

OBJECTIVE(S): To develop a LOX compatible structural adhesive for use in fabrication of the Shuttle External Tank by the weld bond process.

APPROACH: To continue development and synthesis of a LOX compatible structural adhesive based on the modified poly(perfluoropropylene oxide) urethane system and optimize this established base polymer for the weld bond application. To continue LOX compatibility testing of the polymer, and of aluminum panels bonded together with the adhesive, and evaluate the effects of metal surface preparations and various primers on adhesive performance.

STATUS: Technical Progress--Weld bond studies have been conducted utilizing both weld-through of uncured adhesive and capillary fill-in techniques of previously spotwelded adherends. Both techniques provided acceptable results. Superior adhesive performance was demonstrated when a primer system was employed, demonstrating that high quality welds and adhesive values are readily attained by both fabrication methods. Material has shown improvement in LOX compatibility as shown by the most recent LOX impact test results as per MSFC-SPEC-106B. Impact testing has been conducted on the material's usage configuration - that is as a cured adhesive bonding together two aluminum plates. Two batches of the uncured resin have been received from the contractor for in-house fabrication and testing. Several primers were evaluated as to their effect on bond strengths.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

PUBLICATIONS--During the two-year life of this contract 1 Annual, 6 Quarterly, and 23 Monthly progress reports were published. The final 2-year Summary Report is presently being prepared.

FIRST BENEFITTING PROJECT: Shuttle External Tank

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STATUS (CONCLUDED): Management Progress--A no-cost extension was granted the contractor, extending contract activities until 23 August 73. The contract has now expired and the draft copy of the final summary report is presently being reviewed.

Conclusions--On the basis of the LOX impact test results, the material could be considered batch-qualified as per MSFC-SPEC-106B. The feasibility of using the PFPO resin system in the weld-bond configuration has been proven.

Problems--A few LOX impact detonations or flashes continue to be noted, generally on rebound impacts. It is believed these reactions in LOX can be attributed to chance contamination of the samples during synthesis, lay-up, or cure, rather than an intrinsic non-compatibility of the polymer itself. The polymer still remains marginal in tensile strength above room temperature.

Forecast--The contract has expired and no further work by the contractor is planned. However, a low level in-house effort will continue, based on availability of personnel, utilizing the two batches of PFPO adhesive supplied by the contractor in an attempt to resolve the continuing compatibility problem.

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4. TITLE:

Polymers

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN W. J. Patterson	3-1224	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: "Development of Thermally Stable Phosphonitrilic Elastomers for Advanced Aerospace Structures," NAS8-25184, Horizons, Incorporated, Cleveland, Ohio

OBJECTIVE: Development of thermally stable polymers based on phosphonitrilic chloride precursors which shall be processed into elastomers, coatings, adhesives, or sealants characterized by high thermal stability and resistance to hydrocarbon fuels for use on future aerospace vehicles.

APPROACH: Preparation of linear phosphonitrilic chloride polymers and subsequent incorporation of fluoroalkoxy substituents as pendant groups along the polymer chain. The polymers are to be formulated both as high molecular weight millable gums and lower molecular weight liquid prepolymers which can be cured in place. The efforts of the current phase of the program are directed toward the liquid prepolymer formulation and subsequent development of effective crosslinking systems to yield a thermoset sealant composition.

STATUS: Technical Progress--The effort toward development of pourable formulations of fluoroalkoxy-substituted phosponitrilic polymers has resulted in thermoset elastomers of low tensile strength. Films or coatings of high molecular polymers of this type cast from solution have demonstrated high tensile strength and elongation as well as outstanding fuel resistance. The solvent-based coating formulations are being supplied in 1 quart quantities for internal evaluation by MSFC as printed wiring board conformal coating. The final report for this program is being written and constitutes the final effort by the contractor. This RTOP report constitutes

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

PUBLICATIONS: During the course of this program, the contractor has generated 22 Monthly reports, 6 Quarterly reports, and 2 Annual reports. The final Summary report is now being prepared.

FIRST BENEFITTING PROJECT: Sortie Lab

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STATUS (CONCLUDED): the final submission on contract NAS8-25184.

Management Progress--None

Conclusions--The fluoroalkoxy-substituted phosphonitrilic polymer system is characterized by outstanding hydrocarbon fuel resistance and remains a good candidate for an integral fuel tank sealant if additional R&D work can be carried out to provide high strength thermoset materials from an easily applied liquid precursor. The solvent-based, high molecular weight polymer formulations result in improved mechanical properties and offer attractive applications as conformal coatings.

Problems--The thermal stability of the phosphonitrilic polymer system appears to restrict its use to the 300-400°F region and its usefulness as a fuel tank sealant in flight regimes of high aerodynamic heating is thus doubtful.

Suggested Solutions--The basic polymer modifications required to overcome the thermal instability in the polymer are beyond the scope of this program, as this is the close-out report on the contract.

Forecast--The final report will be distributed as soon as it is published by the contractor, and modest internal effort will be sustained at MSFC to evaluate the solvent-based phosphonitrilic coating for printed wiring board applications.

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4. TITLE:

Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
George Fichtl, S&E-AERO-YA	205-453-3109	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK (1) Definition of and Effect of Wind Shear on the Operation of Aeronautical Systems

TASK (2) Fog Microphysical Research and Numerical Modeling of Fog

TASK (3) Wind Profiles Over Non-Uniform Surfaces Relative to Design of Aircraft and Space Vehicles

TASK (4) Atmospheric Parameters for the Definition of Clear Air Turbulence Statistics

TASK (5) Wake Structure Model Development for Aeronautics

TASK (6) Definition of the Horizontal and Vertical Structure of Turbulence for Aeronautical System Design and Operation

TASK (7) Structure of Turbulence in Severe Atmospheric Conditions

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
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FIRST BENEFITTING PROJECT: (See Attached)

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4. TITLE:

Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
George Fichtl, S&E-AERO-YA	205/453-3109	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK(1)Definition of and Effect of Wind Shear on the Operation of Aeronautical Systems
In-House Effort
NAS8-26600, University of Dayton Research Institute, Dayton, Ohio

NAS8-28136, Aeronautical Research Associates of Princeton, Princeton, N. J.

OBJECTIVES: To develop environmental wind models of low-level atmospheric shear flows for the safe design and operation of aeronautical systems. The models shall define the steady-state and turbulent spatial variations of wind along the flight path of aeronautical systems during the take-off and landing flight phases.

APPROACH: Develop models of wind shear which define the average, as well as extreme, wind shears that could occur over and around airports. The analysis will primarily be concerned with wind shear in stable air (nighttime flows) although some consideration will be given to unstable daytime and neutral boundary layer flows. These studies will be based on analyses of atmospheric boundary layer wind profile data from the 150-meter ground wind facility at KSC and the MSFC eight-tower ground wind facility. In addition, aircraft response studies will be conducted to determine those magnitudes of wind shear which adversely affect the landing and take-off of aeronautical systems.

STATUS: Technical Progress: Work has continued on statistical models of shear. The main technical progress concerns results relative to the definition of low level wind shear environments for automatic landing system design. A world-wide distribution of low-level wind shear has been determined whereby design values of wind shear can be determined given the accepted risk of exceeding the design

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-2288	A Model of Wind Shear and Turbulence in the Surface Boundary Layer	James K. Luers	July 1973
NASA CR-2287	Effect of Shear on Aircraft Landing	James K. Luers & Jerry B. Reeves	July 1973

FIRST BENEFITTING PROJECT: Aeronautical (Vehicle Take-off and Landing) & Space Shuttle

STATUS: (continued) shear environment at least once during the operational lifetime of the aircraft.

Conclusions: The main conclusion is that the Federal low-level wind shear compliance criteria for the installation of category II automatic landing systems are too mild. Thus, if automatic landing systems are designed to just satisfy the Federal compliance criteria, the risk of exceeding the design shear environment of these automatic landing systems during their operational lifetime will be relatively large.

Problems: The work concerning the development of low-level wind shear reporting requirements, criteria and procedures to pilots prior to take-off or landing has been delayed, i.e., critical wind shear definition. Causes: This delay has been caused by the delay in FY74 funds.

Forecast: It is anticipated that FY 74 funds will arrive in late November or early December. Scopes of work are being prepared so that the work relative to the definition of low-level critical wind shear can be continued. In the meantime, in-house effort is continuing.

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4. TITLE:

Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YE Otha H. Vaughan	205-453-3272	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK (2) Fog Microphysical Research and Numerical Modeling of Fog
Contract No. NAS8-29583 Colorado State University
Ft. Collins, Colorado 80521

OBJECTIVE(S): To study the life cycle and microphysical properties of both field and laboratory simulated warm fogs, perform studies leading to the development of techniques for field fog modification programs, and develop numerical models of fog formation and dissipation techniques for use in predicting success criteria for field testing in the future.

APPROACH: To develop techniques for use in field fog modification operations requires a thorough understanding of a fog's microphysical characteristics under natural conditions of formation and dissipation, as well as how the fog will react to the modification or dissipation techniques. This research program will use previous reports from other researchers, contracted theoretical and laboratory studies, in-house laboratory studies, as well data generated from field test programs from all available sources. These data will be used in providing the knowledge required to develop the most reliable, ecologically safe, and economic solution to the fog problem.

STATUS: Due to reduction of programmed funds from NASA Headquarters and contract negotiation problems with Calspan Corporation the proposed work effort as reported in the previous RTOP could not be started. Since most of the NASA contracted fog research over the past years had been performed by Calspan the NASA RTOP Manager decided to contract this FY-73's effort to another contractor to get a fresh view of the problem, and to reduce time lost in a procurement cycle. This task was added to an existing MSFC

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FIRST BENEFITTING PROJECT: Aeronautics

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STATUS (concluded):
contract NAS8-29583 with Colorado State University and contract start was August 31, 1973. This task is now underway to perform a state-of-the-art survey which identifies the basic research tasks needed to help resolve the unknowns in warm fog modification and control, based on previous research programs. In addition, CSU is assessing the influence of specific pollutants on warm fog behavior and seedability and is identifying nuclei which are most effective in producing the fog. Dr. M. Corrin is the Principal Investigator on this study. Dr. Corrin visited the COR at MSFC in September to discuss the research program and obtain specific program approach guidelines.

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4. TITLE:

Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
G. H. Fichtl, S&E-AERO-YA	205/453-3168	W. W. Vaughan, S&E-AERO-Y

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK (3) Wind Profiles Over Non-Uniform Surfaces Relative to Design of Aircraft and Space Vehicles

NAS8-29584, University of Tennessee Space Institute, Tullahoma, Tennessee

OBJECTIVES: To develop a mathematical model of the flow of air over low-level natural and man-made obstructions. The model will be used to calculate the flow over the typical types of ground obstructions found at and in the vicinity of airports, heliports, etc. The results will be analyzed to determine if hazards exist in the flows relative to the safe operation of aeronautical systems. The results will be generalized so as to provide guidelines relative to the operation of aeronautical systems over low-level obstacles.

APPROACH: The approach will consist of a mathematical model based on the boundary layer equations for atmospheric flows. The dissipation terms resulting from atmospheric turbulence will be expressed in terms of mean flow parameters. The resulting equations and associated boundary conditions will be solved with numerical finite difference techniques to produce the flow field of air over obstacles for various geometries. The sensitivity of the model relative to the closure hypothesis to represent the dissipation terms will be determined. Various geometries for the low-level surface obstructions (buildings, small hills, etc.) will be selected and an assessment will be made of the character of the flows relative to the safe operation of aeronautical systems. The results of the study will be verified at MSFC with field experiments.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-2182	A Boundary Layer Approach to the Analysis of Atmospheric Motion Over a Surface Obstruction	Walter Frost, J. R. Maus W. R. Sinclair	January 1973

FIRST BENEFITTING PROJECT: Aeronautical (Aircraft Control Systems) & Space Shuttle

JUSTIFICATION, OPERATING PLAN, REVIEW AND REPORTING *(Items 14, 15 and 16)*

STATUS: Technical Progress--The contractor has completed the two-dimensional model of flow up and over to the separation point on low level obstructions in the vicinity of aerodromes. This work is being documented in a report which will be transmitted to the NASA in approximately 6-8 weeks.

Management Progress--The contractor has traveled to MSFC on numerous occasions to confer with the NASA COR on technical points in the contract. A paper is now in preparation for publication which gives the essential results of the contract to date.

Conclusions--The main conclusion to date is that the air flow over buildings is significantly modified so as to pose a potential threat to low flying aircraft in the immediate vicinity of aerodromes. The above mentioned report (see technical progress) will give numerical examples of the types of wind shears and magnitudes that can be induced by buildings and natural obstacles.

Problems--None.

Cause of Problems--None.

Forecast--This contract is being performed on schedule. The next reporting period will be extending the flow field analysis past the separation point and to model the separation bubble over and behind buildings. This will be a two-dimensional analysis and will be extremely useful for determining flows at heliports on tops of buildings. In addition to this, a three-dimensional flow analysis will be initiated of the flow up to the separation point.

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4. TITLE:

Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
George H. Fichtl, S&E-AERO-YA	205/453-3168	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK(4)Atmospheric Parameters for the Definition of Clear Air Turbulence Statistics
In-House Effort
OBJECTIVE(S): To develop models of clear air turbulence (CAT) with detailed wind and temperature profile data between 1 to 18 km altitude.

APPROACH: The plan is to relate nondimensional numbers which define the flow over relatively small vertical scales (100-300 m) to corresponding numbers defined over relatively larger vertical scales (1000-5000 m). This will result in conditional distribution functions of small scale parameters given certain values for the large scale defining flow parameters. This data analysis will establish the statistical relationships between the various scales of motion in the context of the selected nondimensional numbers. One obvious nondimensional number that will be used in the analysis will be the Richardson number; however, it is possible to define others. Once these statistical relationships are determined then the probability of the occurrence of CAT can be determined given the large scale nondimensional numbers, provided that critical nondimensional numbers on the small scale can be defined relative to the generation of CAT. Assuming that this can be accomplished, CAT occurrence climatology can be derived for various locations once the climatology of the large scale nondimensional numbers is known, using relatively available rawinsonde data. The development of the statistical relationships between the large and small scale flows will be first determined for Cape Kennedy, Florida because of the large data base that now exists.

STATUS: Technical Progress: Analyses relative to the spectral structure of detailed wind profiles has been completed and have been documented in the paper cited in the reports section of this progress report.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Fichtl, G. H. and Dennis Camp, 1973: Spectral Structure of Tropospheric Vertical Temperature Profiles over Cape Kennedy, Florida. Journal of Geophysical Research, 78, 6218-6223.

FIRST BENEFITTING PROJECT: Aeronautical (Aircraft Structures) & Space Shuttle

STATUS: (Continued)

Conclusions: The main conclusion concerning the structure of detailed wind profiles is that these profiles contain considerable detail from scales approximately a few meters in length to scales tens of kilometers in length. All of these scales must be considered when discussing the generation of clear air turbulence.

Problems: None

Forecast: Work will continue on studies relative to the development of the Richardson number probability model for clear air turbulence probability determination.

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4. TITLE:
Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
G. H. Fichtl, S&E-AERO-YA	205/453-3168	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK (5)Wake Structure Model Development for Aeronautics

NAS8-29583, "Wind Tunnel Investigation of Wakes Downwind of Buildings and Natural Obstacles" Colorado State University, Ft. Collins, Colorado 80521.

NAS8-29582, "Feasibility of Aircraft Platforms to Measure Building Wakes for Aeronautical Safety Applications," Texas A&M University, College Station, Texas 77843.

OBJECTIVES: To determine the structure of wakes downstream of low-level obstacles for application to the safe operation of aeronautical systems.

APPROACH: 1. Data Acquisition

a. Determine the feasibility of probing these wakes with instrumented aircraft to determine if useful data for the development of wake models can be obtained with aircraft platforms.

b. Determine the feasibility of obtaining realistic useful information about low-level obstacle wakes with wind tunnels. Realistic data will be judged on the basis of similarity considerations.

c. Determine the feasibility of obtaining useful information about low-level obstacle wakes with meteorological towers with the MSFC eight-tower array.

2. Select optimum data acquisition approach and collect data. It may turn

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Reports			

FIRST BENEFITTING PROJECT: Aeronautical (Aircraft Take-off and Landing) & Space Shuttle

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APPROACH: (continued) out that we need to use each approach outlined above.

3. Develop models of low-level obstacle wakes (buildings, hills, trees, etc.) with data using theory and dimensional analysis to guide the model development.

STATUS: Technical Progress: The contractors have completed the literature surveys for these respective programs. The Texas A&M people have laid out a test area within which anemometers will be located and through which the test aircraft will fly. The test area consists of the downwind region behind an aircraft hangar. The instruments for the ground measurements of the building wake have been delivered to A&M and have been installed. The Colorado State group has prepared its wind tunnels and building models and tests are now underway.

Management Progress: A contract has been signed with Colorado State University NAS8-29583, dated 31 08 74.

Problems: None

Causes of Problems: None

Forecast: The Texas A&M group will begin tests in late October to acquire data on wakes. The data will consist of ground wind speed and direction data and aircraft response data. The Colorado State group will continue wind tunnel tests for a variety of shapes and determine the statistical properties of wakes via correlation techniques.

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4. TITLE:
Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
George H. Fichtl, S&E-AERO-YA	205/453-3168	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK(6)Definition of the Horizontal and Vertical Structure of Turbulence for Aeronautical System Design and Operation
Contract No. NAS8-28659, University of Oklahoma, Norman, Oklahoma

OBJECTIVE(S): To define the horizontal and vertical structure of atmospheric turbulence in the atmospheric boundary layer for application to the safe operation and design of aeronautical systems.

APPROACH: Develop models of turbulence with empirical/theoretical techniques. The approach involves the acquisition of atmospheric turbulence data from the KSC 150-meter tower and the NASA/MSFC four and eight-tower arrays. These data will be used to develop statistical and spectral models of turbulence. The models will describe the statistical relationship between turbulence velocity fluctuations at different points in space and time.

STATUS: Technical Progress: During this reporting period the data acquired during the 1972-1973 field program were processed with statistical/Fourier transform programs to obtain a preliminary look at the data.

Management Progress: None

Conclusions: Our studies relative to the simulation of turbulence show that it is possible to develop turbulence simulation procedures which result in turbulence processes with variable integral scales and standard deviation along the flight path of an aircraft as found during take-off and landing.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Fichtl, G. H., 1972: Probability Distribution of Vertical Longitudinal Shear Fluctuations. Journal Applied Meteorology, 6, 918-925.

Fichtl, G. H., 1972: Wind Shear Near the Ground and Aircraft Operations. Journal of Aircraft, 9, 765-770.

FIRST BENEFITTING PROJECT: Aeronautical (Flying Qualities) & Space Shuttle

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STATUS: (continued)

Problems: No funds to continue work on full scale project, can continue with appropriate FY 74 obligation and costing authority.

Forecast: In-house data reduction and synthesis of results to determine a two-dimensional spectral model of turbulence shall continue. However, due to funding delays the pace of the total program will be slower than normal.

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4. TITLE:

Atmospheric Parameters

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YA George H. Fichtl	205-453-3168	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK(7)Structure of Turbulence in Severe Atmospheric Conditions
Contract No. NAS8-27334 Pennsylvania State University
State College, PA

OBJECTIVE (S): Develop models of the horizontal and vertical structure of turbulence in severe atmospheric conditions as found in thunderstorms, etc. for application to the safe operation of aeronautical systems.

APPROACH: Perform scale and dimensional analyses to determine the scaling parameters of the problem and synthesize hypotheses which can be used to model statistical turbulence parameters that are relevant to the design and operation of space vehicles operating in severe weather in the atmospheric boundary layer. The resulting hypotheses will be formulated in such a way that they can be verified by experiment. The verified hypotheses will then be used to develop the models of the turbulence parameters. In addition, the relationships between the scaling parameters and the meso-scale and synoptic scale flow field (using Cape Kennedy, Florida, for example), will be established, if such relationships do in fact exist. These relationships and the turbulence models will be used to develop the climatology of the turbulence parameters.

STATUS: Technical Progress--The contractor has analyzed the bulk of the thunderstorm data which was supplied by the NASA. The report indicated in item 7 above documents much of this analysis. A theory has been developed during the reporting period which will be used to explain the experimental results. The model has been run on the computers at the National Center for Atmospheric Research in Boulder, Colorado, and the results will be documented during the next reporting period.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-2289	Variation of the Low Level Winds During the Passage of a Thunderstorm Gust Front	R. W. Sinclair, R. A. Anthes, & H. A. Panofsky	July 1973

FIRST BENEFITTING PROJECT: Aeronautical (Vehicle Take-off and Landing) & Space Shuttle

STATUS (concluded):

Management Progress--The report indicated in item 7 above has been transmitted to all private and government agencies of concern to the problem.

Conclusions--The main conclusion is that no predictor with skill can be found for predicting the time of onset of the longest gust (peak wind) in a thunderstorm at the ground with larger scale rawinsonde and radar parameters. The result is not conclusive, nevertheless it suggests that the search for predictors of the time of onset of the peak gust in a thunderstorm will be more difficult in the future. The second main conclusion is that the logarithmic wind profile can perhaps be used for altitudes below the 100-meter level for predicting the vertical variation of wind near the ground in a thunderstorm.

Problems--None.

Causes of Problems--None.

Forecast--During the next reporting period the contractor will summarize the results obtained from numerical experiments conducted at the National Center for Atmospheric Research. It is hoped that this analysis will point the way for determining low level thunderstorm gust predictors for aeronautical operations.

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4. TITLE:
Hazard Avoidance and Elimination
(Laser Doppler Wake Vortex System)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF Edwin A. Weaver	205-453-2544	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: NASA Support to FAA on Aircraft Wake Turbulence Problems

OBJECTIVE(S): Develop a system capable of tracking wing tip vortices in an airport environment. Measure flow details in the cores of wing tip vortices of low flying aircraft. Establish a rudimentary vortex tracking system at Kennedy International Airport by 1974.

APPROACH: Develop a laser Doppler system to detect and measure wake vortices. This will require system engineering studies of the vortex problem and the interaction with the laser system. The development of a signal processor and display for observing and tracking ; preparing test plans and data reduction procedures; and evaluation methods for the operational modes will be carried out. Three units will be fabricated, assembled and checked out with verification fly-by testing in the line scan and tracking modes.

STATUS: Technical Progress - The system engineering/simulation effort is progressing on schedule. Data processing programs for system verification and checkout are being developed and should be ready for use in data processing the results of the systems first fly-by test. A real-time total system simulation employing the system display and hardcopy unit is complete and available for operator usage at the MSFC Computer Laboratory.

Two new Raytheon 20 watt CO_2 lasers are now available for use in these systems. An older laser is being reconditioned and will be available by mid-December. A

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: FAA Airport Vortex Detection Project

STATUS (CONCLUDED)

backup Honeywell laser will be used as a standby.

The Bragg cell has been chosen as the desired method for translation of the Doppler frequency. Design of the system is complete and fabrication of the system has been started. Completion is expected by the end of November.

Design of a scan system has been completed and fabrication of a breadboard system is 90% complete. Delivery of the first field unit is scheduled for October 15, 1973.

The processor for the system makes use of a surface acoustic wave delay line spectrum analyzer approach. The overall design is complete and the delay lines have been delivered. Fabrication of the circuitry for the spectrum integrator, velocity discriminator, the formatter, and the display interface is complete and testing is underway. The work is on schedule except for an added display scaling feature modification which was not originally planned.

A field test site has been established for the complete component systems checkout, integration and operational type fly-by tests. This test site is now 90% established with the location of instrument trailers, power distribution boxes and cables and instrumentation lines. The basic features of the site should be completed by October 15, 1973, and be ready to receive and make field installation of the sub-systems.

Management Progress - The following contracts cover the work under this effort and are reported separately under the RTOP: (1) "Design, Fabrication and Development of Signal Processing Units for Use With Atmospheric Laser Doppler Systems," Raytheon Company, NAS8-29822. (2) "Development of a Frequency Translator for Use With Atmospheric Laser Doppler Systems," Raytheon Company, NAS8-29706. (3) "Development and Testing of a Laser Doppler System for Detecting and Monitoring Aircraft Trailing Vortices," Lockheed Missiles and Space Company, NAS8-29824. (4) "Test Planning and Modeling of Laser Doppler Systems," Physical Dynamics, NAS8-28984. MSFC personnel from major design disciplines of the systems have been assigned to the project.

Conclusions - None

Problems - Some difficulty with laser reliability has been encountered as the result of defects in the laser tube design and fabrication. Fixes for these problems are currently underway.

The backscatter from the secondary mirror of the telescope in the present configuration is of such magnitude as to saturate the detector being used. Initial tests have shown that this backscatter can be reduced to a satisfactory level by placing a .4 mm diameter wire directly in front of the secondary mirror. The theoretical implications of this method are presently being investigated. The Laser Safety Regulations for the State of New York limit the maximum permissible exposure to 1×10^{-2} joules/cm^2. This necessitates the incorporation of a shutter in the system. Some difficulty has been experienced in obtaining a shutter with the required speed to insure safe exposure level at the elevation scan turnaround points and in the event of a scanning system failure.

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF James W. Bilbro	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development and Testing of a Laser Doppler System for Detecting and Monitoring Aircraft Trailing Vortices
NAS8-29824
Lockheed Missiles & Space Company
Huntsville, Alabama 35805

OBJECTIVE(S): Laser Doppler systems at MSFC have been employed for monitoring ground winds, clear air turbulence and aircraft trailing vortices. As a result of a NASA-FAA agreement the design and development of a laser Doppler system for the primary purpose of detecting and monitoring aircraft trailing vortices in an airport environment will be undertaken.

APPROACH: An automatic scan system will be developed to allow the laser Doppler system to operate in a three-dimensional line scan mode and a two-dimensional plane scan mode. This system will also operate in a search mode or a detail scan mode. In addition to this development, the system will be upgraded to accept components being developed under other contracts, and field test support will be provided for verification of system parameters.

STATUS: Technical Progress - Design of the scan system has been completed and fabrication of a breadboard system is approximately 90% completed. All vendor components have been received and assembly of the first unit is in progress. Delivery of the first unit is expected October 15, 1973. Delivery of the second and third units are expected November 1, 1973. System upgrade is progressing on schedule and is expected to be completed in time for the delivery of the first

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: FAA Airport Vortex Detection Project

STATUS (CONCLUDED)

scanner unit. The system engineering/simulation effort is progressing on schedule. Data processing programs for system verification and checkout are being developed and should be ready for use in data processing the results of the systems first fly-by test. A real-time total system simulation employing the system display and hardcopy unit is complete and available for operator usage at the MSFC Computer Laboratory.

Management Progress - Contract for this effort was let April 30, 1973. A modification to the contract to extend the level of effort in field testing and documentation is being drawn up and is expected to be in effect by mid-November.

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IR Ed Gleason	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Design, Fabrication and Development of Signal Processing Units for Use With Atmospheric Laser Doppler Systems
NAS8-29822
Raytheon Company
Sudbury, Massachusetts 01776

OBJECTIVE(S): The laser Doppler system yields atmospheric velocity information in the form of a shift in frequency of the signal. This shift is directly related to the wind velocity at the point of interest. To process the signal into meaningful velocity information spectrum analyzers and filter banks have been used with limited success. This task will develop a "state-of-the-art" signal processing system for laser Doppler systems.

APPROACH: Conventional processing systems had limitations in band width, frequency discrimination, were difficult to align, and bulky. This effort will develop and design a system using the surface wave delay line principle which will provide a satisfactory answer to the problem of real time velocity information retrival and display.

STATUS: Technical Progress - Contract NAS8-29822 was let to Raytheon April 26, 1973. The overall design plan was completed and submitted by Raytheon on June 25, 1973, and COR approval was given on July 6, 1973. The SAW delay lines were delivered to the Raytheon Advanced Development Laboratory by the Raytheon Research Division on August 16, 1973. The delay lines met all required specifications. Fabrication of circuitry is presently completed for the specrum integrator, the velocity discriminator,

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: FAA Airport Vortex Detection Project

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CURRENT NO./CODE: 501-38-13

STATUS (CONCLUDED)

the formatter, and the display interface. Tests on these units are presently underway. The front panel layout was submitted to MSFC on August 25, 1973. The overall progress is on schedule as originally contracted for. However, due to a contract modification to include a display scaling feature, an additional two weeks before delivery of the units is anticipated.

Management Progress - A no-cost contract modification was submitted in July to change the integration time range from 1.0 millisecond - 128 milliseconds to 0.5 millisecond - 64 milliseconds. A contract modification to include a display scaling feature and to provide additional contractor manpower for integration and system testing was submitted.

Conclusions - The contract is progressing very well at this time.

Problems - None

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF William C. Cliff	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study on Application of Laser Doppler Velocimeter System
NAS8-25921, Lockheed Missiles & Space Company
P. O. Box 1103 West Station
Huntsville, Alabama 35807

OBJECTIVE(S): Determine and optimize MSFC's existing laser Doppler systems performance under varying climatological conditions. Evaluate previously obtained clear air turbulence data for determination of feasibility.

APPROACH: Obtain atmospheric particulate distributions, calibrate LDV system using a target of known reflectance and optimize overall LDV system performance in varying atmospheric weather conditions. Evaluate and optimize individual components. Use independent means to determine conventional atmospheric statistics.

STATUS: Technical Progress - This task has been completed and is closed out. Final report "Development of Theory and Experiments to Improve Understanding of Laser Doppler Systems" dated June 1973 has been received.

Management Progress - Existing contract was modified with a $58K increase on January 2, 1973.

Conclusions - Preliminary data indicate that the presence of mild fog enhances the ability of a CO_2 LDV system

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
LMSC/HREC TR D306632	Development of Theory and Experiments to Improve Understanding of Laser Doppler Systems. Final Report	M. C. Krause L. K. Morrison C. E. Craven N. A. Logan T. R. Lawrence	N/A

FIRST BENEFITTING PROJECT: FAA-NASA Trailing Vortex Project

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF James W. Bilbro	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of a Frequency Translator for use with Atmospheric Laser Doppler Systems
NAS8-29706
Raytheon Company
Sudbury, Massachusetts 01776

OBJECTIVE(S): To develop a frequency translator for use with the atmospheric laser Doppler system. This translator is necessary to remove the ambiguity in determining velocity direction, thus optimizing system performance of atmospheric measurements.

APPROACH: Two methods for frequency translation will be investigated, the Bragg cell and the offset laser. In the Bragg cell method, a portion of the outgoing laser beam is split off and translated to a particular frequency through the use of acousto-optic techniques. The translated portion is used as the local oscillator for heterodyne detection. In the offset laser method, a separate laser is used to provide the local oscillator signal.

STATUS: Technical Progress - The Bragg cell has been chosen as the desired method for translation. The fabrication of the Bragg cell has been subcontracted by the Raytheon Company to Isomet. Delivery of three Bragg cells to the Raytheon Company is expected by the end of November. Design of the optical mounts for the Bragg cell and interferometer has been completed and fabrication is in process. The first interferometer unit is expected to be delivered to MSFC without the Bragg cell on October 15, 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: FAA Airport Vortex Detection Project

MSFC - Form 360 (March 1973)

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STATUS (CONCLUDED)

Management Progress - The contract for the investigation of translation methods and fabrication of three translators was let April 11, 1973. A change order was initiated May 10, 1973, to delete the investigation of the offset laser method and to substitute the design of an interferometer optics package. One complete optics package was to be assembled and the material for two additional packages was to be provided by the Raytheon Company. A modification to the contract is presently being negotiated which will include the assembly of the other two optics packages, the evaluation of three GFE detectors to be used with the optics package, the design and fabrication of bias networks to be used with the detectors and a complete ray trace of the optics package and telescope of the LDV system. This modification is expected to be in effect by November 1, 1973.

Conclusions: All items covered in the contract and its modifications are expected to be delivered to MSFC by December 15, 1973.

Problems: Late delivery of some optics material by vendors has created some slippage in the original delivery schedule, however, this will cause no major problems.

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF Robert M. Huffaker	205-453-1156	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Test Planning and Modeling of Laser Doppler Systems
NAS8-28984, Physical Dynamics
P. O. Box 1069
Berkeley, California 94701

OBJECTIVE(S): To develop theoretical models of laser Doppler systems. To outline test programs for understanding and improving laser Doppler systems performance. Generate mathematical models of atmospheric targets (CAT, vortices stable-unstable atmospheres).

APPROACH: Using theoretical models developed under previous contracts determine the feasibility of performing ground based CAT measurements. Determine the approach and outline of mathematical realizations of CAT, mountain wave turbulence, stable and unstable atmospheres.

STATUS: Technical Progress - (1) A study to determine the range of condition for which a one-dimensional laser-Doppler scanning system can determine three-dimensional atmospheric wind velocity data has been completed and documented. (2) A study to determine the feasibility of measuring CAT and high altitude winds from a ground based platform using the CAT detection system has been completed. (3) An analysis of the secondary backscatter problem on the FAA optical system has been performed and documented. (4) Studies are continuing to determine the optimum operating mode for the FAA vortex system.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: OAST Laser Doppler Vortex and Clear Air Turbulence Program

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Management Progress - Work is on Schedule.

Conclusions - Study (1) has been implemented in the field test program at MSFC. Study (2) will be used in evaluating the CAT detection system. Study (3) is being considered as a possible solution to this design problem.

Problems - None

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IRT James A. Dunkin	205-453-5912	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of a Laser Doppler Clear Air Turbulence Detection System
NAS8-28424, Raytheon Company
Sudbury, Massachusetts 01776

OBJECTIVE(S): To determine the feasibility of developing a laser Doppler system for the measurement and detection of clear air turbulence for onboard airliner application.

APPROACH: (1) Evaluate data from flight test. (2) System ground test to precisely determine the as-flown condition. (3) Make system modification based on data evaluation. (4) Perform ground test on modified system. (5) Flight test.

STATUS: The CAT transmitter has been returned to Raytheon and has been prepared for ground test. A 13-mile-long ground test site has been located and is being prepared. The CAT signal processor is in good operating condition and has been returned to MSFC for use in data reduction. Data reduction and analysis are continuing at this time and will continue in conjunction with the ground test for the next several months.

Technical Progress - The sealed laser used for the local oscillator in the CAT transmitter has been modified to make the laser refillable in the field. The CAT transmitter has been reassembled and checked out at Raytheon and is now operating at the output level obtained during the flight test.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
ER70-4203	Development of a CO_2 Laser Doppler Instrumentation Detection of Clear Air Turbulence. Final Report. NAS8-24742	C. Sonnenschein A. Jelalian W. Keene	6-5-70
ER72-4243	Development of CO_2 Laser Doppler Instrumentation for Detection of Clear Air Turbulence. Final Report, Modification of NAS8-24742	C. Sonnenschein A. Jelalian W. Keene	May 72

FIRST BENEFITTING PROJECT: OAST Laser Doppler Clear Air Turbulence Project

STATUS (CONCLUDED)

Conclusions - Preliminary results indicate that the feasibility of making turbulence measurements ahead of the aircraft with a pulsed CO_2 laser Doppler system was demonstrated. However, data evaluation is continuing and a final conclusion has not been reached at this time.

Problems - Preliminary aerosol data evaluation indicates that the system should have had clear air returns in many instances when no return was obtained. Investigations are proceeding to resolve this discrepency.

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF William C. Cliff	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Purchase of Equipment for Laser Doppler System
NASA/MSFC
S&E-AERO-AF
Inhouse

OBJECTIVE(S): Purchase required hardware to maintain and optimize system performance and continuously upgrade system in accordance with new developments in theory and instrumentation.

APPROACH: Purchase off-the-shelf items to insure test objectives are met in the shortest possible time.

STATUS: Technical Progress - Purchase for FY-73 included a CO_2 laser and a 5/4 wave-plate, the wave-plate to be delivered in April 1973 and the CO_2 laser to be delivered in June of 1973.

Management Progress - 5/4 wave-plate has been delivered and accepted. The CO_2 laser has been delivered.

Conclusions - Final acceptance of CO_2 laser is anticipated October 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: FAA-NASA Trailing Vortex Project

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF William C. Cliff	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study on LDV Atmospheric Interrogation System
NAS8-29606, Lockheed Missiles & Space Company
P. O. Box 1103 West Station
Huntsville, Alabama 35807

OBJECTIVE(S): Field test and evaluate the feasibility of using a single MSFC ground-based laser-Doppler velocimeter to determine its capability for measuring two- and three-dimensional atmospheric wind fields.

APPROACH: Test a single ground-based LDV radiometer system employing a conical scan as well as a simple two-point spatial measurement in atmospheric boundary layer flows. The measurements are to be made for varying ranges between 10 to 500 meters.

STATUS: Technical Progress - Two-point spatial measurements have been made. Conical scan mount has been designed and fabricated and conical scan measurements have been made.

Management Progress - Progress reports for April, May, June, July and August have been received.

Conclusions - A single MSFC ground based CO_2 LDV system employing a conical scan has shown feasibility for measuring two-and three-dimensional wind components in atmospheric boundary layers. Phase correlation of the Doppler velocity output with a reference signal has been shown to give the atmospheric wind direction while the Doppler frequency indicates wind velocity.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: Laser Doppler Technology Project

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4. TITLE:

Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Ira P. Jones S&E-AERO-AT	205 463-1091	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Comparison Tests for Atmospheric Laser Doppler Systems
Contract NAS8-26234
Colorado State University
Fort Collins, Colorado 80521

OBJECTIVE(S): To determine the operational limitations and accuracy of a laser Doppler system for measuring winds in the atmosphere which will yield information needed for the design of operational systems.

APPROACH: One-and multi-dimensional research systems will be used to perform measurements of atmospheric wind velocity and will be set up so that direct comparisons of wind velocity data can be made between the laser Doppler system and hot wire instrumentation and cup anemometers. Tests will be made over a wide range of weather and pollution conditions.

STATUS: Technical Progress - This contract was completed in June 1973 and the final report on the contract has been received and approved.

Management Progress - None

Conclusions - The gross features of atmospheric phenomena in the boundary layer are measured by the laser Doppler system. Mean values determined from the laser Doppler system data are in general within 5% of other anemometer data for short time periods.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final Report Colorado State University CER 71-72SK35	Comparison of a Coaxial Focused Laser Doppler System in Atmospheric Measurements	Dr. S. Karaki	N/A

FIRST BENEFITTING PROJECT: FAA Airport Vortex Detection Project.

STATUS (CONCLUDED)

The data reduction technique is cumbersome in its present form. The inclusion of online A to D equipment and a special purpose minicomputer could improve the situation.

Problems - None

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Hazard Avoidance and Elimination

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF William C. Cliff	205-453-3598	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Wind Tunnel Experimentation Using Laser Doppler System
NAS8-25896, Remtech Inc.
2603 Artie Street, Suite 21
Huntsville, Alabama 35805

OBJECTIVE(S): Optimize and evaluate MSFC's three-dimensional Argon CW LDV wind tunnel system.

APPROACH: Perform three-dimensional velocity measurements employing radial and axial traverses at the exit of an axisymmetrical turbulent pipe flow. Use independent means to determine the instantaneous axial velocity as well as standard statistical averages.

STATUS: Technical Progress - This task has been completed and is closed out. Final Report "Three Dimensional Laser Doppler Velocimeter Turbulence Measurements In A Pipe" has been received and accepted.

Management Progress - None

Conclusions - Instantaneous velocity comparisons by the LDV and hot wire show remarkable similarity. The comparison of instantaneous velocity measurements were presented in an article in the AIAA journal (see below for details). The three-dimensional LDV system proved to be extremely sensitive to variations in flow conditions. On-line three-dimensional measurements were performed and compared favorably with all existing literature examined.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
RTR 002-2	Three-Dimensional Laser Doppler Velocimeter Turbulence Measurements in a Pipe Flow	Charles E. Fuller	April 1973
NASA TMX-64774	Measurement Capabilities of a One-Dimensional System	William C. Cliff Charles E. Fuller	August 1973
AIAA Journal Vol. 11, No. 5, pp. 748-749	Simultaneous Comparison of Turbulent Gas Fluctuations by Laser Doppler and Hot Wire	William C. Cliff Charles E. Fuller Virgil A. Sandborn	May 1973

FIRST BENEFITTING PROJECT: FAA-NASA Trailing Vortex Project

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 502-01-03	PRIOR NO.: 114-03-01

4. TITLE:

PROPERTIES OF MATERIALS FOR ELECTRONIC APPLICATIONS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. Urban, S&E-SSL-NP I. Dalins, S&E-SSL-N	453-5130 453-5137	R. Decher, S&E-SSL-N

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE(S): The Superconductivity research program will seek increased understanding of the phenomenon of superconductivity and material improvements leading to higher transition temperatures, more stable and less massive conductors, and more easily fabricated instrumentation of greater sensitivity and increased ruggedness for a wide variety of space and ground applications, such as superconducting magnets, sensitive magnetometers, infrared detectors, and magnetic shields.

The Surface Science program will seek to advance the understanding of various atomic, molecular, ionic, and electronic interactions at and on crystalline surfaces having a bearing on physical, chemical, and electronic processes of importance to space science and technology. This technical effort has been reoriented to study the origin as well as the consequences of the existence of surface states primarily in semiconductors with wide energy gaps between the valence and conduction bands.

The technical information obtained from this research is useful in solar energy conversion as well as other electronic processes occurring in semiconductors for applications in light amplification, detection, and generation of electromagnetic radiation. This research in surface science is part of a NASA-wide effort (working group).

APPROACH: The primary research tools in the superconductivity studies include: (1) ultrasonic attenuation and velocity measurements to determine the temperature and magnetic dependence of the energy gap and other parameters in ordered superconducting crystals; (2) study of the critical properties of new superconducting materials fabricated chiefly by, and to improve of known materials by, explosive shock

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
Calculation of the Temperature and Purity Dependence of Sound Attenuation in Superconducting Nb - accepted for publication by Physical Review	C. C. Sung L. L. Lacy	
Properties of Materials for Electronic Applications, presented at the First Annual MSFC Research & Technology Review	L. L. Lacy E. W. Urban	Feb. 1973
Measurements of Ultrasonic Velocities Using a Digital Averaging Technique, J. Acoust. Soc. of Am., 52, p 189-195	L. L. Lacy A. C. Daniel	1972
Ultrasonic Absorption in Superconducting Single Crystals of Nb_{1-x} Mo_x, published in the Proceedings of the Thirteenth International Conference on Low Temperature Physics	L. L. Lacy	Aug 1972

FIRST BENEFITTING PROJECT: SUPERCONDUCTIVITY - Stanford Gyro Relativity Experiment
SURFACE SCIENCE - Solar Power Generation Program

compaction; (3) study of magnetic flux pinning mechanisms and magnetic instabilities through measurements of magnetic flux flow, flux flow resistivity, and the peak effect in Type II superconductors; (4) studies to improve thin film junction and microbridge instruments, such as magnetometers through the use of advanced thin film, microcircuitry, and superconducting materials characterization techniques.

The Surface Science studies are fundamental in character but are oriented as much as possible toward solving the scientific problems encountered in GaAs solar cell development. The major effort is now being made to gain a better insight and make pertinent measurements of surface recombination velocity because this parameter affects the solar cell energy conversion efficiency. The effort is performed in cooperation with MIT, where surface photovoltage spectroscopic methods have been developed to gain insight about the behavior of certain surface states. Equipment to measure these parameters on well characterized GaAs surfaces especially with low Energy Electron Diffraction (LEED) and Auger Electron Spectroscopy (AES) have been, or are in the process of being, developed in-house.

STATUS: Superconductivity - During the reportperiod considerable progress has been made, particularly in the thin superconductor films and materials studies. The thin film studies seek to develop very thin uniform and continuous films on quartz substrates suitable for use in sensitive instrumentation, such as narrow pickup loops for magnetic moment measurements and strips which may be etched into microbridge structures for rugged, stable, low current density Josephson junctions. Optically transparent niobium films approximately 1.5×10^{-8}m (150 Å) thick have been reproducibly sputter deposited on two types of glass substrate. The films were superconducting at 4.2K (their transition temperatures will be measured later) and they exhibited resistivity ratios only a factor of two greater than the value for pure polycrystalline bulk niobium, as compared with factors of three or more reported in the open literature! Two films approximately 5×10^{-9}m (50Å) thick were not superconducting at 4.2K, but this thickness is not necessarily a lower limit for superconductivity and further work is in progress. By guiding the electron beam of a scanning electron microscope, it has been possible to make bridges of the order of 10^{-7}m wide in photo resist, and techniques have been developed for preparing and stripping orsputter-etching thin nonsuperconducting metal films. Studies are now continuing to combine the microbridge, metal etching, and ultrathin niobium film processes to produce the required microbridge Josephson junctions.

The materials studies continue to aim toward superconductors with higher transition temperatures, critical fields and critical currents. The Department of Defense Advanced Resarch Projects Agency (ARPA) funds referenced in the last report have been received by MSFC and contracted to the University of Alabama - Huntsville (UAH). A number of new shock wave compacted specimens have been produced and their properties are now being measured. The Principal Investigator (G. Otto) attended the recent conference on Lattice Instabilities in Superconductors and obtained a great deal of valuable and pertinent information. Preliminary studies have been made to determine immiscible metallurgical system candidates which would be likely to exhibit new or improved superconducting properties if melted, mixed and resolidified in reduced gravity, such as is available in the MSFC drop tower. The improvement of nondestructive materials characterization techniques mentioned in previous reports has led to the development of an automated eddy current decay apparatus in which it is possible to determine very rapidly the electrical resistivity of arbitrary shaped bodies as a function of temperature without making damaging electrical or mechanical contact to the specimens.

STATUS: Continued

Surface Science - During this period the in-house portion of the research concentrated on obtaining atomically clean GaAs surfaces that are verifiable by AES to an ultimate accuracy of 0.0001 of a monolayer. Using an improved ion sputtering gun from Physical Electronics Inc., the removal of practically all of the contaminants (but especially carbon) was successfully accomplished. This process also benefited from improvement of the target preparation techniques (polishing and etching). Extensive ultrasonic cleaning and rinsing in acetone and distilled water were the main features of these improvements. Good LEED patterns of the clean GaAs (111) surface were also obtained after some difficulties caused by interferences generated by magnetic field of the molecular beam ion pump were overcome. Part of the LEED pattern revealed a typical triplet which was also observed on earlier samples. The observation of this triplet on an atomically clean surface has very important consequences pertaining to the crystalline bonding characteristics on the polar surfaces. This is being further investigated because it might very well be the most important factor responsible for the unusually high value of the surface recombination velocity, which, in turn, reduces the conversion efficiency.

Dr. A. M. Horgan (NAS Postdoctoral Fellow, now at Xerox Corporation in Rochester, New York, was able to process some of the experimental data obtained while at MSFC into another paper which has been submitted to Surface Science for review by referees.

MIT continued the studies of surface photovoltage spectroscopy as well as other more or less conventional techniques that might lead to obtaining a value of the surface recombination velocity. So far such techniques have not yielded the desired results, and more sophisticated approaches (more closely related to the in-house effort) are being considered. The basic studies on surface states have yielded new (publishable) information.

Management Progress - Most of the procurement of new equipment in connection with requirements for the recombination velocity measurements has been completed. The light source (nanosecond optical-pulse radiator) developed a defect in the power supply and was returned to the manufacturer for warranty repairs. Some of the ordered attachments (extra storage accessory) to the box car integrator have not arrived, for unknown reasons.

Conclusions - Clean surfaces of GaAs on atomic scale can be readily obtained and maintained in the laboratory ultra high vacuum apparatus that will permit AES, LEED, and other examinations and studies. Based on recent theoretical studies published in literature and experimental data obtained in-house as well as elsewhere, it is concluded that changes of the atomic bonding near or on the surface of GaAs solar surfaces might be responsible for the high recombination velocity value.

Forecast - Possibilities for direct experimental verification of the above conclusion will be investigated in detail.

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7. REPORTS: Continued

Ultrasonic Investigation of the Superconducting Properties of the Nb-Mo System, NASA Technical Note TN D-6828	L. L. Lacy	June 1972

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REPORTS: Continued

Joule Heating Power Dissipation in a Type II Superconductor Tube, Phys. Rev. B, 5, 3530	E. W. Urban	1972
Synthesis of Superconducting Compounds by Explosive Compaction of Powders. U. S. Patent # 3,752,665	U. Roy G. H. Otto O. Y. Reece	Aug 1973
Shock Wave Synthesis and Characterization of Nb_3Sn, submitted to Journal of the Less-Common Metals on March 5, 1973	G. H. Otto U. Roy O. Y. Reece	Mar. 1973
The Precipitation of In_2 Bi from Supersaturated α-Phase, submitted to the Journal of the Alabama Academy of Sciences	G. H. Otto	Aug 1973
The Role of Trapping Photovoltage Spectroscopy Surface Science, Vol. 38 (1573) 252-256	J. Lagowski H. C. Gatos	1973
Surface Photovoltage Spectroscopy & Surface Picsoelectric Effect in GaAs, submitted to Surface Science	J. Lagowski I. Baltov H. C. Gatos	1973
Sticking Probabilities for the Adsorption of Hydrogen on Clean Ni (111), Ni (100) Ni Sheet and Evaporated Ni Films, submitted to Surface Science	A. M. Horgan I. Dalins	1973

The following articles (papers) mentioned in earlier reports as submitted have appeared now in the following:

A Study of the Effectiveness of the Standard Surface Cleaning Techniques as Applied to Ni (111), and Ni (100), and Ni Sheet using Auger Electron-Spectroscopy (AES) - J. Vac Sci. Technol. Vol. 10, (1973) 523-532	A. M. Horgan I. Dalins	1973
Adsorption of Hydrogen, Carbon Monoxide, and Oxygen on Vacuum Degassed Stainless Steel 304 at 20°C, J. Vac. Sci. Technol. Vol. 10 (1973) 559-56	A. M. Horgan	1973

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MSFC	01 04 73 to 30 09 73	502-21-27	114-03-51

4. TITLE:

SPACE VEHICLE THERMAL CONTROL

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Daniel Gates, S&E-SSL-T	453-3102	W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Thermal Control Coatings
NAS8-285 - NETCO NAS8-26791 ITT Research Inst. NAS8-21270 Stanford Res. Inst.

OBJECTIVE(S): Research on the development of thermal control surface coatings will yield a white paint for coating of any size, shape or complex substrate by normal painting procedure. While maintaining the ϵ_h (infrared emissivity) at 0.9, the α (sun spectrum absorption) will be as low as possible, for the least load on the vehicle thermal system. At the same time, there must be little change in these optical properties with extended times of exposure to the space environment.

APPROACH: The development of thermal control surface coatings has the following phases: (1) Inorganic paint technology - pigments and silicate binders, (2) silicone binder development - methyl silicones of the RTV-602 and OI-650 types and their improvement (3) pigment synthesis - low adsorption edge materials such as Zn_2TiO_4 and $CaWO_4$ and, their treatment by reactive encapsulation and calcining of the surface, and (4) general paint studies - solar simulation facility, correlation with space experiment results, degradation of optical properties investigations, and paint surface protection systems.

New equipment being used includes: (1) the CREF (combined radiation environmental facility), which exposes samples to vacuum, ultraviolet and proton radiation and measures the optical properties in reflectance mode while in vacuum, and (2) the ISSIS (in-situ system for infrared studies), which measures samples in the transmittance mode with similar exposure to the CREF.

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
Investigation of Environment Effects on Coatings for Thermal-Control of Large Space Vehicles. Final report on Contract NAS8-5379, IITRI Report # IITRI-U6002-97, October 9, 1971	G. A Zerlaut J. E. Gilligan N. A. Ashford	1971
Recent Advances in Environmental Testing of Thermal Control Materials, presented to the AIAA 7th Thermophysics Conference, San Antonio, Texas		Apr 1972
Advanced Technology Developments in Thermal Control Materials, invited paper presented to 74th Annual Meeting of American Ceramic Society, Washington, D. C., May 9, 1972	G. A. Zerlaut	May 1972

FIRST BENEFITTING PROJECT: SKYLAB

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STATUS: Technical Progress - A OI-650 binder/Zn_2TiO_4 paint has been prepared with an αs = 0.12 and good stability to simulated environment of ultraviolet, vacuo and protons. The α_s is 0.01 with up to 2000 ESH uv at a 3X factor of exposure. Stability of Zn_2TiO_4 with and without reactive encapsulation has shown marked improvement by plasma calcining. Combination of methyl silicone (OI-650) with ZnO pigment to form a paint has been satisfactory, and continued testing has established that this is a viable coating system. This new paint is designated A-429m. The ISSIS, an instrument for transmission measurements, is complete and is being assembled and tested. Zn_2TiO_4 has been made from an oxalate precursor and exhibits excellent batch-to-batch reproducibility. OI-650 glass resin has been end-blocked, and the resultant binder has been found to retain the desired elastomeric qualities.

Management Progress - NAS8-26791 has been negotiated for 12 months extension and the work scheduled within this framework. Addition of one man to the IIT Research Institute has been found necessary for the pigment pilot plant production of Zn_2TiO_4 to meet the time line. The Zn_2TiO_4 pigment with end-blocked OI-650 vehicle should be available by mid 1974, with the present revised schedule. A contract has been awarded to NETCO (NAS8-28517) to provide assistance in theoretical studies of the reactive encapsulation process for pigment stabilization.

Conclusions - Progress on the Zn_2TiO_4 paints is satisfactory and samples have been provided of methyl silicone and silicate binder coatings for space experiments. This pigment is appreciably better than present ZnO both in initial αs and $\Delta\alpha_s$. Calcining in the RF facility is a viable method of completing reactions or fixing reactive encapsulation. Samples of Zn_2TiO_4 in silicate binder are on OSO-8 and English Black-Arrow Space Experiments. The Zn_2TiO_4 pigment with end-blocked OI650 vehicle should be available as viable paint by June 1974.

Problems - Space experiments, for calibration of experimental progress, have not been available in sufficient numbers to obtain a high degree of confidence in the use of new and improved coatings on unmanned and manned vehicles. Cleaning and/or restoration of coatings while in space remains to be done if extended life above 3 to 5 years is to be obtained. Soiling of coatings in handling, assembly, erection, etc., required development of strippable (or other) protection. Production processes of new improved paints should be initiated with user (MSFC & MSC) as early as feasible. The present situation of IIT manufacture of paint and/or pigment for S-13g needs to be reduced to engineering practice; but even if this is accomplished, there will still be dependence on the "consulting" available from the IITRI group.

Forecast - (1) Use of the CREF will give experience, as data is generated, in the problems of environments which contain high-energy components. (2) With the availability of the ISSIS instrumentation, the examination of changes in transmission of the vehicles will allow improvement of this part of the paint system. (3) Completion of the chemical reactions in pigment preparation can be obtained with good control of the process by use of the RF plasma and without agglomeration of the particles. (4) By means of reactive encapsulation and/or calcining, the surface of the pigment may be passivated toward use with methyl silicone binders to accrue the advantages of this type of paint binder. (5) Our efforts will continue to be able to supply a white thermal-control paint for space use, at any time, on which optical and other pertinent measurements have been consistent with the state-of-the-art at this time. (6) A contract is anticipated from the contamination program concerning cleaning of various optical surfaces in space, including thermal control paints.

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REPORTS: Continued

Thermal Control Materials and Technology in the 1970's. Presented to the ASME Intersociety Conference on Environmental Systems, San Diego, Cal.	J. E. Gilligan G. A. Zerlaut	July 1973
A Review of Current Refractory Composites Research in Ceramics. Presented to the 21st Meeting of Refractory Composites Working Group, Los Alamos, NM	S. A. Bortz Y. Harada	July 1973
Improved Zn_2TiO_4 Thermal Control Pigment. Presented at the 26th Pacific Coast Meeting of the American Ceramic Society, San Francisco, Cal.	D. W. Gates J. E. Gilligan	Oct 1973
Report #IITRI-C6233-28 (Triannual Report) Development of Space Stable Thermal Control Coatings for Use on Large Space Vehicles. Jan. 1 through Apr. 30, 1973.	J. E. Gilligan Y. Harada	

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MSFC	01 04 73 to 30 09 73	502-21-28	114-03-07

4. TITLE:

OPTICAL CONTAMINATION

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Hoyt M. Weathers	205 453-3040	Hoyt M. Weathers

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Optical Contamination

Contract No.	Contractor
NAS8-29268	Walter C. McCrane Associates
NAS8-29269	Commonwealth Scientific Corp.

OBJECTIVE: To provide the basic research data and technological development information needed to further define and characterize the induced environment of spacecraft. This basic and applied research is being applied in experiment/sensor definitions for the Shuttle payload programs. The end items of this task will be technical reports and informal data used as input to other program activities of other MSFC elements.

APPROACH: The optical environment for purposes of contamination research is considered to include the X-ray, ultraviolet, visible, and near infrared portions of the electromagnetic spectrum. Emphasis is being placed on the extreme and vacuum ultraviolet wavelengths as it is in this region that contamination's greatest effects upon optical efficiency have been observed. Recognizing that some finite amount of contamination will be unavoidable on Shuttle payloads, SSL is investigating long-term subtle degradation effects and techniques of avoiding the more severe damage early in the payload's mission life.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA TM X-64742	The Gaertner L119 Ellipsometer and Its Use in the Measurement of Thin Films	Michael Linkous	March 16, 1973
NASA TM X-64747	X-Ray Reflection Efficiency of Nickel-Coated Quartz Optical Flats	J. Reynolds S. Fields R. Wilson	May 10, 1973
NASA TM X-64775	A Modified Quadrupole Mass Spectrometer with Custom RF Link Rods Driver for Remote Operation	P. Tashbar D. Nisen W. Moore	August 1973

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STATUS: Skylab experience has shown that thin film deposition and agglomeration from vacuum condensable material can be controlled more easily than that of particulate generation and migration. X-ray optical systems are more sensitive to particulates than are systems whose operational wavelengths are in the visible or infrared regions. Optical samples exposed on flight experiment T-027 have been returned to the laboratory and analyzed. A report of the results is in progress toward publication.

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NASA/MSFC	01 04 73 to 30 09 73	502-21-29	114-03-46

4. TITLE:

Ground-Based Meteor Observations

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. Clifton, S&E-SSL-PA	205-453-0183	R. J. Naumann, S&E-SSL-P

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Meteoroids
NAS8-25998
NAS8-26190
NAS8-24393

OBJECTIVE(S): To determine by ground-based optical equipment the flux, physical nature and orbital characteristics of near-earth meteoroids in the mass range (10^{-2} gm - 10^{-4} gm) most hazardous to long-term orbiting spacecraft. The results are used as input data for meteoroid-protection design criteria of Skylab.

APPROACH: Ground-based meteor observations are being made in-house with low-light-level television systems. Observations are conducted at remote sites and used in conjunction with moving target video processors, video analyzers, spectral gratings, and filters to enable the calculation of the influx rates of meteors at different limiting magnitudes, their photometric light curves, spectral characteristics, color characteristics, orbital elements velocities, and heights. Methods for automated data analysis are being investigated and utilized.

STATUS: Technical Progress -- (1) Present efforts are directed to photometric analysis with TV systems. (2) Moving target calibration of the SEC vidicon has been completed. Results have been published. (3) Preliminary results for the determination of the slope of the mass flux curve in the region (10^{-1} gm - 10^{-3} gm) have been completed and published. (4) Observations are being made to determine an additional,

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA TND-6303, Airborne Meteor Observations at High Latitudes	K. S. Clifton	1971
NASA SP (paper in publication) Mass Influx Obtained from LLL TV Observations of Faint Meteors, presented at 13th IAU Colloquium	R. J. Naumann & K. S. Clifton	1972
NASA TMX Mass Influx from Low Light Level Television Observations of Faint Meteors	R. J. Naumann & K. S. Clif ton	1972
Application of Coherent Optical Matched Filtering for Detection of Meteor Trails, in Proceedings of the Conference on Holography and Optical Filtering.	Gee, Allen & Clifton	1973
Television Studies of Faint Meteors, submitted to the Journal of Geophysical Research	K. S. Clifton	1973

larger mass point. (5) Seasonal flux data is being accumulated. (6) Spectral data is being accumulated.

Management Progress: Working agreement is in effect with the National Research Council of Canada for analysis of meteor spectra.

Conclusions: Application of low-light-level TV equipment to meteor observations has proven to be extremely successful. Meteors have been detected to the 8th magnitude. Preliminary lab tests and calibration procedures with the SEC vidicon indicate that photometry can be accomplished from the TV image. The SEC vidicon used with a spectral grating has also proven successful in obtaining large numbers of meteor spectra.

Problems: (1) Time-consuming analysis of TV tapes. (2) Low travel funds limit observations under ideal sky conditions. (3) Reduced co-op student program lengthens analysis time.

Forecast: (1) Photometric light curves of selected meteors are to be determined with video processors now in-house. (2) Spectral observations will continue. (3) Experimental procedure for analysis of meteor spectra to be defined. (4) Observations to be made to determine "large" mass point.

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4. TITLE:

Environmental Design Criteria

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YS Robert E. Smith	205/453-3140	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASKS: (1) Theoretical Model of Thermospheric Heating
Contract No. NAS8-25750, University of Alabama Huntsville, Huntsville, AL 35810

(2) Traveling Ionospheric Disturbances
Contract No. NAS8-29317, University of Alabama Huntsville, Huntsville, AL 35810

OBJECTIVE(S): Complete the development of technically sound and concisely written engineering descriptions in the earth's ground winds, inflight winds, inflight atmosphere, surface extremes, space and terrestrial environment, lunar surface, earth orbit, planetary, and other environments in which space vehicles may be expected to operate. To examine, on a continuing basis, natural environment data obtained from ground, flight and other means to determine the need for updating or modification to engineering design criteria documents, reports, and monographs. The resulting product shall provide engineering interpretations of the environment applicable to design/operation problems and use in development of specific space vehicle design criteria.

APPROACH: (1) Develop a theoretical model from basic principles and adjust resulting equation parameters so that calculated results agree with observational data from satellite orbital decay analyses.

(2) Develop an empirical/theoretical model of the effects of traveling ionospheric disturbances (TID) on the neutral atmosphere. Model to be based on TID data from Doppler array and ionosonde data.

STATUS: Technical Progress--A closed form analytical solution to a set of magnetohydrodynamic equations has been developed which will be used to study the effects of Joule

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROGRAM: Space Shuttle

STATUS (continued): heating on the upper atmosphere. Study results will be used to develop a simplified model which can be incorporated into the current static models of the upper atmosphere. The resultant "dynamic" model will be used in vehicle development programs in the development and verification of guidance and control and navigation techniques.

Model only partially developed due to problems associated with getting the Doppler array operational.

The Earth Orbital Atmosphere Model Monograph has been published as NASA SP 8021 dated March 1973.

Management Status--This effort will terminate in December 1973, due to termination of this funding source.

Conclusions: Analytical model works; however, development of a simplified version for use in engineering applications is required. This may be a long term item.

Problems: Simplified engineering model appears to be a long term development. Existing data required in verifying the model calculations are inadequate. Collection of additional data is lagging due to observational equipment problems.

Forecast: Project cannot be completed this year; however, this funding source has been terminated. Therefore, this effort will be terminated in December 1973.

No Reports

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4. TITLE:

Environmental Design Criteria

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YT Lee W. Falls	205-453-3141	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Statistical Studies of Atmospheric Variables Related to Skylab and Space Shuttle Programs. Contract No. NAS8-29286.
Appalachian State University
Department of Mathematics
Boone, North Carolina 28607

OBJECTIVE: Investigations will be made which will provide solutions to statistical problems encountered in the Skylab and Space Shuttle programs.

Task (1): The frequency distribution for the number of overshoots (or exceedences) in a gaussian stochastic process is required. This distribution will provide a model for the number of times certain atmospheric variables, such as wind speed or temperature, exceed a specified level during a time interval of arbitary length.

Task (2): A numerical method including a computer program is required for the evaluation of multivariate normal distributions. This distribution for dimensions two, three, and four is directly applicable to meteorological variables which may be constraints to NASA missions. For example, wind components are known to be bivariate (two dimensions) normally distributed.

Task (3): Many classical statistical methods require independence (no correlation) in the data. An investigation of the effects of autocorrelation existing in atmospheric variables will be conducted.

Task (4): Certain atmospheric variables are distributed according to multivariate gamma and beta distributions. These distributions will be investigated as prospective

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-129008	"An Empirical Analysis of the Distribution of Overshoots in a Stationary Gaussian Stochastic Process"	M. C. Carter & M. W. Madison	July 1973
NASA CR-129005	"Multivariate Normal Integration"	M. C. Carter	May 24, 1973
NASA CR-2280	"Estimation in a Modified Binomial Distribution"	M. C. Carter	June 1973

FIRST BENEFITTING PROGRAM: Skylab

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OBJECTIVE (cont'd): models and parameter estimation techniques will be developed.
Task (5): Investigations will be made on statistical variability in nonlinear systems which involve atmospheric and engineering parameters which are correlated in time and space.
Task (6): Convolutions of distribution functions shall be developed to calculate launch delay risks due to constraints caused by several dependent and independent atmospheric variables.
Task (7): A distribution function for launch delay risk will result from Task (6). A modification of this distribution shall be performed in order to develop the distribution of duration of atmospheric variables above a given threshold or constraint.

APPROACH: The tasks will be accomplished using known statistical methods including (1) Monte Carlo procedures, (2) multivariate analysis (3), decision theory, (4) combinatorial analysis, and (5) probability theory. Where required, known statistical methods will be modified to meet the specified needs of the problem. The contractor will work closely with inhouse activities which are directly related to the tasks outlined.

STATUS: Technical Progress: Task (1): NASA CR-129008, "An Empirical Analysis of the Distribution of Overshoots in a Stationary Gaussian Stochastic Process" has been published. The distribution of overshoots is the Poisson, binomial, or negative binomial depending upon the relationship of the variance of the process to the mean.
Task (2): NASA CR-129005, "Multivariate Normal Integration" has been published. A computer program is operational which evaluates the multivariate normal integral for dimensions one through five.
Task (3): No progress to date.
Task (4): Extensive cloud cover data has been supplied to the contractor for analysis in terms of the multivariate beta distribution. Parameter estimation problems have been solved. A computer program is operational for this distribution.
Task (5): No progress to date.
Task (6): No progress to date.
Task (7): No progress to date.

Problems: No significant problems encountered.

Forecast: Investigations are continuing under Tasks (3), (4), (5), (6), and (7) with present emphasis on Task (4).

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4. TITLE:

Environmental Design Criteria

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. C. Brown	205-453-3141	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Environmental Design Criteria
Contract No. H-84897A H 95560A
NOAA-EDS, National Climatic Center
Asheville, North Carolina

OBJECTIVE: Complete the development of technically sound and concisely written engineering descriptions of the earth's ground winds, inflight atmosphere, and surface extremes. To examine, on a continuing basis, natural environment data obtained from ground, flight and other means to determine the need for updating or modifying engineering design criteria documents, reports, and monographs. The resulting product shall provide engineering interpretations of the environment applicable to design/operational problems and use in development of specific space vehicle design criteria.

APPROACH: Together with other knowledgeable scientists, establish natural environmental criteria for design and engineering application to the overall space vehicle system and assist in the interpretation and utilization of these data. This will include developing and evaluating new methods for the description of natural environment parameters for application to vehicle engineering design and operational problems, performing studies of terrestrial environment parameters and formulating scientific and engineering documentation on natural environment in the form of reports or monographs. Due to the integrated nature of this effort between environment specialists and the design users, interface efforts will be exercised to insure engineering validity in the guidelines and monographs produced. Inhouse and contractual activities

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA TMX-64757	Terrestrial Environment (Climatic) Criteria Guidelines for use in Aerospace Vehicle Development, 1973 Revision	Glenn E. Daniels	July 5, 1973

FIRST BENEFITTING PROGRAM: Space Shuttle

MSFC - Form 360 (March 1973)

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
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APPROACH (cont'd): will be utilized in developing the necessary criteria formulations. Work is of a continuing nature and involves phases of problem identification, environment interface, data analysis, interpretation, criteria formulation, documentation and review.

STATUS: Technical Progress: A detailed description of equivalent headwinds for Space Shuttle Orbiter ferry flights was completed. These winds were developed for several altitudes on each proposed leg of the cross-country flight. A sample graph displaying Cape Kennedy wind shear statistics calculated over several time periods and at several altitudes is being reviewed.

Management Progress: Period of performance extended to June 30, 1974.

Conclusions: The detailed wind analysis was necessary to satisfy more exacting Orbiter ferry requirements.

Problems: Difficulty in establishing adequate NASA natural environment data study support for application to various NASA engineering programs. Subject requires additional funding and coordination of efforts to meet NASA needs.

Forecast: Continue work toward completion of design criteria monographs currently under study. Direct selected contractual efforts and revisions in the extensive technical review and critical analysis of atmospheric parameters concerned with entry heating models and atmospheric dynamics in particular.

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MSFC	01 04 73 to 30 09 73	502 21 30	502 21 30

4. TITLE:

Environmental Design Criteria

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Lewis E. Andrews, S&E-AERO-YS	205/453-3149	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Martian Surface Models Monograph
Contract No. NAS8-29605, TRW Systems Group

OBJECTIVE: To formulate the available knowledge, experience, and pertinent data into a useable set of surface models of the Martian surface for space vehicle design purposes.

APPROACH: Collect and review Mars surface data. Data will include Mariner IX, and Russian orbiters Mars 2 and 3 data, along with Martian surface data prior to Mariner IX. From the data collected, formulate Mars Surface Models.

STATUS: Technical Progress--Close coordination with the various NASA Centers is prevalent in this phase of the study. Dr. Hutton is also utilizing information and expertise from Lowell Observatory, U.S. Geological Survey, and the Planetary Science Institute.

Conclusions: NONE.

Problems: NONE.

Forecast: NONE.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Reports			

FIRST BENEFITTING PROJECT: Viking

MSFC - Form 350 (March 1973)

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 502-23-16	PRIOR NO.: 115-22-05

4. TITLE:
Airborne Visible Laser Optical Communications (AVLOC)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
P. J. Marrero, S&E-ASTR-RP	205-453-4702	J. C.Taylor, S&E-ASTR-R

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Ground Station Development/Experiment Aircraft Development

NAS8-20629 ITT-Optical Division, San Fernando (OpCom Package)
March 18, 1970 - May 31, 1973 (Est)

NAS8-25418 Chrysler Corporation, Space Division, Michoud (Integration Contractor)
April 2, 1970 - May 31, 1973 (Est)

OBJECTIVE: Development and proof-of-concept of optical communications techniques and systems. This development must include laser sources, modulators, acquisition and tracking techniques, etc. Full development is expected to yield lightweight systems, physically small, low in power consumption, and capable of providing very high data rates in applications such as optical communications satellites.

APPROACH: As a first step toward an optical communications satellite, an experimental laser communications system has been incorporated into a high-flying RB-57F aircraft. Utilizing previously developed acquisition and tracking techniques and subsystems, a two-way optical communications link will be established between the Aircraft System (He-Ne laser) and the Ground Station (Argon laser) on Madkin Mountain, located on Redstone Arsenal. Having established the link, large quantities of scintillation data, bit error rate data and various other experimental data will be recorded both onboard the aircraft and on the ground. Experience gained from this aircraft program should be immensely helpful toward development of the optical communications satellite experiment.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
February 1973	Summary Flight Reports for flights 9 through 15	MSFC	
February 1973	Test Report	MSFC	

FIRST BENEFITTING PROJECT: Shuttle

MSFC - Form 350 (March 1978)

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STATUS: Technical Progress: No experimental flights were conducted this period; Flight No. 15 completed the flight test portion of the program. Subsequently, S&E-ASTR-GD personnel reworked the AOCP fine tracking system electronics, resulting in much improved operating characteristics for acquisition and tracking as well as vastly improved reliability of the system. With these corrections of the most glaring system deficiency, hardware development on this project was concluded.

Management Progress: Most of the work on the project's Final Report was completed during this period.

Conclusions: The AVLOC program successfully proved the basic feasibility of airborne laser tracking systems. Although commands were transmitted on the uplink laser beam, the downlink high data rate laser communications system was not successfully demonstrated due to very poor modulation provided by the laser modulator. Further laboratory testing and additional flights would be required in order to achieve this basic program objective.

In addition to demonstrating the basic system feasibility, data was obtained on atmospheric effects on laser beams propagated vertically through the atmosphere.

Problems: The program has come to an end before resolving all of the major problems encountered during the flight tests. An additional flight test phase would seem to ensure a much more satisfying conclusion to the program.

Forecast: The only work presently remaining to be done is finishing up the Final Report.

This will be the final RTOP progress report unless work on this project is renewed.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	502-23-21	115-22-09

4. TITLE:
Large Telescope Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. L. Randall, S&E-ASTR-R	453-3770	J. C. Taylor

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Active Mirror Program, IH/NAS8-28019, University of Alabama, Tuscaloosa, Alabama.

OBJECTIVE: To develop the technology required for actively correcting the figure of a large telescope primary mirror (3 meter diameter). Large diffraction limited telescopes such as LST impose tolerances on the figure of the primary mirror which are unprecedented in large optics. For manufacture and testing in a "one g" gravitational field and later for operation in "zero-g" the primary mirror will require a multi-point corrective mount to achieve the required surface quality of $\lambda/50$ RMS. This research is principally an experimental program to verify structural models of mirrors under point and distributed loads, development of interferometric methods for measuring surface errors to one-hundreth wave accuracy and verification of control algorithms which define the corrective forces.

APPROACH: The MSFC experimental facility currently consists of a 20 inch diameter thin deformable spherical mirror with 16 force actuators on the back. The mirror is mounted with optical axis horizontal in a seismically isolated vacuum tank. The mirror is defined by a three point kinematic mount. Gravity induced sag is counteracted by force couples at 19 points. A laser unequal-path interferometer located at the center-of-curvature senses the figure errors as commanded by a digital computer. The computer processes the error signals, calculates the appropriate corrective forces and updates the commands to the force actuators.

This facility is an adequate test-bed for developing and refining much of the technology required for active correction of mirror figures. However, it is unrealistically simple in two regards.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
BER-153-09	"Active Control of Primary Mirror of an Orbiting Telescope with Thermal Excitation" University of Alabama, NAS8-28019	J. Hill & J. Youngblood	May 73

First Benefitting Project: LST

MSFC - Form 350 (March 1978)

First, a center-of-curvature laser interferometer is not practical for use on large space telescopes. Secondly, the structural modelling of a thin deformable mirror is trivial when compared to the complexity of modelling a thick light weighted structure.

A second experimental phase which will utilize a thick light weight 27 inch diameter mirror will follow the thin mirror program. A focal plane figure sensor which utilizes stellar illumination to interferometrically measure the total wave front error is being developed under contract.

STATUS

Technical Progress

1. The vibrations in the interference pattern that had degraded the performance of the figure sensor have been eliminated. After exhaustive investigations the trouble was traced to a lightly damped mode of the vacuum tank air suspension system that was being acoustically excited

2. Linearity and superposition of the mirror deformation have been verified over a wide range of force levels and for combinations of forces.

3. An experimental flexibility matrix for the mirror has been measured. This matrix agrees closely to within a multiplicative constant with that predicted by the NASTRAN program; whereas comparison with the MIT STRUDL program prediction shows not only gain discrepancies but different shapes for the influence functions.

4. The mirror figure has been improved from an initial error of 1.29λ RMS (4.84λ peak to peak) to better than .04λ RMS (0.22λ peak to peak). This degree of improvement has been demonstrated numerous times from a variety of initial conditions. The procedure normally requires about 4 consecutive iterations of control due to inaccuracies in the flexibility matrix currently stored in the computer.

5. The residual hardware from the Langley Research Center/Perkin Elmer 30 inch thin deformable mirror program has been disassembled, tested, and is ready for modification for use in the upcoming 27 inch light weight mirror program.

6. The design of all new fixtures, facility modifications and hardware modifications for the 27 inch light weight mirror program is completed and documented.

7. The linearity and resolution of the figure sensor has been significantly improved by redesigning the optics which focuses the interference pattern on the image dissector.

Management Progress

After numerous delays, an agreement was finally reached with Perkin Elmer Corporation to turn over the residual hardware from the Langley Research Center active mirror program. All of this equipment has now arrived intact at MSFC.

Conclusions

NASTRAN's finite element modelling of the 20 inch thin mirror is more accurate than MIT's STRUDL program. However, this conclusion should not be extrapolated to complex three dimensional mirrors which cannot be modelled with plate elements.

Problems

1. There is evidence that the 20 inch thin mirror mount changes occasionally in a discrete manner resulting in discrete change in the mirror figure. Most probably this stems from friction in the supports that results in extraneous torques applied to the mirror.

2. The experimental program with the 20 inch mirror has suffered numerous delays and interruptions due to temporary loss of the computer for high priority SKYLAB work. The total loss of time would total about two weeks.

3. The final design of the 27 inch light weight mirror hardware was delayed several months waiting for the LRC/Perkin Elmer hardware to arrive. Some of this equipment had to be tested before design modifications could be completed.

Forecast

1. Experimental work on the 20 inch thin mirror will be completed in the next quarter. The final mirror figure quality will easily exceed the design goal of $\lambda/30$ RMS.

2. Procurement and manufacture of the 27 inch thick mirror system will begin soon and be ready for installation near the end of the calendar year.

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MSFC	01 04 73 to 30 09 73	502-23-31	115-23-40

4. TITLE:

Optical Mass Memory

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Earl J. Reinbolt, S&E-ASTR-R	453-3770	J. C. Taylor

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Optical Memory System, Breadboard and Components and Technique Development
NAS8-26672, Radiation, Inc., January 1962 - July 1974
NAS8-26808, RCA, March 1971, April 1974
NAS8-28949, Radiation, Inc., June 1972 - November 1973

OBJECTIVE: Projected spacecraft systems of the 70's and 80's will require onboard multi-functional integrated computer systems of large capacity. Mass memories of 5×10^{12} or larger will be associated with such systems. The long range objective of this RTOP is a random access, read-write memory of 10^{12} bit capacity utilizing holographic techniques for writing on an erasable medium. Ideally, this memory should replace all storage media associated with a large operational computer. Most certainly this replacement will include everything from on-line discs, drums, etc., to stored tapes. The memory is to have limited or no moving parts, occupy a relatively (to present systems) small volume and be available for spacecraft use in the next decade. The large memory capacity does not, of course, have to be used in conjunction with a computer. It can be used as storage for data to be transmitted (or carried to earth) at a later time.

APPROACH: The key elements of a read-write holographic optical mass memory are a laser(s), beam deflector(s), block data composer, reversible holographic storage medium, and an output detector array. These elements combined with suitable optics, electronics and mechanical structures provide a functioning read-write memory. The RTOP approaches the problem on three levels:

1. Overall Memory System. This includes system design to accomplish progressively higher bit capacity and a study of memory architecture and computer interfaces.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NAS12-2200 October 1970	Investigations of Optical Memory Techniques	Radiation, Inc.	
NAS8-26360 February 1971	Optical Read/Write Memory System Design	Radiation, Inc.	
NAS8-26672 February 1972	Optical Read/Write Memory System Components	Radiation, Inc.	
NAS8-26635 May 1972	Dynamic Holographic Storage in Lithium Niobate	Isomet	
NAS8-26808 November 1972	Interim Report - Optical Memory Development Vol. 1: Prototype Memory System Vol. 2: Gain-Assisted Holographic Storage Media Vol. 3: The Membrane Light Valve Page Composer	RCA	
August 1973	Updated Optical Read/Write Memory System Components	Radiation, Inc.	

FIRST BENEFITTING PROJECT: Shuttle/LST

MSFC - Form 350 (March 1978)

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APPROACH (CONCLUDED):

2. Optical Memory Component and Technique Development. Special emphasis is placed on critical items such as the storage material and block data composer.

3. Optical Memory Breadboard. A breadboard containing all of the key elements has been constructed and is and will continue to be used experimentally to study all component interfaces within the memory, allow development of new devices, and the enhancement of old devices. Plans are to interface the breadboard with an operating computer to study the computer-memory relationship.

This approach provides vital information as to system feasibility in an economical way and helps avoid premature large fund-commitment to such computer memory systems.

STATUS: Technical Progress: The memory breadboard has been functioning and has proved helpful in identifying system problems not apparent when only considering system components. New designs for the photoplastic holographic storage array are being tested. Increased numbers of recording cycles and reduced exposure times should result. Improvements are being made in the thermoplastics storage material itself. Work is continuing on the ferroelectric ceramic, PLZT, for the page composer. Material (PLZT) provided by vendors has proved to be poor, but efforts to improve this situation are having some success. Device fabrication techniques are improving also. The PLZT is now being studied for three possible modes of operation; strain, scattering and interferometric. The membrane approach to the block data composer has been successful on an 8 x 8 page composer. Prospects are now good for having the breadboard functioning with a 32 x 32 block data composer, a 5 x 5 holographic array, and a 32 x 32 photodetector array by the end of 1973, with an experimental interface to an operating computer well under way. The extension of the 32 x 32 photodetector array to a 128 x 128 array or mosaic is technically feasible; however, the cost would divert needed development in more critical areas. Work on characterization of doped lithium niobate as a memory storage material is under way at RCA, Princeton. Quarterly Progress Reports dated April 14, 1973 and July 14, 1973 are available. Since in the past no effort has been made to characterize and use lithium niobate as a operating element of a Holographic Optical Mass Memory as specified in the objectives to this RTOP, this is proving to be a valuable study.

Device fabrication problems with PLZT are under control. Material (PLZT) from suppliers continues to be a problem. Efforts to completely characterize the PLZT both chemically and with respect to desirable optical properties are being accelerated. Increased pressure is being exerted on suppliers to maintain consistency and exact specifications. Lack of uniformity in the PLZT and difficulty in performing exact analysis have prevented Radiation from achieving a 128 x 128 page composer at this time.

Management Progress: The RCA contract NAS8-26808 has been extended to April 1974. An interim report has been completed. The Radiation contract NAS8-26672 has been extended to July 1, 1974. An interim report is now available. These dates represent program stretch-outs and these changes and other consequences are reflected in the milestone schedule.

Electro-optics Center, Radiation, Inc. transferred operations from Ann Arbor, MI to Melbourne, FL. Approximately 50% of the personnel working on this contract were lost in the move; however, most key personnel were retained. Total effect of this move on the R&D contract has not yet been fully assessed.

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Conclusions: Both in-house and contractual efforts are progressing well. The breadboard facility is providing useful information for evaluation and optimization of system components and their interrelationships. A 10^8 bit capacity planar optics memory of relatively small size will be possible in the near future.

Forecast: A fully operational breadboard in 1974. A 32 x 32 block data composer, 5 x 5 hologram array and 32 x 32 photodetector array.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
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MSFC	01 4 73 to 30 9 73	502-23-42	115-17-05

4. TITLE:

Inertial Components

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
B. F. Walls/S&E-ASTR-G	205-453-0793	Richard Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Three-Axis Ring Laser Guidance Platform Development Inhouse

OBJECTIVE: To produce a three-axis strapdown inertial navigation system using laser gyros with performance that is equal to or exceeds the present high quality inertial navigation systems in accuracy and reliability with a considerable reduction in weight, size and cost.

This system will be used in a wide range of navigation vehicles including ships, space vehicles and aircraft.

The system will have the following advantages over present navigation systems:

1. Weight, less than 20 lbs
2. Lifetime, greater than 2 years
3. Power, less than 30 watts
4. Volume, less than 300 cu-in
5. Warm-up time, less than 20 minutes
6. Cost, less than $20,000
7. Digital output to interface with strapdown digital computers
8. Easily adaptable to redundant configurations
9. Fast preflight checkout

7. REPORT NO.: TITLE: AUTHOR(s): DATE TRANSMITTED

1. Ten Monthly Progress Reports, Dec 1970 to Sept 1971, File 4720 CF.2.33658, "Three-Axis Strapdown Ring Laser IMU", Sperry Gyroscope.

2. "An Improved Ring Laser Rate Sensor for Use in Strapdown Inertial System" by I. N. Hutchinson, P. K. Inglima. Sperry Gyroscope presented at AIAA Guidance, Control and Flight Mechanics Conference, August 1970, Santa Barbara, California.

3. "Effect of Discharge Tube Aging on Laser Gyro Drift Stability" by E. Vaher, W. M. Macek and John M. Abdale, Sperry Gyroscope, presented to CLEA Conference in Washington, D. C. on June 4, 1971.

4. "Improvement in Laser Gyro Technology", Vols I and II, by E. O. Vaher and I. N. Hutchinson, Sperry Gyroscope, prepared under contract NAS8-24436.

5. Seven Monthly Progress Reports, April to November 1972, "Three-Axis Strapdown Ring Laser IMU", Sperry Gyroscope, contract NAS8-24436.

FIRST BENEFITTING PROJECT: Not yet program oriented.

APPROACH: A. Technology Development - Perform development testing to identify problem areas and possible improvements in the bias techniques, discharge tube life, and control electronics. Modify these components for improvement.

B. Environmental and Operational Tests - Perform environmental and operational tests to prove the capability of the laser gyro to function in a three-axis attitude reference system.

C. System Integration - Interface the three-axis laser gyro strapdown sensor package (including accelerometers) with computer and software for a complete navigation system.

D. Overall System Performance Tests - Perform navigation system field test in a mobile van and in an aircraft flight to prove capabilities of a laser gyro navigation system.

STATUS: Technical Progress:

A. Technology Development - The laser gyro tube life has been increased from an average of 200 operating hours to better than 10,000 hours and all tubes are still operating. At present, the nine improved tubes have accumulated over 98,000 hours without a failure. Development work to improve the biasing techniques and stability of the control electronics are continuing.

B. Environmental and Operating Tests - The three-axis laser gyro strapdown platform has accumulated over 4000 hours of operating time in environmental and operational tests. The latest developments have improved the long-term drift stability to better than 0.02 °/hr, repeatability to better than 0.2 °/hr and scale factor linearity well below 0.01% up to 200 °/sec input rate. The test data has provided information for the improvement to the control electronics, voltage control, temperature control and vibration stability.

C. Complete System Integration - Work is progressing on the design, build and documentation of the updated three-axis laser gyro package, including three accelerometers and the computer interface. This work will result in a complete laser gyro navigation system with computer and software.

D. Overall System Performance Tests - Plans are being made at MSFC to perform navigation system field tests in a mobile van on the complete laser gyro navigation system and also to perform flight test evaluation on this system in an aircraft at Langley Research Center.

Management Progress:

1. Presented data and development progress at the Interagency Laser Gyro Meeting on June 6-7, 1973 at Applied Physics Laboratory. This meeting was attended by representatives of various Centers of the Navy, Air Force, Army and NASA. Several Centers expressed interest in cooperating with us on our planned system van test and flight test programs to the point of assisting with technology, equipment and possible funding.

Management Progress (cont)

2. Evaluating test data, writing reports and preparing technical presentations for candidate user project offices.

3. Preparing the work statement for the next development phase.

Conclusions:

A. Technology Development - The operating life of the laser gyro has a proven increase from 200 hours to greater than 10,000 hours. The life tests are continuing with every indication of proving even greater life. One tube already has over 24,000 hours of operation. This year's work has included making defined modifications to the electronic control circuits, correcting grounding problems and improving vibration capabilities and temperature sensitivities.

B. Environmental and Operational Tests - These tests on the present three-axis laser gyro development system have shown that the laser gyros can fulfill the requirements for many navigation system applications in accuracy, stability and life, with a reduction in cost by an order of magnitude. The laser gyro system has the very unique feature of easily performing self-tests for preflight operational tests.

C. Complete System Integration - During the computer interface definitions for the laser gyro system it was found no complicated compensation for many of the terms, including output axis coupling, spin axis coupling, and anisoinertia effects, would be required as for a conventional gyro system.

D. Overall System Performance Tests - The three-axis accelerometer package is being built at MSFC. A computer and the mobile van are available at MSFC. The interface definition is being done at MSFC. Discussions and flight planning have begun with Langley Research Center.

Problems:

The problems at the present time are defining the computer requirements with respect to computers available for this program at little or no charge and the approach to the computer programming. These discussions are being made by evaluating past strapdown system computers and taking advantage of the work already done in this field.

Forecast:

The work for FY-74 is to interface the laser gyro system into a complete navigation system including accelerometers, computer interface, computer, software and readout and display for a flight test in an aircraft in FY-75. The six-pack redundant system design will be done in FY-74 also.

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MSFC	01 04 73 to 30 09 73	502-23-51	115-25-02

4. TITLE:

Design, Processing and Testing of LSI Arrays

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. L. Anderson, S&E-ASTR-RM	205 453-3770	J. C. Taylor

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: LSI Materials, Array Design and Technology
NAS8-26594; RCA, Solid State Division, Somerville, NJ
NAS12-2207, RCA, Princeton, NJ
NAS8-26379, Texas A&M, College Station, TX
NAS8-26749, Mississippi State University, State College, MS
NAS8-26384, Autonetics, Anaheim, CA
NAS8-25621, M&S Computing Company, Huntsville, AL
NAS12-2233, RCA, Camden, NJ

OBJECTIVE: To develop the design capability, processing techniques, and test methods for large scale integrated circuits (LSI) that will be required in future programs.

APPROACH: Utilize computer techniques and programs for design and testing of LSI arrays. Some of the work to be completed will be an improved method of cell design, a two-dimensional layout and interconnection program for LSI arrays, test sequence generation program for sequential circuits, etc.

Develop advanced integrated circuit processing techniques that can, with proper emphasis and guidance, be ready for Space Station use. Longer range efforts will be to explore advanced ideas and theories of such items as bulk effect integrated circuits, line modeling, line automation, silicon on sapphire beam-lead processing and surface and bulk studies in silicon material.

All in-house programs in all types of microelectronics will complement contract efforts in accomplishing the above program objectives.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Internal Report November, 1972	Guidelines for Ceramic Dielectric, Monolithic Multilayer Chip Capacitors	MSFC	
Internal Report November, 1972	Guidelines for Thick-Film Single Chip Resistors and Custom Networks	MSFC	
Internal Report December, 1972	Guidelines for Beam Lead Transistors	MSFC	
73-0002 January, 1973	Artwork Interactive Design System (CIDS) Program Description	M&S Computing, Inc.	
73-0003 January, 1973	Sigma 2 Graphic Display Software Program Description	M&S Computing, Inc.	
NAS12-2233 November, 1972	SUMC-DV Hardware Manual	RCA, Camden, NJ	

FIRST BENEFITTING PROJECT: All MSFC Approved Programs

STATUS: Technical Progress:

NAS8-26594 - The technology encompassing C-MOS/beam lead/Si gate has been developed and was applied to the ALU devices for the SUMC computer. The circuits to be delivered under this contract did not operate properly. The request for a no cost extension was granted. This extension period has only a month left before delivery. No further effort is anticipated under this contract.

NAS12-2207 - This contract was established to develop the necessary system, circuit and processing techniques for the fabrication of high speed, low power complementary silicon-on-sapphire random access memory arrays. The delivery of 10 beam leaded RAMs was made. These memories are waiting to be tested and evaluated. Although work is continuing on the leakage tests to determine its effect on yield and reliability, it is felt the contract should be modified to include the following:

1. Establish a process for a hermetically sealed beam lead chip, including $Si_3 N_4$ or $Al_2 O_3$ if necessary, with the potential for high yield in a manufacturing environment.

2. Determine the source of the yield and reliability defects and develop technology to minimize these defects and reduce parameter spread.

NAS8-26379 - During Phase I of this effort (Aug. 1970 - Feb. 1971), the contractor Sirtl-etched a number of Lepex and Czochralski silicon wafers from a major supplier and found a general pattern of swirls, pits, and related defects. It has been difficult to find sufficiently good wafers to test the effect of thermal stresses. It has been shown that wafers held in position other than horizontally tend to induce defects during heat cycles. However, if stress-relieved plain wafers (as chemically etched) are placed on a flat surface, they can be thermally shocked as high as 1150°C and then cooled to room-ambient quickly without propagating defects. Therefore, heat gradients are not of themselves detrimental to the wafer if it does not have inherent stresses or is not to the point that the following interim conclusions are made:

1. Commercial wafers have a wide range of damage in general.

2. This damage is caused by poorly controlled ingot growth and wafer preparation, mostly the latter.

3. A slow rate of polish and fine grit reduces this damage.

4. Flat quartz slabs no less than 1/4" thick are recommended for placing the wafers on during oxidation, epitaxy, or diffusion.

5. Steam oxidation produces more defects than does dry or wet oxidation. The water bath should be kept at constant temperature, as at 25°C.

6. X-ray topography does not reveal defects on wafers as well as does Sirtl-etch.

7. A source for very low-defect wafers has been found. It has been shown that wafers may be 100 percent Sirtl-etched as a selection approach on a nondestructive basis. The Cr present can be removed as shown by neutron activation analysis detecting residual Cr as low as one part in 10^{12}. The relationship between time of Sirtl-etch,

degree of agitation, and temperature (quantity related) has been established in terms of defect type and location on the wafer, whether surface or bulk.

8. It has also been shown that completely Sirtl-etched wafers do not induce dislocations during thermal cycle even if placed over the hole in a quartz slab. Current efforts involve the effects of oxidation, epitaxy, and diffusion on defect count, using the refined Sirtl-etch for evaluation.

9. CV plots on a 7000Å wet oxygen oxide showed that the minority carrier lifetime is decreased in the presence of excess dislocations, causing the MOS device to behave as a low frequency device.

10. A study of SiO_2-Si interface stress showed that wet O_2 is the best compromise for growing the oxide.

11. A study of boron diffusion showed that damage at drive-in is less if deposition is made at 950°C rather than at higher temperatures. Longer drive-ins produce more damage.

12. Dry O_2 oxidation creates more Si SiO_2 interface stress than does steam oxidation.

13. Considerable calculations have been made on modeling the Si-SiO_2 interface stresses.

Current efforts concentrate further on effects of oxidation and diffusion on wafer damage. Fabrication of bipolar devices is underway, with nine wafers completed, all to be evaluated.

MOS circuits have been fabricated, using both ion implantation and diffusion techniques. Each has two subgroups: one thermally stressed and the other standard. The thermally stressed wafers were subjected to two additional minutes of thermal cycling on a horizontal flat quartz carrier with a 1/2 inch hole, and at a fast rate. Electrical probing is underway.

NAS8-26749 - CCD Model: An electrostatic model of the CCD with different numbers of grid points has been developed. This is a finite different technique using a specified number of points. By using this information with the computational model, experiments are being conducted to relate the experimental and theoretical charge transfer times and efficiencies of the CCD circuit. Preliminary results look very good.

Diffusion Modeling: Laboratory work was performed at MSFC during the summer months on diffusion from a "doped oxide." This particular method involves the deposition of an oxide at low temperature (approximately 350°) and at the same time adding impurities, either N or P type, or doping the oxide as it is being deposited. At present, tables have been prepared showing a 1 hr diffusion as a fraction of surface concentration and temperature for boron (a "P" type dopant). From this table one should be able to predict for any time the depth and sheet resistance of the diffusion. Work will continue in this area to try to correlate the experimental results obtained this summer with theoretical curves obtained from two independent sources.

NAS8-26384 - Autonetics has essentially completed most of the laboratory work on this phase of the contract. Testing was performed on five selected adhesives that are currently used most often as bonding agents for discrete parts in microcircuits.

The characteristics being tested are bond strength, corrosivity, and outgassing (including analysis by mass spectrometry and gas chromatography). Results are completed on all tests except long-range outgassing effects. A final report is being prepared. Although only a select few materials were chosen for testing, preliminary results show that by careful screening and qualification, organic adhesives can reliably be used in assembly of microcircuits. This study was restricted to non-conductive adhesives. An extension to the present contract with Autonetics has been negotiated to extend the work they are doing on evaluating bonding adhesives. The range of adhesives has been extended to include two gold-filled, one silver-filled, and one non-precious metal-filled conductive types. The previous work concerned only electrically insulative adhesives. In testing the conductive adhesives, uncased MOS, pnp and npn transistors and integrated circuits will be mounted on alumina substrates having thick-film gold conductors and thick-film resistors. The compatability of the adhesives with the parts and substrates and the electrical integrity of the bond joints will be thoroughly evaluated. These evaluations will cover as a minimum: adhesive strength, corrosivity, high temperature life test outgassing, and voltage-current interface breakdown phenomena. The work under this new phase of the task has begun with all of the sample materials having been started in the high temperature and long term outgassing portions of the overall tests. Equipment for bond strength testing was modified to handle the ranges of pull required for the adhesion tests.

NAS8-25621 - The two dimensional layout program for the C-MOS, Beam Lead Silicon Gate technology has been updated with changes received from RCA in September 1973. A multilayer (greater than 2) version of the automatic hybrid layout program has been implemented and exercised with satisfactory results. Numerous test runs were made to determine a set of optimized layout and routing parameters. These tests provided a better understanding of the utility of these program parameters in controlling the layout of circuits. An initial version of the Mask Analysis Program (MASK) has been completed. This version will be utilized to analyze orthogonal artwork. It has been designed, however, to accommodate the addition of non-orthogonal shape processing at a later date. This contract was modified in June 1973 for the following:

1. Modification of the Cell/Circuit Analysis Programs to accept and analyze silicon gate layouts and to work from a flexible data structure so that adaptations to future technology requirements can be more readily implemented.

2. Modification of the FETSIM/LOGSIM program to permit definition of equivalent analog and digital networks which may alternately be used to simulate portions of a design.

3. Expansion of the Item/Circuit/Cell Design program to perform various design rule checks on all or parts of a design.

NAS12-2233 - An update of the two dimensional layout program for the C-MOS and the C-MOS, Beam Lead, Silicon Gate technologies was delivered in September 1973. This update will reduce the resistance and capacitance of polysilicon interconnects, eliminate crossovers and tunnel ends in the vicinity of the I/O pads, reduce chip area by increasing the density of the metal, and provide the ability to handle larger arrays. All of the cells in the extended Silicon Gate library have been characterized and data sheets completed although not delivered. Tests of two chips designed with these cells have demonstrated a low yield. Process variations and modifications are being implemented to improve and firm up the process and to finalize the design and layout rules. Computer simulation analysis is underway in the C-MOS/Silicon on Sapphire (CMOS-SOS) technology with the objective of determining optimum device size and standard cell topology.

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In-house Activities - A C-MOS/Si Gate/Beam-lead process has been developed and sample circuits produced. Some refinement is still required before the process can be considered complete. Doped oxides are being deposited as a diffusion technique with good results.

Plans for a clean room to house the monolithic processing laboratory are completed. Bids for construction have been received and negotiations are progressing. The purpose of this facility is to, as nearly as possible, process wafers with zero defects.

Logic devices have been fabricated for the Computer Division's HODAD Computer. These devices are working well within the design specifications. A design modification has been made to reduce by approximately half the number of components in the circuit. This should improve both yield and reliability.

Several prototype hybrid microcircuits have been developed with OAST equipment support. These circuits are experimental and are primarily for development of thick-film multilayer techniques. Guidelines for hybrid microcircuits are being generated in several areas using experience gained from this in-house processing work.

Extensive use has been made of the interactive graphics cell design and array modification properties of the Computer Aided Design And Test (CADAT) system in the design of process masks for a digital to analog P-MOS array. This project which includes mask fabrication, wafer processing, testing and packaging will save MSFC $2,000,000 as compared to design and fabrication at a commercial vendor.

A sophisticated bus operated multiplexer which makes extensive use of global feedback has demonstrated weaknesses in the automatic test pattern generation program, IASAR. This multiplexer chip which was designed and fabricated in-house in the C-MOS technology will be a benchmark for improvements of the test pattern generation software.

The mask-making techniques and CAD software developed under this RTOP have at present been applied in the following areas: LSI arrays, hybrids, optical random pattern arrays, optical grid arrays, computer generated holograms, holographic memory substrates, grid and line patterns to check image orthicons, pressure transducers, resolution test patterns and process validation masks for surface wave filter processing, accoustic surface wave filters, solar cell elements, special field-effect-transistor devices, and in the microwave area: Tchebycheff filters, tuned stubs, mixers, gun oscillators, attenuators and RF amplifiers.

In cooperation with Goddard Space Flight Center, a comparison will be made of commercial chip fabrication costs in multiple technologies under a regimen that handicaps the standard cell design approach of the CADAT system but is illustrative of an off occurring circumstance. That circumstance is the transfer of a TTL universal array design to a C-MOS standard cell design. In addition the TTL design will be transferred to C-MOS universal arrays for further comparison. If unhandicapped, the standard cell approach would utilize more logic per chip and a logic format more compatible to C-MOS, thus yielding lower overall cost and higher performance. It is anticipated that the design will later be transferred to the C-MOS silicon gate and C-MOS silicon on sapphire technologies.

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Management Progress: All FY 73 funds have been obligated. Planning is underway on programs using FY 74 funds.

Forecast: A fully automated microelectronics capability should be functioning by the end of FY 75. The design phase is well advanced at this time. Automatic testing at 10 MHz is presently available, but this must be increased in speed by 5 to 10 times. Wafer process automation will now receive primary attention and should be complete by the projected time.

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MSFC		CURRENT NO.:	PRIOR NO.:
	01-04-73 to 30-09-73	502-23-52	115-25-03

4. TITLE:

Screening and Reliability Testing of Microcircuits and Electronic Parts

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. C. Hamiter, Jr. S&E-QUAL-QT	205/453-3986	Spencer E. Smith, S&E-QUAL-Q

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE: To develop approaches for assessing and assuring predictable long operating life of microcircuits and other electronic devices used in aerospace applications.

APPROACH: This activity is coordinated with the NASA Predictable Long Life Microelectronics Program. Specific tasks are:

1. Elimination of microcircuit failure mechanisms caused by loose conducting particles, bad wire bonds, and damaged or improperly dressed lead wires. This is being accomplished primarily by the transition from "flying leads" to "beam leads" and the development of metallization passivation techniques.

2. Development of an all tantalum capacitor (wet tantalum slug and tantalum case) to eliminate failure mechanisms caused by silver electromigration during reverse bias.

3. Develop new and improved microcircuit screening and accelerated testing techniques for quicker more accurate assessments of long life stability and characteristics. This includes development of electromagnetic screening techniques of microcircuits and development of screening requirements for photomultiplier tubes.

(Cont'd on page 2)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NAS8-26809	Monthly Progress Reports	Macrodata Co.	Apr. 1973-June 1973
NAS8-28096	Monthly Progress Reports	Texas Instruments	May 30, 1973
NAS8-29819	Monthly Progress Report	Sprague	September 15, 1973
NAS8-29940	Monthly Progress Report	Hughes Aircraft	August 14, 1973

PROGRESS REPORT
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CURRENT NO./CODE: 502-23-52

STATUS: Technical Progress:

1. NAS8-26809, "MOS and Bipolar/LSI Automated Electrical Test System, "Macrodata Company - The finished package test station has been delivered, installed, and accepted. This completes the LSI test system.

2. NAS8-28096, "Development and Production Implementation of Packaged Beam Lead Low Power Transistor - Transistor Logic Integrated Circuits with Protective Overlay Coating," Texas Instruments - The devices have been manufactured, and environmental and life tests are in progress. These microcircuits should exhibit improved reliability since the beam leads have eliminated the "flying leads."

3. NAS8-29819, "Design, Development, Manufacture, and Qualification of Wet-Slug All-Tantalum Capacitors," Sprague Electric Company - During the startup period, work has been concentrated on personnel assignments, design of special tools and equipment, specification and procurement of parts, initiation of development and evaluation programs, and documentation of test specifications.

4. NAS8-29940, "Procedure Development for Application of Parylene Coating and Associated Controls and Inspection Criteria, "Hughes Aircraft Company - The initial activity of the contract has been to determine the minimum serviceable parylene coating thickness. In addition, specific semiconductor devices were selected to provide the test vehicles for determining effects of the parylene coating (and any necessary pretreatments) on active microcircuit devices.

5. NAS8-28265, "Photomultiplier Tube Reliability Study," Bedford Engineering - This period has consisted of defining the additional tests to be performed and procuring additional photomultiplier tubes.

Management Progress:

1. Contract NAS8-29940, "Procedure Development for Application of Parylene Coating and Associated Controls and Inspection Criteria," has been awarded to Hughes Aircraft Company. This program is to develop a passivation technique for use in hybrid microcircuits.

2. A scope of work for "Assessment of Application and Environmental Stresses on Long Life Chracteristics of Solid Tantalum Capacitors," has been prepared. This program is to identify capacitor degradations resulting from exposure to space environments and applications. The program will result in solid tantalum capacitor derating guidelines for designers.

3. Contractor proposals for "Electromagnetic Radiation Screening of Microcircuits for Long Life Applications," have been evaluated and a contract should be awarded no later than October 30, 1973. This is a follow-on to NAS8-28937. This new contract will concentrate on studying the effects of X-ray radiation on semiconductor devices. The goal is to determine the relationship between electrical response during exposure to C-ray radiation and manufacturing defects in the semiconductor substrate.

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STATUS: (Cont'd) 5. Contract NAS8-28265, "Photomultiplier Tube Reliability Study," Bedford Engineering Company, has been modified to include additional fatigue testing (used to electrically stress the dynodes) and testing of additional tube manufacturers.

PROBLEMS: None

FORECAST: None

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	502-24-17	502-24-17

4. TITLE:
Solar Array Technology for SEPS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Dr. J. B. Stephens JBS S&E-AERO-YA	205/453-3167	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Environmental Impact of Solar Electric Propulsion System Operation
NAS8-29621, Rockwell International Space Division, Downey, California

OBJECTIVE: The objective of the study is to determine whether or not the operation of a mercury ion thruster will impact the earth's environment; therefore, any operation which results in an adverse perturbation of the environment must be studied in detail.

APPROACH: Identify and investigate in detail the impact on the environment of using a solar electric propulsion system with a mercury ion thruster. All aspects of the operation of such a thruster from the time of its launch up to geosychronous altitude and return shall be studied. Normal usage as well as possible abort modes will be analyzed in detail. Results of the investigation and analysis will be used to prepare an environmental impact statement; therefore, lifetimes of mercury ions at orbital altitudes, trajectories, and/or precipitation into the lower atmosphere or to the surface will be studied for the various modes of usage in earth orbital operations, i.e., operation in near-earth orbits, operation between near-earth and geosynchronous altitudes, operation at geosynchronous altitude, operation from near-earth to heliocentric orbits, and catastrophic failure during any of the above normal operations or during launch in another vehicle.

Develop analytical models which can be used to study the motion, dispersion, diffusion, mirroring, or precipitation of the mercury ions into the atmosphere during the operational and abort modes. Utilize the NASA/MSFC Multilayer Diffusion Model to ascertain the transport patterns of mercury released in the troposphere.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NONE			

FIRST BENEFITTING PROJECT: Solar Electric Propulsion System (SEPS)

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STATUS: Technical Progress: The failure mode analysis for a SEPS mission has been completed and shows that mercury would be normally just be released in the magnetosphere or above, unless there is a failure. The transport and decay of mercury in the magnetosphere has been analysed using the program SPIRAL. The effects due to aborts resulting from explosion have been analyzed in the ionosphere and the ozone layer. The NASA/MSFC Multilayer Diffusion Model has been utilized to analyze on-pad explosions and aborts in the troposphere.

Management Progress: None

Forecast: None

Problem: None

Conclusions: The normal operations of the SEPS in the magnetosphere will result in the ionized mercury being held in the earth's magnetic field and slowly diffusing back to the earth at rates well below the toxic threshold for mercury. The effects on communications will be limited to wavelengths which are normally reflected by the E-layer; therefore, there will not be an adverse impact in this area. Worst case analysis shows that an abort explosion in the ionosphere or the ozone layer would result in a perturbation of these region of the same order as normally experienced in the nature cycle.

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 502–24–17 180–17–57	PRIOR NO.: 502–24–17 180–17–57

4. TITLE:

Solar Array Technology for SEPS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. E. Young	453–4566	R. M. Aden S&E–ASTR–E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Solar Array Technology for Solar Electric Propulsion Stage

Contract No: NAS8–30315, Lockheed Missiles & Space Co.

Objective: Insure the availability and adequacy of solar array technology necessary to fulfill the SEPS Solar Array design requirements (30 watts/lb., 5 Yr. Lifetime, Temperature Limits –150°C to +150°C) and to reflect this in an array system preliminary design and test hardware.

Approach: The objective will be accomplished in three phases:

Phase I – Identification of technology deficiencies by performing a preliminary design.
Phase II – Development of specific hardware to fulfill the deficient technology areas.
Phase III – Design, fabrication, and test of a full scale array wing sufficient to verify technology readiness.

Status: Solar array requirements are being identified, assembled, and compared against existing technology. The requirement for partial and/or total retraction, plus re–deployment is one of the most significant in terms of technology availability. The roll–up technology can accommodate this requirement but with an apparent weight penalty compared to the fold–out, flexible array which presently cannot be partially, effectively deployed.

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No reports have been published to date.

First Benefiting Project: SEPS

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Status: (Cont'd)

In comparing the welded interconnect technology to acceptance test and inspection requirements, it is observed that no good acceptance methodology and criteria exists. This is an area scheduled for considerable attention.

Other technology requirements, particularly in the boom area, are still being generated.

Management Progress: A contract with Lockheed Missiles and Space Company to accomplish a preliminary design and identify technology deficiencies was signed on Sept. 24, 1973.

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MSFC	01 04 73 - 30 09 73	CURRENT NO.: 502-24-21	PRIOR NO.: None

4. TITLE:

Launch Vehicle Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
K. W. Gross	205-453-3815	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Boundary Layer Integral Matrix Procedure (BLIMP), NAS8-23667, Aerotherm Division, Acurex Corporation, Mountain View, California

OBJECTIVE: Provide a computer program and documentation for rocket nozzle boundary layer performance loss and heat transfer calculations capable of treating regenerative, transpiration, film, and ablatively cooled designs. This program will become a part of the standardized JANNAF rocket nozzle performance determination methodology.

APPROACH: Tailor the existing BLIMP program to rocket nozzle boundary layer analysis. Accept solutions from other JANNAF reference programs to account for the streamwise variations in the gas elemental compositions, pressure, enthalpy, and velocity from the combustion chamber to nozzle exit. In compliance with standard procedures, the thrust chamber contour radii as a function of axial distance will be used, and the thrust loss and boundary layer displacement thickness along the wall will be incorporated. The existing thermochemical calculation procedure will be replaced by the JANNAF one-dimensional equilibrium (ODE) model. A "refit" option, rearranging nodal points across the boundary layer under large parameter gradient conditions, will be included. An interim user's manual will be provided emphasizing the important input/output formats and program options. The computer program must be compatible with MSFC's UNIVAC 1108 computer and program operation will be verified with a liquid engine test case. To establish the validity of the code for problems of immediate concern, the code will be verified by comparing predicted results to well documented high quality experimental data for flows which include the following features: turbulence, blowing, streamwise pressure gradients and variable free stream gas composition.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Project Work Plan	Howard Morse	3 July 73
	First Monthly Status Report	Howard Morse	1 August 73

FIRST BENEFITTING PROJECTS: Shuttle and Tug

MSFC - Form 350 (March 1978)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 502-24-21 PAGE 2 OF 3

STATUS: Technical Progress: The project work plan was submitted and has been evaluated and accepted. The computer program has been modified to accept data from other JANNAF programs. Introduction of the standard coordinate system and adoption of the ODE thermochemical calculation model is almost completed. The refit option has been incorporated into the program and is operational.

Management Progress: Requests have been forwarded to various government agencies and private industry to provide experimental data which will be compared with analytical predictions of the BLIMP program to establish the validity of the code.

Conclusions: It is expected at this point in the program that the task objective will be successfully met.

Problems: None

Forecast: Preparation of a user's manual describing the computer program input requirements and available experimental data will begin shortly. Available experimental data will be compiled and screened for the program verification task. The computer program will be made operational on MSFC's UNIVAC 1108 and checkout will be verified by execution of a liquid engine test case.

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4. TITLE:

Launch Vehicle Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
K. W. Gross	205-453-3815	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Coaxial Injection Combustion Model, NAS8-29664, North American Rockwell, Rocketdyne Division, Canoga Park, California

OBJECTIVE: Provide an operational computer program and documentation applicable to coaxial injection and combustion of liquid-gas propellants for advanced rocket engines. Structure the computer program to fit into the standardized JANNAF performance evaluation procedure.

APPROACH: Modify the numerical analysis of an existing computer program to increase solution accuracy and to reduce computer execution time. Update and extend the physical propellant properties to conform with the format of other JANNAF computer programs. Provide adequate documentation to operate the program.

STATUS: Technical Progress: A detailed program plan was submitted, evaluated, and accepted. The computer program modularization has been completed. All physical properties in the form of curve fit data have been replaced by generalized property table subroutines. The program has been modified in the area of droplet heating and vaporization to obtain higher calculation accuracies and a reduction in computer execution time. The existing program printout has been reviewed and proposed alterations have been forwarded to the contractor.

Management Progress: Contract was initiated on May 2, 1973.

Conclusions: The task objective is expected to be successfully met.

Problems: The computer program modifications will extend into October.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
-	Program Plan	L. P. Combs	21 May 73
Monthly Progress Report for: Period Ending:	31 May 1973	L. P. Combs	13 June 73
" "	30 June 1973	L. P. Combs	12 July 73
" "	31 July 1973	L. P. Combs	10 August 73

FIRST BENEFITTING PROJECT: SSME

MSFC - Form 350 (March 1978)

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STATUS (CONCLUDED):

Cause of Problem: Contractor manpower availability was reduced due to vacation schedules and heavy workloads for other JANNAF programs.

Solution of the Problem: The contractor is studying ways to increase the manpower necessary to rapidly complete the computer program modifications.

Forecast: Physical properties for the surface tension and viscosity of the liquid and the compressibility factor for the injection gas will be generalized. A review for LOX/GH_2 propellant systems at high pressures and temperatures is continuing to insure that the model is adequate for computations up to and exceeding 5000 psi. Debugging and checkout computations as well as interfacing of the model with the DER JANNAF program will continue.

Documentation will begin after the finite difference equations used in the calculation of the droplet temperature have been re-examined and a decision has been made with regard to the concept of intra-element mixing.

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MSFC	01 04 73 - 30 09 73	502-24-21	113-31-12

4. TITLE:

Launch Vehicle Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
K. W. Gross	205-453-3815	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Performance Data Analysis Manual, NAS8-28603; North American Rockwell, Rocketdyne Division, Canoga Park, California

OBJECTIVE: Develop a JANNAF reference manual which specifies standardized methods for determining rocket engine performance from test data.

APPROACH: Identify particular measurements for overall and individual performance loss determination. Specify methods for instrument calibration, data recording, data averaging, and uncertainty determination. Establish acceptable measurement practices and criteria for test model selection. Determine optimum methods for reducing existing test data which has been accumulated without the benefit of these standardized measuring procedures. Select specific experimental performance data for the calibration of analytical performance evaluation procedures.

STATUS: Technical Progress: All task items have been completed and a draft copy of the final document has been delivered including Lunar Module test data for a sample case. Test data for two other sample cases, the J-2S engine and the stratified flow motor, are presently being compiled. Comments and suggestions resulting from the evaluation of the manual by various Government agencies have been included in the document.

Management Progress: Based upon the JANNAF Performance Standardization Working group decision, the draft manual was forwarded for comment to private industry engaged in rocket engine development. This action required another extension of the contract which has been obtained without any additional funding. It was decided that the test data for the three selected sample cases be placed in a separate volume which will also include analytical performance predictions for these same engines provided by AFRPL contract F04611-72-C-0092.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Performance Data Analysis Manual (Draft)	Rocketdyne	1 March 1973

FIRST BENEFITTING PROJECT: SSME

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STATUS (CONCLUDED):

Conclusion: The program objective was successfully met. A standardized technique for treating performance data obtained from engine testing is feasible provided the proper measurements are made.

Problems: No further problems are anticipated in the development of the Performance Data Analysis Manual.

Forecast: Comments and suggestions received from the industry review of the draft copy of the manual will be assessed by the CQR in early October and the resulting modifications will be included in the final document which will be issued on or about October 31, 1973.

The contractor will continue to compile test data for the J-2S and stratified flow motor sample cases to be published in a separate volume on or about October 31, 1973.

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4. TITLE:

Launch Vehicle Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. A. Gross	205-453-3816	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Dynamics of Unsteady Cavitating Cascades, NAS8-29313, NAS8-28046; California Institute of Technology, Pasadena, California

OBJECTIVES: The dynamics of the cavitating pump inducer represent the major area of limited understanding in describing the engine for vehicle Pogo evaluation. This requires that acceptable engine Pogo data await the availability of engine test results. The objective of this effort is to improve the basic understanding of cavitating inducer dynamics so that accurate engine model for Pogo can be prepared and used prior to acquisition of test results.

APPROACH: Analysis of the dynamics of cavitating pump inducers will be conducted based upon blade cavitation and bubble growth theories of cavitation. The results of these analyses will be correlated with existing data where possible. In addition, the analyses results will be used to guide the design of a verification test facility. The test facility will be designed and built and analyses verification tests will be run.

STATUS: Technical Progress: Employing finite cavity cascade theory, both quasistatic and a more complete, general dynamic analyses were made for the compliance of a cavitating cascade. The general dynamic case is a new fundamental problem in unsteady dynamics. The basic analytical formulation of this case was completed and work is continuing with the objective of obtaining numerical results. In the quasistatic case the completed analysis was extended to a number of existing turbopumps (J-2, F-1, H-1) rocket engines and the resulting compliances compared with values deduced from experiments. Though the validity of much of this experimental data is open to some doubt, the fact that the

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
ASME Polyphase Flow Forum - San Francisco	A Note on Turbopump Blade Cavitation Compliance for the POGO Instability	C. Brennan and A. J. Acosta	March 1972
Journal of Spacecraft and Rockets, Vol. 10, No. 3, pp 175-180	Theoretical Quasistatic Analyses of Cavitation Compliance in Turbopumps	C. Brennan and A. J. Acosta	March 1973
Submitted for publication to ASME	A Note on the Unsteady Cavity Flow in a Tunnel	J. H. Kim and A. J. Acosta	--
ASME Paper 73-FE-34	The Dynamic Behavior and Compliance of a Stream of Cavitating Bubbles	C. Brennan	June 1973

FIRST BENEFITTING PROJECT: SSME

MSFC - Form 350 (March 1973)

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
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STATUS (CONCLUDED):

theory underpredicted by as much as an order of magnitude in some instances motivated a study of other forms of cavitation as a source of compliance. As a result, an in-depth study of the dynamic behavior and compliance of streams of cavitating bubbles was undertaken with both mainstream and backflow streams in mind. This investigation led to some very satisfactory results in terms of agreement with existing data.

To verify the results of these analyses, a small-scale model system is being constructed. This consists of a 3" pump loop with provisions for flow perturbation upstream and downstream of the pump. Perturbation amplitude will be measured using laser velocimeters. Provision for visual and photographic observation of the inducer. The facility will become operational during the fall of 1973.

Management Progress: Plans are presently being made to extend this program an additional year.

Conclusions: Quasistatic analysis of blade compliance gave results which are significantly lower than available data. Analysis based upon dynamic behavior of streams of cavitating bubbles gave compliance reasonably close to existing data. This analysis gives a result which is mathematically complex and frequency dependent.

Problems: None

Forecast: The majority of the activity in the next 6-month period will be in support of the dynamic pump facility activation and operation.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 502-25-73	PRIOR NO.:

4. TITLE:
Multi KW DC Distribution System – Evaluation and Demonstration

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. L. Felch	(205) 453-4631	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Study on Multi-KW DC Distribution System

Contract: NAS8-28726 TRW Inc., Redondo Beach, CA

Objective(s): To demonstrate the significant benefits of reliability, weight and system design flexibility disclosed by the Space Vehicle Electrical Power Processing, Distribution, and Control Study (RTOP 113-60-21) for DC power distribution in excess of 100 volts.

Approach: Contract effort for program definition of detailed test objectives, test article sizing/selection and test procedures. MSFC inhouse effort for design, procurement and installation of the technology test facility; component and system testing, analysis and evaluation.

Status: Technical Progress – Program objectives and system baseline are being established and system design started.

Management Progress – Procurement of hardware with FY-74 funding will be initiated during Dec. 73/Jan. 74.

Conclusions – None

Problems – TRW Contract effort has not progressed as rapidly as was projected, however, additional manpower resources will be utilized beginning October 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

First Benefiting Project: CVT

MSFC - Form 350 (March 1978)

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RESEARCH AND TECHNOLOGY OPERATING PLAN
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CURRENT NO./CODE: 502–25–73

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Status: (Cont'd)

Forecast – Initial milestone schedules have been extended from 3 to 5 months to complete the system objectives and establish a valid baseline. A coordination meeting at MSFC with TRW is planned for October 1973.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 502-33-53	PRIOR NO.: 502-33-86

4. TITLE:

Sensors and Instrumentation Research

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMF Alex Hafner	453-3940	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Gas Analyzers
NAS8-29031, Tyco, Waltham, MA
NAS8-30254, Honeywell, Inc., Minneapolis, Minn.

OBJECTIVE(S): To develop gas sensor systems and environmental control monitors to determine the amount of O_2 and CO_2 in the habitable atmosphere on the Space Shuttle, and to detect the presence of hazardous or toxic gases and leakage or accumulation of fuel or oxidizer.

APPROACH: A study of the requirements and constraints of the applications and the techniques available is continuing. Appropriate sensors are being evaluated and tested and new techniques investigated. A contract has been awarded for a pulsed inlet mass spectrometer. After preliminary investigations and evaluations are completed, a development program will be initiated for flight systems.

STATUS: Technical Progress - The breadboard model of a CO sensor under Contract NAS8-29031 with Tyco has been delivered. In-house evaluation testing will commence in the near future. Solid state combustible gas sensors have been received and preliminary testing begun. Contract has been awarded for development of a pulsed gas analyzer.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1. 9th Monthly Report, Contract NAS8-29031		Bradspies, Holleck, & Brummer, Tyco, Inc.	4/10/73
2. 10th " " "		"	5/10/73
3.	Instruction Manual for Prototype CO Detector, Contract NAS8-29031	Tyco, Inc.	7/13/73
4. Monthly Report #1, Contract NAS8-30254	Cabin Atmosphere Monitoring System	W. W. Bursach Honeywell, Inc.	9/12/73

FIRST BENEFITTING PROJECT: Space Shuttle, Sortie Lab

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	502-33-53	115-24-05

4. TITLE:

Sensors and Instrumentation Research

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMF J. Goldstein	453-5622	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Cryogenic Mass Flowmeter
NAS8-27732, Simmonds Precision Products, Inc., Vergennes, VT

OBJECTIVE(S): To develop a capacitance densitometer coupled with a head type meter for providing a rugged flight type cryogenic mass flowmeter capable of operating over the flow range of 100-200 lbs/sec for LH_2 and 475-1200 lbs/sec for LOX with a pressure drop of 5 psi to 10 psi.

APPROACH : A combination capacitance densitometer head meter will be developed which will adhere to the Shuttle engine line configuration. A model of this device will be built and tested for flow rates up to 90 lbs/sec.

STATUS: Technical Progress - Work is completed on the fabrication of the 4" prototype meter.
Management Progress - The 4" prototype meter has been delivered to the test stand and testing will begin when a test date is approved by management.
Problems - With the funds presently available, the contractor was only able to complete work on the 4" prototype meter. Additional funding will be required to complete work as specified under the original contract.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Phase I Report		

MSFC - Form 350 (March 1973)

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 0473 to 30 09 73	502-33-53	115-24-05

4. TITLE:

Sensors and Instrumentation Research

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. E. Thompson S&E-ASTR-IMF	453-3942	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Propellant Quantity Gaging under Zero G
NAS8-28574, TRW Systems, Redondo Beach, CA
NAS8-30160, Bendix, Davenport, IA
NAS8-25097, Metro Physics, Phoenix, AZ

OBJECTIVE(S): To develop an instrumentation system capable of providing accurate propellant quantity measurement under zero "g" conditions. The system shall be capable of providing a measurement of propellant quantity of the maneuvering tanks with an accuracy of better than two percent. Hopefully, the technique chosen will be capable of providing a highly accurate quantity measurement at accelerations of earth gravity, boost phase, and zero "g" so that one system can be used for quantity measurements under these conditions.

APPROACH: A survey and evaluation has been conducted to define techniques for zero "g" quantity gaging, including those within the present state-of-the-art and promising potential techniques. Extensive evaluation was made of the various techniques, both experimentally and by means of computer simulations, to select the most promising for further development. A detailed development specification will be prepared embodying the most promising approach.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Final Report	Contract NAS8-26116 TRW; Zero "G" Propellant Gaging of Cryogenics NASA Technical Memorandum NASA TMX-58063, Volume II. Phase A Final Report Contract NAS8-30160, Bendix Corporation	N. E. Stanley R. G. Morrison	

FIRST BENEFITTING PROJECT: Space Shuttle

STATUS: Technical Progress

1. Contract NAS8-28574, TRW Systems, Inc. The contractor is developing a resonant infrasonic gage to operate in an isothermal mode. Previous analysis made with RIGS operating in an adiabatic mode showed errors large enough to prevent accurate tank gaging. However, if RIGS can be modified to obey isothermal gas laws, the accuracy of the system should greatly improve. In adiabatic operation variations in γ (ratio of specific heats) of the ullage gas cause gaging errors.

In isothermal operation γ approaches unity and has no effect on gaging accuracy. If RIGS can be operated in an isothermal mode, it should be suitable for gaging LOX. It appears that LH_2 cannot be gaged by this system. An isothermal RIGS was constructed on a gimbaled water tank and test results showed it did produce a repeatable calibration curve with less than 1% error. A RIGS to gage LOX was tested at the Capistrano Test Site April 1973. Due to bellows problems the test was inconclusive. An improved RIGS is under construction and will be tested this November 1973.

2. Nuclear Attenuation Gaging Systems are under study. This method seems promising for LH_2 but the source strength required to gage LOX is so high as to be a safety hazard.

3. Point Sensor Contract NAS8-25097 with Metro Physics, Inc. is for furnishing four zero "g" point sensors with electronic readout units to gage cryogenics. The point sensors use carbon film electronic beam deposited on the glass substrate. Trouble has been experienced in producing uniform carbon films but it is believed problems have been solved and delivery of the sensors is expected in October 1973.

4. RF System, Bendix Contract NAS8-30160. A flight system was flown aboard the KC-135 aircraft during September 1972. Flight data from 66 parabolas during low "g" and two "g' maneuvers agreed closely with the calibration obtained on the ground in one "g".

An 18,500 gallon LOX tank was gaged at MSFC in February 1973. Preliminary tank gaging studies were performed using the math model to select a gaging frequency and predicted observable mode count when empty and full. After the predicitions were made, Bendix came to MSFC and ran the tests to verify their calculations. The tank measurements and the predicted response based upon the math model agreed closely.

Bendix has constructed a vacuum jacketed cryogenic tank for LOX and LH_2 test. The tank holds about 250 gallons and is designed to gimbal. A data acquisition system has been installed in the test area which can record data rapidly at each fill level as the tank is rotated. These tests will be performed using LO_2 and LH_2 in September and October 1973 and will complete Phase B of the contract. Phase C is under contract

and includes improvements to mode processing circuits, additional testing with cryogenics and storable propellants pressure tests, and the gaging of a large LH_2 tank.

Management Progress - Contract NAS8-30160, Bendix Corporation. Due to requirements for reduced spending rate, test schedules have been stretched out and tasks modified to reduce costs. Tasks planned for accomplishment in March 1973 were delayed until June 30, 1973. Additional tasks to obtain circuit refinements and improved gaging accuracy are to be accomplished by June 30, 1974.

Contract NAS8-28574, TRW Systems. Additional funds have been obtained for TRW to complete the isothermal RIGS to gage LOX. It appears that the bellows and isolation diaphragm design and materials are critical and more work will be required on these items.

Conclusion - The Bendix RF system is capable of gaging fluids though more refinement is required. Analysis of the RIGS operating in adiabatic mode showed gaging errors to be too great to warrant development of this system. By modifying the RIGS to operate in an isothermal mode, it appears to have promise and development will be pursued along this line.

Problems - The Bendix RF system is capable of gaging fluids though a better understanding of the math model and of the elements which comprise the math model is required. It is believed that further analysis of past tank data along with data from the 18,500 gallon LOX tank and from the vacuum jacketed cryogenic tank will offer significant information and lead to a better definition and understanding of the tank parameters and gaging system elements and of how they relate to each other. Improvements in antenna design have been made wich produce a more uniform illumination of the tank.

Forecast - The Bendix Corporation RF system will be used as a basis for establishing the most feasible approach to pursue in prototype hardware.

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4. TITLE:

Sensor and Instrumentation Research

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMF John Hamlet	453-3943	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Propellant Utilization Instrumentation,
NAS8-27657, SCI Electronics, Inc., Huntsville, AL

OBJECTIVE(S): To develop instrumentation for shuttle propellant utilization.

APPROACH: Areas requiring technology advancement will be defined based on system requirements. Engineering model will be developed under contract to demonstrate achieved improvements. Loading requirements and liquid level measuring requirements will be incorporated with this work where applicable.

STATUS: Technical Progress - Major problem areas in signal conditioning have been defined, Phase I, design definition, is completed and design goals established. During the reporting period, the three engineering models were completed and evaluation started.
Management Progress - Contract extended to March 31, 1973. The contract was modified to delete the qualification and reliability requirements and to specify that three engineering models be built instead of the qualification unit and production unit.
Conclusions - None.
Forecast - Evaluation of the hardware will require more time than originally estimated because of the additional engineering models to be tested and because of lack of manpower.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Phase I	Design Definition		
Final Report			
Operations Manual and Documentation			

FIRST BENEFITTING PROJECT: Space Shuttle

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 503-24-01	PRIOR NO.: 112-30-13

4. TITLE:
Terminal Tools for Space Teleoperator

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. Blaise S&E-PE-MS W. Thornton S&E-ASTR-MS	205-453-5085 5530	W. Angele J. Boehm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Terminal Tools for Teleoperators

Contracts: NAS8-27013, URS/Matrix Co, Huntsville, AL
NAS8-29073, Univ. of Mass., Amherst, MA
NAS8-29188, Rancho Los Amigos Hospital, Downey, CA

Objective: To develop and evaluate advanced terminator tools for space teleoperator.

Approach:

1. Review and analyze space teleoperator missions and applications for terminal tool requirements. Define families of tools and analyze for commonality and minimum types. Update as space missions are better defined.

2. As appropriate, adapt and evaluate existing and in-house designed tools to manipulator arms and evaluate in-house.

3. Investigate design concepts of general purpose end effectors and advanced terminal tools for integration with advanced design manipulators.

4. Using existing in-house remote manipulator system simulation facilities, evaluate end effector and terminal tool hardware in an operating environment.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
PRL 321	A Study on Teleoperator System Performance Requirements	E. Saenger C. Pegden	11/72
URS/Matrix PRL 321	A Study on Teleoperator System Performance Requirements	E. Saenger C. Pegden	11/72

First Benefitting Project: Free Flying Teleoperator

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 503-24-01 PAGE 2 OF 3

Status:

Technical Progress:

1. Demonstration and bench proof testing of the Terminator Kit Assembly was accomplished at Rancho Los Amigos Hospital on September 10 & 11, 1973. Testing was accomplished in accordance with the approved test procedure. The TKA did function as required by the technical terms of the contract and was approved for shipment in the near future. All drawings except the mechanical top sheet, Master Control Handle modification and electrical sheet were reviewed and approved. The contractor was requested to forward these drawings for review as soon as possible. A review of the requirements for the Operation and Maintenance Manual was held. Phase I, II, and III-3 is now considered complete.

2. Phases I, II, & III on the Definition, Design, and Fabrication of a Working Model of a General Purpose End Effector for a Remote Controlled Manipulator at the Univ. of Mass. have been completed. Fabrication is 90% complete but is being held up by late delivery of motor parts. Assembly and checkout will be completed upon arrival of the motors.

Upon completion, the End Effector will be demonstrated to Dr. Kay and the Committee for Prosthetics of the National Research Council prior to its being shipped to MSFC.

Conclusions:

The TKA functioned as required by the technical terms of the contract according to the following proof test procedure:

I. Functional bench test (to assure all parts work as intended without interference).

A. Operate End Effector through full range with switch controls.

1. Verify interference-free operation.

2. Measure speed of opening and closing.

B. Operate End Effector through full range with proportional control.

C. Operate each tool with End Effector and verify insertion and removal from tool kit.

II. Verify tools stay retained in tool container against gravity.

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III. Final bench test to verify operating performance

A. Operate each tool with End Effector.

B. Perform the task for which each tool was intended (i.e., cut and strip wire, operate snap ring, etc.).

IV. Specification Demonstration Tests

A. Weigh End Effector.

B. Weigh each tool.

C. Measure pinch force between jaws of End Effector with pinch gauge.

Problems: None

Management Progress: This work will be reported under RTOP 970-63-20 beginning July 1, 1973.

Forecast: This RTOP will no longer be reported.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	503-24-06	112-30-19

4. TITLE:

Reusable Nuclear Stage Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMT Joe E. Zimmerman	453-5618	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Thin Film Cryogenic Thermometer
H-92167A, NBS, Boulder, CO

OBJECTIVE(S): The objective of this task is to optimize the thin film deposition parameters and manufacturing techniques of carbon thin film thermometers, and to produce representative quantities for field applications.

APPROACH: The thin film deposition parameters (pressure, substrate material, substrate temperature, and rate of deposition of the carbon film) will be varied during the initial deposition runs to determine the optimum conditions for producing the most repeatable and reproducible films for application as cryogenic temperature sensors. The initial deposition runs will also serve to define how closely the deposition parameters must be maintained to produce good quality films. Seventy-five films will be deposited as deliverable items. Ten of the films will be subjected to intensive calibration and thermal cysling to verify the analytical expression of resistance versus temperature between 6°K and 80°K.

STATUS: Technical Progress - The thin film deposition process has been finalized and the required number of deliverable items completed. Thermal cycling tests and calibration tests at 15 points between 6°K and 80°K have been completed on 10 films while the remaining films have been calibrated at 3 points. The final

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
*NBS 9744	Final Report on Low Gravity Thermometer Program	J. C. Jellison, R. S. Collier, L. O. Mullen, & R. J. Richards	11/69

*This report describes the original thin film thermometer investigation conducted prior to the present program.

FIRST BENEFITTING PROJECT: Tug

PROGRESS REPORT
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STATUS (CONCLUDED): Technical Progress (cont'd) - report was being prepared at the close of this reporting period.
Management Progress - A contract extension was finalized to extend delivery date to July 15, 1973.
Conclusions - Pending receipt of final report.
Problems - Completion of the program was delayed due to manpower and calibration facility allocation restrictions at NBS. The delay has not created any significant problems on MSFC's main programs.
Forecast - The thin film thermometers and final report on the program should be delivered by October 31, 1973.

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MSFC	01 04 73 to 30 09 73	503-24-06	112-30-19

4. TITLE:

Reusable Nuclear Stage Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IM T. N. Marshall	453-4626	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Solid/Triple Point Liquid Hydrogen Mixture Measuring System
H-13232A, National Bureau of Standards, Boulder, CO

OBJECTIVE(S): To develop instrumentation for slush hydrogen. The instrumentation to be developed will be density, mass flow, temperature, level, and phase.

APPROACH: A hydrogen slush density reference system was developed at NBS, Boulder and used as a standard for evaluating density measuring techniques. This reference system was used in establishing the most feasible methods for measuring hydrogen slush density. A hydrogen slush flow loop at NBS, Boulder has been used as a system for evaluating hydrogen mass flow techniques. This study is to be used as a basis for determining the techniques that can be developed into prototype mass flowmeters. A large slush hydrogen flow/generation system being fabricated at MSFC will be utilized to develop prototype instrumentation to an operational status.

STATUS: Technical Progess - The flowmeter spool piece consisting of a capacitance densitometer, thermal flowmeter and a microwave doppler flowmeter has been tested at MSFC.
The final report is in progress and will be issued within the next quarter of CY 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: TUG

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MSFC	01 04 73 to 30 09 73	503-24-06	112-30-19

4. TITLE:

Reusable Nuclear Stage Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. R. Feltner, S&E-ASTR-R	205 453-3765	J. C. Taylor

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Wide Temperature (-250°C to +300°C) Radiation Resistant Power Semiconductors and Microcircuits
NAS8-25917, Solitron Devices, Inc., May 1970 to July 1972
NAS8-26311, RCA Corporation, June 1970 to September 1971
NAS8-27086, RCA Corporation, May 1971 to May 1972
NAS8-28263, RCA Corporation, May 1972 to May 1973

OBJECTIVE: To develop wide temperature tolerant and radiation-resistant power transistors, diodes and microcircuits. The devices are to withstand 1×10^8 rads (Si) gamma and 1×10^{17} n/cm^2 at E > 1 MeV. The silicon and the gallium arsenide (GaAs) power device is to operate in a -55 to 300°C temperature environment. The microcircuits are to operate under a temperature range of -250°C to +300°C.

The silicon power devices are 100 amp and 5 amp transistors with 90 V_{CEO}, and 10 amp diodes with 200 V_R. The gallium arsenide power device is a 5 amp NPN transistor with V_{CEO} greater than 50 V. The microcircuits will be low power μW devices in the ±6 to ±15 volt range. Complementary P-channel and N-channel MIS devices will be used as a vehicle to develop a radiation-hardened dielectric.

The results will be used in the development of adequate electronic systems for operation in environments where wide temperature variations (-250°C to +300°C) and intense radiation could be present for long periods.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final Report	Prototype GaAs Bipolar Transistors - June 1972	RCA Laboratories Princeton, NJ	
Progress Report	Al_2O_3 as Gate Dielectric for Radiation Hardened C-MOS Monolithic Microcircuits	RCA Laboratories Princeton, NJ	

FIRST BENEFITTING PROJECT: N/A

MSFC - Form 350 (March 1973)

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APPROACH: Under contracts with major semiconductor manufacturers, the weakest links in the development of radiation hardened semiconductors have been attacked. These are power devices and dielectrics. Since silicon has been developed more than any other semiconductor material, the first effort was to develop radiation-hardened silicon power devices. Aluminum oxide shows the most promise as a radiation-hardened dielectric; therefore, it was developed primarily for use on MIS (Metal-Insulator-Semiconductor) microcircuits but has also been applied to other devices. GaAs shows promise as a high-temperature device with improved (50%) radiation hardness over the silicon. It was developed as a 5 amp NPN bipolar transistor.

STATUS: Technical Progress: For the silicon power devices the following prototype designs have been completed:

a. The 5 amp transistors (20 each) were delivered to MSFC June 1971, and have been temperature and radiation tested.

b. The 100 amp power transistors have been delivered to MSFC and have been electrically tested.

c. The 10 amp diodes (20 each) were delivered to MSFC August 27, 1971, and have been tested.

In the development of Al_2O_3/SiO_2 sandwich for MIS microcircuits, all the devices have been delivered under the RCA (Somerville) contract. Under the extension of this contract with RCA(Princeton), additional wafers were fabricated with a single layer of pyrohydrolytic (PHL) Al_2O_3 with (V_T) threshold voltages of +1.4 volts and -.65 volts, respectively for N and P channel devices and have been delivered. Radiation testing has been done on these devices at 10^8 rads Si. This is three orders of magnitude higher than was specified in the contract. In the development of the 5 amp GaAs bipolar transistor, three layer transistor structures of GaAs have been prepared by an epitaxial vapor-phase growth technique and have been fabricated into interdigitated bipolar transistors.

Management Progress: A contract (NAS8-26311) was signed with RCA Corporation on June 26, 1970, to develop a radiation-hardened dielectric for use with MIS microcircuits and other semiconductors. It was extended 3 months with an additional scope of work to be performed jointly by RCA (Somerville, NJ) and RCA (Princeton, NJ), and has now been completed. A contract, NAS8-27086, was signed on May 4, 1971, with RCA (Princeton) to develop a 5 amp power GaAs bipolar transistor has been completed. A contract NAS8-28263 was negotiated with RCA to optimize and characterize Al_2O_3 as a gate-radiation-hardened dielectric for limited production on May 2, 1972.

Conclusions: The development of radiation hardened power transistors is a compromise between radiation hardening and other important parameters. As a result of this and other efforts, these trade offs are better understood. Transistors can now be designed for the degree of radiation resistance required for a given application if electrical parameters of the device do not fall below requirements.

The use of Al_2O_3 was investigated for use in radiation hardening MIS integrated circuits. This work was not completed due to cancellation of the contract but important information was gained. It was definitely concluded that higher radiation resistance was gained if the Al_2O_3 was properly deposited.

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Problems: The development of new and better semiconductor materials for power transistors that must meet the most demanding radiation requirements.

Forecast: As funding for this RTOP was discontinued, a 'STOP-WORK' notification was issued to RCA February 1, 1973, regarding contract number NAS8-28263, the only active contract at that date. Work on development of radiation-hardened semiconductors has been discontinued. This will be the final progress report submitted.

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		CURRENT NO.:	PRIOR NO.:
Marshall Space Flight Center	01 04 73 - 30 09 73	503-24-06	112-30-19

4. TITLE:

REUSABLE NUCLEAR STAGE TECHNOLOGY (PART I OF II)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Eric H. Hyde	453-3852	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Systems Study of Slush H_2 Handling and Quality Upgrading

CONTRACT: (In-House Development)

OBJECTIVES: To demonstrate that the cell 115 slush H_2 facility can be used to produce slush H_2 using the freeze-thaw process at the rate of 450 Kg's/hr, develop metrology (mass, density, liquid level, flowrate), and determine stratification effects.

APPROACH: The freeze-thaw process will be used to produce slush H_2. This process uses discrete open and closing valve cycle to alternately lower the slush generator ullage pressure. Heat through the side wall thaws the friable crust formed at the top of the liquid and a stirring device will be used to produce a homogeneous mixture.

STATUS: The cell 115 facility is complete; all hardware is installed and functional. Limited instrumentation has been installed. Three tests have been performed. Television camera video tape showed slush hydrogen was produced in the third tests. Data is now being correlated and a final report will be written.

REMARKS: This effort has been terminated in compliance with a NASA Headquarters directive. Slush H_2 quality measurements were not taken. Instrumentation necessary to make slush quality measurements was not fully developed and calibrated to measure quality and upgrading as a result of NASA Headquarters cancellation of the nuclear program.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

1. Numerous in-house and National Bureau of Standards memorandums have been written.

2. S&E-ASTN-PF(72-168), subject: "MSFC Slush Facility Test Plan," dated November 1, 1972.

FIRST BENEFITING PROJECT: NUCLEAR STAGE

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
Marshall Space Flight Center	01 04 73 - 30 09 73	503-24-06	112-30-19

4. TITLE:

REUSABLE NUCLEAR STAGE TECHNOLOGY (PART I OF II)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Eric H. Hyde	453-3852	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Characteristics of a Gelled Liquid H_2/PPO Foam Open-Cell Cryogenic Insulation System

CONTRACT: NAS8-27203, General Dynamics/Convair, San Diego, California

OBJECTIVES: The objective of this research program is to evaluate analytically and experimentally the compatibility and characteristics of a gelled liquid hydrogen/PPO foam open-cell cryogenic system. True gels must "shear thin" rapidly when exposed to a shearing stress, flow like a fluid, and then set back up when stress is removed.

APPROACH: The techniques were evaluated for gelling liquid hydrogen with small particles of ethane based on the gelant gas condensation process. Phase I, "Interfacial Phenomena and Transfer," involved an investigation of techniques for producing gelled liquid hydrogen on a large scale, a study of gel transfer characteristics, and an investigation of the phenomena occurring at the gel/PPO foam interface.

STATUS: The effect of repeated shearing, or transfer, of gelled liquid hydrogen on its at-rest structure was investigated, and it was concluded there was no significant shear degradation of the gel structure. The "inside-tank" or "static" technique, where the gelant gas is injected below the liquid surface of a tank of LH_2, was found to produce gel having a lower gelant weight concentration than that produced by the "outside-tank," or flowing technique where the gelant is injected into a flowing stream of LH_2 and the resulting gel is collected in a tank.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
GDCA 632-3-169	Final Report (Phase I) 15 February 1973	F. O. Bennett	

FIRST BENEFITING PROJECT: NUCLEAR EFFORTS

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 503-24-06
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REMARKS: This is a final contract report due to NASA directive to cancel effort related to the nuclear stage. Although this was a three-phase effort, only phase I was completed

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	755-43-11	115-22-06

4. TITLE:
Visible Laser Communication Experiment

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
F. A. Cagle, S&E-ASTR-ST	453-3448	F. W. Wagnon, S&E-ASTR-ST

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Visible Laser Communication Experiment

CONTRACT NUMBER: Contract No. NAS8-29191 ITT, NAS8-29203 B&C

OBJECTIVES: The objective of this program was to develop and implement a flight project to prove the concept of Optical Communication (Op/Com) in space between a synchronous orbiting satellite and a ground station. Specifically, the objectives were: (a) Determine the effects of the atmosphere on laser propagation along a near vertical path between the spacecraft and the ground in two directions, (b) Prove the feasibility of wide angle acquisition and tracking between two optical terminals, (c) Prove the feasibility of precision pointing and tracking in space to approximately one microradian, (d) Prove the feasibility of establishing an optical communication link with a capacity of 30 megabits per second, (e) Obtain operating experience with a laser communication system in space in order to aid in the design of future systems and (f) Provide for a future data relay link with a low-earth orbit spacecraft.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
001	Technical Progress	ITT	11-20-72
002	Technical Progress	ITT	12-20-72

FIRST BENEFITTING PROJECT: VLCE

MSFC - Form 350 (March 1973)

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 755-43-11

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APPROACH: An optical communication experiment package was to be flown on the ATS-G synchronous orbit satellite. The optical package in the spacecraft would consist of a 5 mW HeNe laser with an optical transceiver. The system would have a 30 megabit per second data rate capability to evaluate communications performance. Two ground stations would be instrumented for this program. They were the Madkin Mountain Station at MSFC and a mobile station to be used part time at Mr. Hopkins, AZ and the Mojave Desert, CA. A 4880 Angstrom argon laser would be used as the ground beacon. The mobile ground station would utilize a 183 cm (72 inch) receiver for communications at the 30 megabit data rate. The fixed ground station at MSFC would use the existing 61 cm (24 inch) telescope transceiver to track and receive the incoming beam.

STATUS: The ITT contract (NAS8-29191) was awarded Sept. 18, 1972, and the Boller and Chivens contract (NAS8-29203) was awarded Dec. 11, 1972. The Preliminary Requirements Review on the flight transceiver and the ground station transmitter was held November 8-10, 1972, and the ground station receiver review was conducted on Dec. 14, 1972. CEI Part I Specifications had been prepared on all major components.

The project was cancelled on January 5, 1973 by TWX from the Associate Administrator for Aeronautics and Space Technology to Director, MSFC as follows:

"The agency has made a decision to cancel the ATS-G spacecraft. The VLCE dependence on ATS-G presents us no alternative other than cancelling the VLCE experiment under MSFC, ITT and Boller and Chivens cognizance. Send information copies of your termination messages to OAST, Code RE. Prepare an outline of your implementation plan including a schedule of termination negotiations and estimated cost. Submit a copy of your plan to OAST, Code RE by Friday, January 19, 1973.

The actions specified above are in no part related to MSFC performance on the VLCE experiment. Your center planning and management of the experiment have been a model of sound technical judgment, accurate fiscal projections and realistic scheduling. Headquarters, OAST had high aspirations for the success of the VLCE experiment and its contributions to the emerging field of laser applications. It is with regret that we direct you to take the actions noted above."

Both contracts (ITT and Boller and Chivens) were terminated immediately with final close-out expected by Nov. 30, 1973. All remaining project funding, not required for final settlement, have been deobligated.

This is the final progress report on this RTOP.

OFFICE OF MANNED SPACE FLIGHT

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 - 30 09 73	908-51-02*	

4. TITLE:

Space Station Thermal Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. Middleton	205-453-3828	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Evaluation of Absorption Cycles for Space Station Environmental Control
NAS8-25986

OBJECTIVE: (a) Evaluate the performance and capabilities of absorption refrigeration cycles for spacecraft thermal control.

(b) Using space system analysis tools evaluate the spin-off application of solar powered cooling and heating systems for residential applications. Using previously developed analytical techniques define, in conjunction with MSFC in-house efforts, solar collector, thermal storage, and modifications required for commercially available air conditioners for a full scale demonstration project of solar powered residential heating and cooling.

APPROACH: (a) Computer analysis programs were developed and system components performance requirements and designs were generated.

(b) The space systems analytical tools were used and the potential for a residential system using minimum electrical power was assessed.

STATUS: Technical Progress - (a) The space system was analyzed and parametric comparisons made. A conceptual breadboard system was designed, fabricated and tested. This system incorporated all gravity sensitive sub-components, and was successfully operated at design conditions. A detailed final report was written and published. No further contractor effort is planned at this time

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC D306225	Evaluation of Absorption Cycle for Space Station Environmental Control System Application, LMSC D306225	Sims O'Neal Ried Bisenius	Nov. 1972

* Follow-on effort under objective (b) is being accomplished under code 161-80-01.

FIRST BENEFITING PROJECT - MSFC In-House Solar Heating/Cooling Demonstration Program

MSFC - Form 350 (March 1978)

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
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Technical Progress Cont'd - This is the final report on the space application of the absorption cycle.

(b) The feasibility study of residential application was completed in November 1972 and a detailed final report published. The contract was amended to permit additional analytical effort in conjunction with the MSFC demonstration program. Design analysis have been completed on the solar collector, thermal storage system, and control system. This effort will continue thru December 1973.

Management Progress - Contract modifications to permit component design/analysis have been completed.

Conclusions - (a) Spacecraft thermal control can be accomplished using absorption cycle refrigeration for certain space thermal environment/conditions. Breadboard tests have proven component design adequacy.

(b) Residential heating and cooling utilizing solar powered absorption refrigeration systems is potentially desirable considering increases in conventional fuel cost and decreased availability. Spacecraft technology can make the residential cooling project successful.

Problems - None

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 908–51–05	PRIOR NO.: 908–51–05

4. TITLE:

Electrical Power – Space Station

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. E. Young	453–4566	R. M. Aden S&E–ASTR–E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Thermoelectric Power Generation

Contract No: In–house

Objective: To support the technology development of a reactor/thermoelectric power system which is a candidate for manned Earth Orbital Applications. Subsidiary objectives include evaluation of performance, lifetime, and reliability characteristics from life test data; determination of thermal and electrical characteristics; comparison of actual device performance with predicted performance derived from computer modeling; and performance of detailed post–test analysis.

Compliance with these objectives will provide technology readiness necessary to accommodate thermoelectric power system go–ahead.

Approach: The objective will be accomplished through a continuation of in–house effort on the basic research device, development of user application criteria, and integration studies.

Status: Technical Progress:

Tests are in progress; data is being gathered and evaluated.

Phase I – Experimental devices have been procured (1 Each TEM/9U and 1 Each TEM/X Module) and have been on test in a subsystem environment.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1	Test & Evaluation of a Tubular Thermoelectric Module (TEM–9U, S/N 17)	S&E–ASTR–EPN	May 1, 1972

First Benefiting Project: Space Station

MSFC - Form 350 (March 1978)

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 908-51-05

Status: (Cont'd)

Tests were terminated as scheduled on TEM/9U after more than 20,000 hours of operation. The TEM/X Module has been on test for over 4400 hours. All facilities for testing and data gathering are operating satisfactorily.

Management Progress:

A facility has been established for test and evaluation of thermoelectric devices.

The TEM/X currently is operating 24 hours/day.

Conclusions:

Results of TEM/9U testing and analysis indicate that a Space Station Thermoelectric Power System could be fabricated using TEM/9U basic technology. However, improvements in the form of lower rates of power degradation and higher efficiency performance are desirable. The TEM/X series of modules have incorporated design changes which should provide these improvements.

Problems:

Module power degradation resulting from thermal cycling has been a problem. Test evidence indicates that this problem has been solved in the TEM/X series modules. The problems associated with expanding available component technology into system technology need attention and will be worked.

Forecast: The remaining part of the fiscal year will be devoted to gathering and evaluating data from the TEM/X converter and preparing a final report.

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	908-51-08	908-51-08

4. TITLE:

Stabilization and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
G. Doane III S&E-ASTR-G	453-0787	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Control Moment Gyro for Stabilization and Control
NAS8-25756 The Bendix Corporation

OBJECTIVE: To develop a modularized family of CMGs which will be able to meet various requirements of future Space Station/Space Base vehicles. The modularized CMG system will be centered around nominal 2000H to 6000H CMGs which have as much commonality of design as is feasible. Prime emphasis is being placed on long life, and repairability in the Space Station environment, monitoring impending failure and incorporation of redundancy where feasible.

APPROACH: The approach for developing long life, highly reliable CMG system is based upon the following improvments. (1) Replaceable spin bearings, (2) Brushless dc spin motors, (3) Improved wet lubricated actuators with brushless dc torquers and tachometers, and spin motor electronics, and (4) Increasing reliability and improving the electronics.

STATUS: Technical Progress - The assembled double-gimbal 2000H CMG is being modified to run at a 3000 ft-lb-sec momentum level to support the baseline CMG-kit definition for the Sortie Lab.

The 6000H inner gimbal and rotor assembly is still undergoing testing to verify spin bearing design at Bendix/Teterboro.
The delivery date for the 6000H unit will be extended to 4th quarter of CY73 to permit continuation of the spin bearing analysis and testing.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

The following presentations have been reproduced and bound for distribution.

"Design Review, ATM CMG Product Improvement Program," NAS8-27756, at MSFC, July 21, 1970, presented by Bendix Corporation, Navigation and Control Division.

"Advanced Design CMG Critical Design Review, ATM CMG Improvement Program," NAS8-25756, January 22, 1971.

FIRST BENEFITTING PROJECTS: Large Space Telescope and Sortie Lab

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MSFC	01 04 73 to 30 09 73	908-51-08	

4. TITLE:

Stabilization and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. A. Swords S&E-ASTR-GMF	205-453-5753	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: CMG Bearing Signature Analysis
NAS8-25706 Mechanical Technology, Inc., Latham, NY

OBJECTIVES: The objective of this effort is to develop a method of early detection of bearing failure in CMG type spin bearings. This method will serve to give useful data on impending failure of CMG bearings before and after launch where failure would be catastrophic.

APPROACH: Phase I - CMG Investigation - Data has been taken on a multiplicity of CMG bearings mounted in CMGs by using high frequency accelerometers mounted strategically around the CMG. Readings were taken on bearings known to be good and bearings showing signs of failure. After the readings were taken on the subject bearings, they were disassembled to verify the predicted failure. At the completion of Phase I, a report was issued giving the results.

Phase II - Spin Bearing Investigation - To eliminate the harmonics of the CMG bearings and to further refine the failure detection technique, individual sets of CMG bearings are being run in a bearing test fixture. This eliminates the CMG housing and allows a study of bearings as individual components. A series of bearings determined to be good and a series of bearings with known defects are being run to obtain signatures and establish a criteria for determining when a bearing is beginning to degrade and what effect flaws have in the signature. At the

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MTI-71TR1	Design and Fabrication of Prototype System for Early Warning of Impending Bearing Failure	J. J. Broderick R. F. Burchill H. L. Clark	Jan. 1972
MTI-73-TR-33	Review of Mechanical Vibration Tests conducted on Control Moment Gyros and Life Test Fixtures	R. F. Burchill	Aug. 24, 1973

FIRST BENEFITTING PROJECT: LST

MSFC - Form 360 (March 1978)

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APPROACH: Phase II (cont'd)

completion of this effort an overall review of the data will result in limits being established on the signature to separate good bearings from bad ones.

STATUS: All spin bearing tests have been completed and the final report is being prepared. It is scheduled for completion by November 1, 1973.

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MSFC	01 04 73 to 30 09 73	908-51-08	

4. TITLE: Stabilization and Control - Modern Sampled-Data Control Theory

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. M. Seltzer S&E-ASTR-A	453-4715	for Hans H. Rosenthien

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities): (NAS8-28584, Systems Research Laboratory)

OBJECTIVE:

The objective is to make optimum use of an in-flight digital computer so that it may be sized as small as possible. The techniques that are now being developed under modern control theory will be expanded. Analytical tools will be developed so that the design engineer can use them in the design of sampled-data control systems. A potentially powerful modern technique is under development for digital redesign of an existing acceptable (in terms of dynamic response) continuous control system. New innovations in the state space techniques that enable one to design a sampled-data control system using continuous system techniques will be thoroughly investigated. These investigations should extend the newly achieved results of sampled-data analysis in the state space domain and should investigate their applicability to space vehicle control system design. These investigations should further explore the techniques for solving linear continuous-data systems, such as the Nyquist criterion, Routh-Hurwitz criterion, root locus diagram, or Bode diagram extending these to the study of linear and nonlinear sampled-data control systems. The synthesis of linear continuous data systems and nonlinear continuous data systems will be determined. The ultimate goal of these investigations should achieve a sampled-data design tool that may be employed by the control system engineer who does not possess a deep mastery of mathematical and control system theory.

APPROACH:

A comparison of the various state space implementations will be made with existing

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
DCN 1-2-40-23018	Final Report. Research Study on Stabilization and Control-Modern Sampled-data Control Theory	B. C. Kuo G. Singh R. A. Yackel	April 1973
Bimonthly Report I-73	I. Computer Simulation of the Attitude Dynamics of a Large Space Telescope (LST) Model	B. C. Kuo G. Singh R. A. Yackel	July 9, 1973
	II. Continuous-Data Describing Function Analysis of the Frictional Nonlinearity of the CMG of a Large Space Telescope (LST) System.		
AIAA Paper #73-894	Design of a Digital Controller for Spinning Flexible Spacecraft	B. C. Kuo S. M. Seltzer G. Singh R. A. Yackel	August 22, 1973

FIRST BENEFITTING PROJECT: LST

modified frequency domain techniques, such as the familiar z-transform technique. These comparative results will determine those techniques which are most easily implemented by the space vehicle control system designer. Analytical tools will be developed so that the design engineer can use them in the design of sampled-data control systems. The approach includes the following activities.

1. Suitable dynamic models will be developed for use in the major activities of this research task.

2. Professor Kuo has developed a technique for designing a sampled-data system whose response matches that of a continuous data system model at the sampling instants. The technique is rigorously applicable only to regulator problems and as such will be developed further.

3. The point-by-point comparison method (activity 2) will be extended from the regulator problem to the tracking problem. The extension technique will be scrutinized mathematically.

4. The convergence properties of the series approximations used in the point-by-point methods (activities 2 and 3) will be investigated as a function of the sampling period.

5. Optimal control theory (the Riccati equation in particular) will be utilized to develop a sampled-data design technique, using a quadratic performance index rather than a point-by-point comparison technique. An investigation will be made of complexity versus accuracy improvements achieved through the solution of the inverse problem of optimal control and a Liapunov function equation.

6. Since the optimal control method (#5) is really applicable to the regulator problem, an attempt will be made to develop a technique that extends this method to solve the tracking problem.

7. The point-by-point method (#2) will be compared with the optimal control technique (#5) for the regulator problem.

8. The two methods (#3 and #6), as extended to apply to the tracking problem, will be compared.

9. A parameter optimization digital redesign technique will be developed. A quadratic performance index is defined by using the difference between the status of a continuous data system and the states of the digital system to be designed. This index is minimized by selecting optimal values of the chosen parameters.

STATUS:

1. The accuracy of the discrete-data describing function analysis (reported in Item 1 under Status, last Progress Report) has been verified by computer simulation.

2. A realistic model for the frictional torque characteristics of the CMG has been derived. A continuous-data describing function for this nonlinearity has been developed and is being used by NASA to investigate limit cycle characteristics of the LST.

3. A discrete-data describing function for the nonlinearity in Item 2 (above) is being derived.

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Item #7 Continued

Bimonthly Report II-73	Modeling of the LST System with the CMG Nonlinear Friction	B. C. Kuo G. Singh R. A. Yackel	September 1, 1973

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	908-51-18	908-51-18

4. TITLE:

Checkout

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
G. W. Kurtz S&E-QUAL	453-1435	R. M. Henritze

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Fastener Load Analysis Method, NAS 8-25362, Midwest Research Institute, Kansas City, Missouri

Objective: Develop method and equipment for determination of assembled bolt fastener loads, within 2-5% accuracy, using ultrasonic velocity change techniques.

Approach: Phase I - Program Plan and Feasibility Study: Covers preparation of detailed program plan, study of techniques, choosing electronic techniques and equipment, bolt testing, probe investigation, analysis of variables effect on accuracy, and technical report. Phase II - Prototype System Development: Perform testing on specific bolts under variable conditions to establish probe design and system accuracy. Phase III - In-House Evaluation and Coupling Wrench Development: Evaluate system as received and establish applicability to production use. Ruggedize coupling wrench and revise design for specific bolt applications.

Status: Technical Progress: Prototype system was designed and fabricated. A technical operating manual and final technical report were prepared. System was delivered to NASA/MSFC, a demonstration/presentation given, and training of personnel conducted. Phase III evaluation was completed. Design,

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR 61354	"Fastener Load Analysis Method"	F.R. Rollins	April 2, 1971

First Benefitting Project: Space Shuttle - Savings in weight through use of fewer and smaller bolt fasteners will be accomplished due to capability of measuring bolt loads more accurately than present day torque wrenches.

PROGRESS REPORT
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(Continuation Sheet)

CURRENT NO./CODE: 908-51-18

Status: (Continued)
fabrication and testing of a special coupling wrench and transducer for Saturn type engine mount bolts applicable to Space Shuttle engines was completed. Testing of this wrench uncovered potential problems in liquid coupling between the transducer and bolt head. Experimental testing utilizing various coiled compression springs to achieve a constant pressure between transducer and bolt head was tried. Successful coupling was attained through use of heavier springs and the problem appears to be solved.

Management Progress: Contract completed and closed out. Report mentioned is final report of this project.

Accomplishments:

Conclusions: Ultrasonic analysis of bolt loads during initial assembly can be accomplished with prototype equipment on hand within 2-5% accuracy.

Problems: Development of electronic assemblies necessary for measuring post-assembly bolt loads will require extensive analysis and testing. Limitation of funds to continue this project for post-load measurement capability, will curtail this effort.

Causes of Problems: (As mentioned above).

Status: (Concluded): The project as originally described has been successfully completed. This is the final progress report.

Forecast: The system as developed, will be employed on special bolt joint assemblies where applicable.

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1. CENTER	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	31 03 73 to 30 09 73	908-51-21	908-51-21

4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. B. Beal, S&E QUAL	453-1435	R. M. Henritze

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Development of Solid State Radiographic Image Amplifier, Direct Viewing NAS 8-25678, Westinghouse Electric Corporation, Elmira, N.Y.

Objective(s): Obtain information, design parameters, detail drawings, fabrication details, and solid state image amplifier (SSIA) panels sensitive to X-ray energy used in nondestructive evaluations of space vehicle hardware. Image retention, image erasure, sensitivity to incident radiation changes, reuse (lifetime) and portability characteristics shall prevail in order to supplant use of X-ray film and other display methods. Both image storage and image non-storage, (Fluoroscopic-type) panel development, to meet 2% thickness sensitivity requirements of MIL-STD-453, is required.

Approach: Phase I - Technical Survey: Perform literature and technical survey of existing SSIA technology and equipment in-house. Phase II - Contract Effort NAS 8-25678) for SSIA Panels: Design, develop, and fabricate and test storage and nonstorage SSIA panels. Phase III - Power Supplies: Fabricate, in-house, suitable power supplies for all of the SSIA panels to be delivered by contractor. Phase IV - SSIA Panel Evaluation - Define panel capabilities, limitations, and characteristics in-house. Implement SSIA panels and application techniques for production, repair, refurbishment and receiving radiographic evaluations.

Status: Technical Progress: Operational checkout and determination of optimum radiographic equipment settings for best image has been completed on the panels available for implementation. Panels and power supplies implemented for receiving inspection evaluations, where applicable.
Management Progress: Contract completed and closed out. This is the final report on this project.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-61377	"Solid State Radiographic Image Amplifiers Final Report, Part C"	Dr. Zoltan Szepesi	June 1971

First Benefitting Project: Space Station

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RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 908-51-21

5. Accomplishments: (continued)

Conclusions: Image storage panels now meet requirements of MIL-STD-453 and program objectives. Image non-storage panels provide improved fluoroscopic imaging capabilities, i.e. higher resolution, contrast, and brightness than the fluoroscopic screen (Dupont CB-2)

Problems:

Panels developed are of a fragile glass substrate construction, and this will limit implementation.

Forecast: See Remarks

Remarks: Technology spin-off from this program has resulted in improved fluoroscopic imaging systems for medical and veterinary applications and checking parcels and baggage for contraband and explosives. Evaluation continues for panel applications through study contracts issued by the Technology Utilization Office. Development of flexible panels, on plastic or metal substrates, is feasible, but requires more funding, which is not available. Delivered panels have glass substrates, are fragile, and implementation is limited due to their prototype nature.

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MSFC	01 04 73 to 30 09 73	908-51-21	908-51-21

4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. C. McIlwain S&E-Qual	453-1435	R. M. Henritze

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Detection of Lack of Fusion Using Opaque Additives
NAS 8-28708, McDonnell-Douglas Astronautics Company, Huntington Beach, California.

Objectives: (1) To develop a reliable means of detecting lack of fusion; (2) To develop a means of maintaining cleanliness in weld area indefinitely using thin copper coatings.

Approach: A thin copper coat preplaced in joint area protects cleanliness by preventing formation of aluminum oxide. When welded into joint, any remaining trace of coating in radiographs is readily seen, and is an indication of lack of fusion. The program will be accomplished in two phases.

Phase I: Development of Methods - This phase will concern itself with the development of a technically feasible and metallurgically acceptable coating.

Phase II: Evaluation of Coating - This phase will determine the level of confidence attained in the radiographic determination of LOF by the opaque tracer developed in Phase I. Phase II will also determine the effectivity of this coating as a protection for maintaining welding cleanliness for extended periods.

Status: Technical Progress: Phase II has been completed and the final contractor report has been delivered. In Phase II, it was determined that opaque additives (copper) of a thickness of 0.0004 inches would yield 100% detectibility for LOF defects in 1/2 inch thick 2219-Aluminum welds. It was also deter-

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MDC G4298	Detection of Lack of Fusion Using Opaque Additives	J. L. Cook	Oct. 1972
MDC G4538	Detection of Lack of Fusion Using Opaque Additives (Final Report)	J. L. Cook	May 1973

First Benefitting Project: Space Shuttle - All programs requiring weld inspection.

mined that the vapor deposited copper plating used as the opaque additive protected the surface cleanliness of the aluminum for periods up to 60 days. No detrimental effects on weld strength, due to the opaque additive, were noted in the study. However, the metallurgical studies conducted on weld specimens by the contractor were very limited. Additional metallurgical studies will be performed in-house to more completely characterize weld microstructures containing the copper additives.

Management Progress: The contractual phase of this study has been completed.

Conclusions: The opaque additives provide protection to maintain surface cleanliness and provides 100% detectability of LOF type defects. However, no plating process exists which would allow application of this inspection aid on an economical production basis.

Problems: This program did not evolve an economical production type plating process.

Forecast: In-house studies will be conducted on contract residuals to (1) determine if opaque additive enhances ultrasonic detectability of LOF; and (2) to fully characterize the metallurgical structure of weldment with opaque additives.

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4. TITLE:

Control System Technology for Shuttle Vehicles

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
P. Golley S&E-ASTR-GM	453-5755	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Actuator-to-Digital Interface Units
NAS8-26755 Electric Communication, Inc.

OBJECTIVE: To develop a suitable interface between the Shuttle data bus and two types of redundant hydraulic servo actuators. One type is double fail-operate "look and switch;" the other is a single fail-operate majority vote.

APPROACH: In-house investigation led to the conclusions that the most reasonable way to perform the interface between the basically analogue actuator and the quad-redundant data bus was through an electronic interface unit. These units are to be designed to provide the following functions: to perform actuator redundancy management, self-test; to report redundancy status; to decode incoming information and encode return information; and to perform the necessary D/A and A/D conversions and analogue signal amplification. Separate designs will be required for the "look and switch" and "majority vote" actuators.

STATUS: Technical Progress - Delivery and evaluation of the majority vote DIU has been completed with satisfactory results. Delivery of the "look and switch" unit is expected in early October 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

A final report on the actuator-to-digital interface units will be available in October 1973.

FIRST BENEFITTING PROGRAM: Space Shuttle

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4. TITLE:

Stabilization and Control - Analysis and Applications

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M.E. Polites S&E-ASTR-SG	453-4587	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Reaction Control System (RCS) Studies, NAS8-26580, Auburn Research Foundation, Auburn, Alabama

Objective: The basic object of the research effort is to develop improved techniques for generating RCS engine firing commands over a range of operating conditions including the phase of flight where both RCS and aerodynamic control surfaces can be used.

Approach: Investigate the application of adaptive control techniques to RCS control system logic with the goal of improving control system performance in terms of pointing accuracy and fuel consumption over a wide range of operating conditions.

Status:

Technical Progress - A time-domain model-reference adaptive control scheme has been developed which is assured to be asymptotically stable through the application of Liapunov's Second Method. The scheme has been compared with similar ones previously developed and was shown to provide less oscillatory transient responses with smaller peak errors. Through linearization techniques and conventional root locus methods, synthesis procedures have been developed to allow the designer to select the adaptive gain parameters to produce a desired response damping and settling time. The feasibility of implementation has been tested for a single axis model of a shuttle-type vehicle during its reentry phase through the atmosphere when the dynamic pressure on the control surfaces undergoes drastic variations. Analytical expressions have been developed for estimating the magnitude of the maximum error during adaptation.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Monthly Progress Reports: Feasibility Study of Reaction Control Systems	Joseph Boland III	from Jan. 5, 1971 thru Aug. 12, 1973
	An Adaptive Control Bibliography	Joseph Boland III	Apr. 5, 1971
	Time-Domain and Frequency-Domain Techniques for Model-Reference Adaptive Control Systems	Joseph Boland III	Oct. 15, 1971
	Some Optimal Considerations in Attitude Control Systems	Joseph Boland III	Sept. 14, 1973
	Comparison of Thruster Configurations in Attitude Control Control Systems	Joseph Boland III	Sept. 14, 1973
	Design Implementation in Model Reference Adaptive Systems	Joseph Boland III	Sept. 14, 1973

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6. Accomplishments (Milestones, Problems, Near term activities):

An RCS thruster configuration which requires only four thrusters for three axes control was devised and was compared with a conventional six thruster configuration in terms of propellant requirements and system performance. Digital computer programs simulating vehicle responses with each thruster configuration have been developed for the comparison. Results shows no significant difference in propellant requirements or vehicle response characteristics with either configuration. It is felt that the four engine configuration could reduce RCS system cost and weight without increasing propellant usage or sacrificing vehicle performance.

Management Progress: Contract NAS8-26580 was awarded November 17, 1970, to Auburn Research Foundation, Auburn, Alabama, for studies of various reaction control systems for Space Shuttle. Meetings were held Jan. 29, Mar. 26, May 20, July 15, Sept. 1, and Oct. 14, 1971, and Jan. 25, Mar. 21, May 18, July 1, Aug. 15, Oct. 1, Nov. 15, 1972, Jan. 15, Mar. 15, June 5, Sept. 10, 1973 to review progress. The schedule was revised to agree with the capabilities and the performance that the contractor has demonstrated and the rate of the expenditure of funds. The contract was extended through Feb. 1972, by a no cost extension. A further extension through Feb. 1973, using FY 72 funding had been made, and the contract had been modified to include additional study areas. A contract extension beyond Feb. 1973, to Sept. 15, 1973, had been requested and approved. Contract was completed on schedule Sept. 15, 1973.

Conclusion: Contract was completed on schedule Sept. 15, 1973.

Problem: None

Forecast: None

7. Report No:	Title:	Author(s):	Date Transmitted
	Final Report	Joseph Boland III	Sept. 15, 1973

First Benefitting Project: Shuttle

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4. TITLE:
Control System Technology for Space Shuttle Vehicles

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-DDD Stephen W. Winder	205 - 453-2521	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Control System Technology for Space Shuttle Vehicles
NAS8-29193, Northrop Services, Inc., Huntsville, AL

OBJECTIVE(S): The planned generation of Space Shuttle vehicles pose several challenging control problems over its operational range. In particular, the ascent phase of flight is one area in which new problems arise. In ascent, the mated configuration has only one plane of symmetry causing the inherent problem of zero lift and zero moment occurring at different angles of attack. Cross-coupling problems are also severe in some candidate designs.

The parallel burn configuration currently being considered has insufficient control authority in its orbiter engines to control headwinds or crosswinds unless the aerodynamic surfaces on the orbiter and/or the solid rocket motors are used. When these additional control effectors are used, the number of control effectors becomes greater than the number of states to control. Hence, the way to blend these effectors to produce the proper control forces and moments will have to be determined from an infinity of possible solutions. One way to approach the problem is to determine the blending of the control effectors to produce a trim solution of zero forces and moments acting on the vehicle.

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None			

FIRST BENEFITTING PROGRAM: Space Shuttle

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APPROACH: The solution to the trim problem does not yield a unique set of trim conditions. The proposed approach is to include in the equations defining trim, the penalty functions that arise from hinge moment contraints, thrust losses and similar constraints, and then solve the trim problem for the optimum trim condition. This procedure will result in an algebraic optimization problem that will select the trim point.

Valuable insight can be gained by first solving for the trim boundaries that are defined by the trim equations and the control limits without penalty function considerations.

The proposed technical approach is divided into three tasks:

o Task 1 will be technology development and consist of three phases:

* Phase I will formulate constraints and limits for the control deflections in a performance index suitable for analysis.

* Phase II will involve solving the trim problem without "hard" limits on the control deflections. In addition the trim boundaries will be established.

* Phase III will be an extension of Phase II procedures to include performance indices that cannot be handled analytically. "Hard" limits on the control deflections will be considered as an integral part of the problem and its solution.

o Task 2 will involve solving a sample shuttle problem to illustrate the techniques developed under Task 1 above and will run concurrently with the studies of Task 2.

o Task 3 will assess the dynamic responses as influenced by the chosen trim solution.

The completion of the above tasks will yield computational algorithms capable of establishing the trim solutions (or any specified desired state) for several types of performance indices that include hard constraints. Computer programs necessary to demonstrate the ability of the algorithms will be developed.

STATUS: Technical Progress: Phases I and II of the study have been completed. In the first phases of the study the performance indices were considered quadratic in nature and no "hard" limits were imposed on the control deflections. In Phase III performance indices which considered thrust & drag loss due to control deflections and hinge moment constraints were used. In order to minimize the performance index and consider the hard constraints on the variables, a simplex iteration method has been developed that seems to work quite well. Subsequent studies are continuing to improve the iteration algorithm by selection of the initial starting conditions.

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STATUS (CONCLUDED):

Management Progress: A no-cost extension has been approved to further investigate the iteration techniques and performance index formulation. The period of extension is for 3 months.

Conclusions: The techniques developed this far do provide an investigative tool that will allow an assessment of the control authority/performance interaction. This type of analysis will show trends of how to blend various control deflections to achieve desired control forces and moments.

Problems: None

Forecasts: None

Publications: Only monthly progress reports have been received to date. A final report will be published at the completion of the study.

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4. TITLE:

Control System Technology for Space Shuttle Vehicles R&R

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-DDD Stephen W. Winder	205-453-2521	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Advanced Control Concepts
NAS8-29192, The Singer Company, Kearfott Division, Little Falls, NJ

OBJECTIVE(S): Because of the possible launch configurations required to boost a Space Shuttle into orbit, it is anticipated that a large number of control effectors, including both aerodynamic surfaces and gimballed rocket engines, will be required to control the vehicle during ascent through the atmosphere. One objective in controlling the vehicle is to determine the deflection angle settings of the control effectors required to trim the vehicle for headwind and sidewind disturbances. Because of the launch configuration and the large number of controls, the control engineer is faced with two challenging problems. First, to compute the trim solution may entail solving a system of coupled, nonlinear equations. Second, if the number of control variables exceeds the number of independent trim equations to be satisfied, then the trim solution is not unique.

APPROACH: To solve the uniqueness problem, additional constraints must be imposed. A logical choice for the additional constraints is the minimization of a performance criterion that penalizes the degradation in vehicle performance caused by large trim deflection angles. The performance criterion proposed for the investigation penalizes the following effects:

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None			

FIRST BENEFITTING PROJECT: Space Shuttle

APPROACH (CONCLUDED):

- o Thrust loss (gain) by gimballing the engines away from their nominal condition.
- o Thrust loss due to drag caused by deflecting aerodynamic surfaces.
- o Excessive hinge moments on aerodynamic surfaces.
- o Large movement of the actuators for trim which hampers the flexibility needed for dynamic response.

The inclusion of a performance criterion in the problem formulation results in an optimization problem with equality constraints to be solved for the trim solution. This formulation eliminates the uniqueness problem but the control engineer is still faced with the problem of explicitly solving the equations for the trim solution. Furthermore, the control engineer is likely to want to perform the trim computations many times in order to consider changes in the following:

- o Flight regime (dynamic pressure)
- o Desired trim conditions

In general, a feedback control system would be used to damp out perturbations about trim. Prior to designing the feedback control system, the control engineer is interested in determining if the vehicle has sufficient dynamic control authority after the trim conditions have been achieved. An approach based on the controllability matrix is proposed for determining the "energy" expended by the controls in damping out errors from the trim conditions.

To examine these various facets of the control problem, the following developmental phases have been undertaken:

Phase I. Generate the means of solving the trim problem when a performance index is specified. A representative shuttle model for the lateral directional control during ascent will be used to test the methods.

Phase II. Investigate the controllability and dynamic response of the system about its trim solution. Because the system is not unique, changing the performance index changes the trim solution. This part of the study will develop means of estimating how a particular trim solution influences the control authority and the dynamic response of the system. Phase II investigations will be performed with the dynamical model of Phase I with computer modifications as necessary to support this phase of the study.

STATUS: Technical Progress: Theoretical work in Phase II has developed techniques that appear promising as means of answering the questions posed in this part of the study. In order to determine the amount of control authority remaining about any given trim solution, the control Grammian is computed,and may be used as a convenient measure for determining the relative effectiveness of each control effect or about a given trim solution. Computer techniques have been developed to calculate the control

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STATUS (CONCLUDED): Grammian. The dynamic response investigation involves generating a closed loop optimum controller upon which a simulation of the closed loop performance will be performed, and movements of the control variables observed for various disturbances. A correlation of the optimum control approach for complete state feedback and quadratic performance criterion to the trim control approach has been obtained. This correlation relates the optimum steady state control value to the trim solution. Computer simulations will be used to check the validity of such a concept.

Management Progress: The principal investigator on this contract has been absent because of a jury duty requirement. Therefore, the period of performance of the contract has been extended on a no-cost basis.

Conclusions: None

Problems: None

Forecasts: None

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4. TITLE:

Guidance and Navigation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. L. Wyman, S&E-ASTR-R	205 453-3770	J. C. Taylor

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Laser Rendezvous and Docking Component Improvement - GaAs Lasers (908-52-10-05)
Beam Steerer (908-52-10-06)
NAS8-26846, Development, Fabrication, Testing and Delivery of Improved Beam Steering Devices, GT&E
NAS8-11974, Coherent GaAs Arrays, IBM

OBJECTIVE: To develop critical components of a scanning laser radar for rendezvous and docking assuring availability for Shuttle, Tug and future mission hardware. Specifically the two items under development are the source, a diffraction limited GaAs laser, and a beam steerer used for scanning the laser beam, eliminating or reducing the necessity for gimbals.

APPROACH: The beam steerer has been under development for a number of years. This activity is explicitly to space qualify the device and to improve accuracy and linearity.

The GaAs laser will undergo further development to verify the basic design concept and to undergo preliminary environmental testing.

STATUS: Technical Progress: Both contracts are complete. All requirements have been fulfilled and this effort is closed. Final reports have been received.

The beam steerers enable deflection of a .1 degree beam over a 30^{o} X 30^{o} field, i.e., 300 spots with an accuracy of one part in 1500, and deflection rates up to 1300 Hz.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
July 1972	High Radiance Room-Temperature GaAs Laser with Controlled Radiation in a Single Transverse Mode	Elisabeth M. Phillip-Rutz IBM	
March 1973	Manufacturing Drawing and Test Procedures PBM Beam Steerers	GT&E Laboratories	
April 1973	Design, Fabrication and Testing and Delivery of Improved Beam Steering Devices	GT&E Laboratories	

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The GaAs laser demonstrated diffraction limited performance, 10 kHz pulse rate, 30 ms pulse width, average power about 1 mW.

One model of the lasers cavity has been loaned to IBM for them to pursue investigations of diffraction limited arrays and use of single and double heterostructure diodes. These activities hold promise of diodes with two to three orders of magnitude more power, which would greatly increase the versatility of scanning laser radars using this type laser as a source.

Management Progress: Effort complete, all requirements fulfilled and closed out. This is the final progress report to be written on this task.

Conclusions: Devices have been developed for use in a scanning laser radar. The radar design exists, a prototype exists. Using these devices with this radar design, automatic rendezvous and docking can be performed for virtually any cooperative vehicle.

Problems: None

Forecast: None

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4. TITLE:

Guidance and Navigation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. R. Kissel - S&E-ASTR-GDA	453-4276	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Strapdown System Development and Field Test
NAS8-27335 TRW, Inc.

OBJECTIVE(S): To develop concepts for checkout, failure detection, failure isolation and correction, and redundancy management in a redundant sensor strapdown system.

APPROACH: Residual hardware was used to assemble a prototype redundant (dodecahedron) sensor strapdown system. This system will be used to test the redundancy management concepts and demonstrate the failure detection and isolation schemes. Testing includes van tests, rate tests and g-sensitive drift tests. Demonstration occurs when the concepts are being tested.

STATUS: Technical Progress--The strapdown system is operational and functioning satisfactorily with its test console. Preliminary work was started on debugging the calibration and navigation computer programs. The system is now inactive. The TRW study has been completed and a final report published on schedule.

Management Progress--The TRW contract was concluded on schedule.

Conclusions--Two of the seven simulated FDIC methods were consistently better performers than the rest. These were the minimax and the squared error methods, both products of MIT personnel.

Problems--Due to reduced in-house contractor support and other higher priority programs, all tests have been suspended. Also the software development work in-house has been suspended. All remaining FY73 funds were expended on the TRW contract.

Forecast--Complete software development to perform navigation (SEE PAGE 2)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
18313-6004-RU-00	Competitive Evaluation of Failure Detection algorithms for Strapdown Redundant Inertial Instruments.	James Wilcox	April 1973

FIRST BENEFITING PROJECT: Shuttle

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and calibration routines and also incorporate the most desirable FDIC scheme from the TRW study effort.

Perform laboratory and field tests on the completed system and analyze the test data.

Publications--"Competitive Evaluation of Failure Detection Algorithms for Strapdown Redundant Inertial Instruments." Final Report, April 1973. TRW Report No. 18313-6004-RU-00.

Remarks--The results of the TRW work were presented by TRW at the AIAA Guidance and Control Conference held in Key Biscayne, Florida on Aug. 20, 1973.

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4. TITLE:
Shuttle System Studies and Hardware Investigations

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. W. Brown/R. Evans	453-4583/ -1572	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Objectives:

a. Establishment of the Avionics On-board Checkout and Redundancy Management System configuration and requirements for the Space Shuttle that accomplish preflight, flight, and post-flight checkout and redundancy management concepts.

b. Development of test methods and acceptance criteria to be used in an electromagnetic interference specification suitable for modern space equipment.

Approach:

This program is being conducted under the following two separate tasks:

a. Inertial Measuring Unit Checkout

b. Electromagnetic Interference Specification

Status: See individual tasks.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

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4. TITLE:

Shuttle System Studies and Hardware Investigations

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. E. Brown S&E-ASTR-SG	453-4583	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Inertial Measuring Unit Checkout
NAS 8-27624 Charles Stark Draper Laboratory, Inc., Cambridge, Mass.

OBJECTIVE(S): The efforts are directed toward establishment of the Avionics On-board Checkout and Redundancy Management System configuration and requirements for the Space Shuttle that accomplish preflight, flight, and post-flight checkout and redundancy management concepts. The studies will provide information that will be a part of the overall Space Shuttle data base from which the final avionics and vehicle specification requirements and design criteria will be derived.

APPROACH: The contractor will study and evaluate various on-board checkout, failure detection, isolation, and correction (OFDIC) concepts and determine their applicability to the Space Shuttle Inertial Measuring Unit (IMU) System. He will perform basic investigation of checkout parameters, sampling rates, limit checks, performance checks, and other features important to establishment of the IMU OFDIC configuration. From studies of OFDIC concepts and data from other Space Shuttle efforts, the contractor will define what parameters and concepts will be candidated for an IMU OFDIC subsystem.

From the above data, the contractor will finalize on a proposed IMU OFDIC system with recommendations. Included in the study will be the equipment requirements, experiments definition, software development and fabrication of hardware necessary to implement and demonstrate the proposed IMU OFDIC system.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Avionics Memo No. 73-12, MSFC Test Plan Development for Reporting Multiple IMU System Performance for Shuttle Application, R. McKern and D. Swanson, 4/4/73

Avionics Memo No. 73-15, Questions and Answers Relating to PIU, IU and KT-70 System, K. Vincent, 6/1/73

Avionics Memo No. 73-16, Modifications Required to Present KT-70 Auto Cal Program in Order to Obtain Three Additional Gyro Parameters, D. Swanson, 6/29/73

Avionics Memo No. 73-17, Multiple IMU System at NASA/MSFC, R. McKern, D. Swanson and M. Landey, 7/3/73

Avionics Memo No. 73-18, Multiple IMU System Final Requirements, M. Landey, 8/17/73

Avionics Memo No. 73-19, HP2116B/4πCP2 Interface for Test Data Acquisition in the Multiple KT-70 Demonstration System, R. Whittridge, 8/21/73

Avionics Memo No. 73-20, Failure of APS NASA Serial No. 003, M. Landey, 8/28/73

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STATUS (CONT'D): Technical Progress -- Studies required to support the milestone charts for this reporting period have been initiated. Revised schedules are presented on the milestone charts.

Subtask II Item 4 -- The redundancy and checkout system demonstration test plan has been revised to reflect shuttle priorities and further revisions are expected as integrated system testing is performed.

Subtask III Item 3 -- The design and fabrication of interface hardware has been completed. The design was reviewed by NASA/MSFC and the fabricated interface hardware met its volume and weight requirements. Fabrication of all interface hardware except 2 of the 3 identical interface units (IU) was completed in May, 1973. Fabrication of the remaining two IUs were completed in July, 1973 after checkout of the first IU was completed.

Subtask III Item 4 -- The schedule has been revised to reflect the proposed contact extension that Draper will request in early October, 1973. The integration and checkout of hardware was complete the latter part of September, 1973. The integration of software and hardware will begin in October, 1973. All software except the calibration program has been checked out on an 4πCP-2 computer simulator. The calibration program was not checked out on the simulator since the calibration program would require too much simulator time. The 4πCP-2 computer is the computer that will be used in the demonstration tests to be conducted at NASA/MSFC.

Subtask IV Item 1 -- All government furnished software has been delivered. The Government Furnished Calibration Program Software was a late delivery.

Subtask IV Item 3 -- The failure detection, isolation and redundancy management software has been checked out on a 4πCP-2 computer simulator.

Subtask IV Item 4 -- NASA/MSFC and Draper Laboratory agreed that the prelaunch routines functions would be satisfied by the calibration program for demonstration test purposes and that no further efforts should be expended on this item.

Management Progress -- A change order to the contract was issued in July, 1973 to change the contractor from MIT to Charles Stark Draper Laboratory, Inc. (CSDL) since CSDL divested from MIT. CSDL in May, 1973 submitted a proposal requesting additional funds and a contract extension until September 30, 1973 due to late delivery of government furnished software. Shuttle Project Resources were used to fund the proposal. This is the last progress report under the RTOP reporting system since Shuttle Project Funds are being used to continue the study.

Conclusions -- The contract will not be completed by September 30, 1973. Verification of the integrated hardware has been completed. The verification of the integrated hardware and software will begin on October 1, 1973 and will be completed the latter part of November, 1973. Based on a detailed schedule of activities for October and November, 1973 (presented to NASA/MSFC on September 27, 1973), status of software checkout, manpower allotments and documentation schedules the objectives of the contract will be obtained.

Problems -- Failures in the Government Furnished Equipment (GFE) and unforeseen technical problems in verification of the integrated hardware has caused a delay in the September 30, 1973 completion of the contract. The failed GFE is being repaired. NASA/JSC has loaned NASA/MSFC IMU parts which has enabled CSDL to continue working on the contract

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STATUS (CONCLUDED):

while the GFE is being repaired. From August 10, 1973 to September 24, 1973 GFE failures cause a loss in verification time of all but nine days. The milestone charts presents the schedules being submitted by CSDL in a proposed contract extension.

Forecast -- The Shuttle Project has been requested to make available resources to fund the proposal CSDL will submit in earlier October, 1973.

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7. Reports (CONCLUDED):

Avionics Memo No. 73-21, KT-70 Error Parameter Stability, M. Landey and D. Swanson, 8/29/73

Avionics Memo No. 73-22, Failure and Replacement of KT-70 IMU NASA No. 003, M. Landey, 9/7/73

Avionics Memo No. 73-23. Failure of APS NASA Serial No. 001, M. Landey, 9/24/73

A paper entitled "Failure Detection and Isolation of Redundant Inertial Systems for Space Shuttle" By H. Brown of NASA, R. McKern and D. Dove of MIT was presented in Genoa, Italy, to the Fifth IFAC Symposium (Automatic Control in Space) in June, 1973

A paper entitled "Redundancy Management of Inertial Systems" By R. McKern and H. Musoff was presented in Key Biscayne, Fla., to the Guidance and Control Conference of AIAA in August, 1973.

Monthly Progress Reports

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MSFC	01-04-73 to 30-09-73	908-52-18	908-52-18

4. TITLE:

Shuttle System Studies and Hardware Investigations

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. Evans S&E-ASTR-SC	453-1572	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Electromagnetic Interference Specification
In-House

OBJECTIVE: The objective of this effort is to develop test methods and acceptance criteria to be used in an electromagnetic interference specification suitable for modern space equipment.

APPROACH: Conduct an in-house study to determine the types of tests required, the best methods of performing these tests, and a reasonable acceptance criteria for each test. Various test fixtures and equipment will be procured in order to evaluate and perfect each new test method.

STATUS: A line impedance measuring method utilizing a pair of current transformer probes was devised for determining the series impedance of inductive power lines without making a direct connection to the line. The impedance response to a swept frequency signal source was displayed on a CRT for direct viewing. The technique may be utilized to determine RF conducted susceptibility as a product of current squared times line impedance rather than in terms of a voltage level which does not take line impedance into effect.

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FIRST BENEFITTING PROJECT: SHUTTLE

MSFC - Form 860 (March 1978)

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The measurement of voltage induced on to signal lines as a function of frequency was accomplished for different line lengths using a standard line coupling test fixture. Prediction of theoretical signal levels due to line coupling was within 6DB of measured data for signal wavelengths equal to or greater than sixteen times the line length used. This method may be used to predict susceptibility levels on power and signal lines which are placed in close proximity to CW signal generating sources.

The magnitude and waveform of transient voltage induced on to signal lines of varying lengths by means of switching relay and capacitor loads located in close proximity to the signal line was measured. A standard line coupling test fixture was utilized and susceptibility to transient generation was noted. Susceptibility was also measured using a pulse generator as a transient generator. The effects of transient rise time and pulse rate on line interference magnitudes was investigated.

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4. TITLE:

Shuttle Systems Studies and Hardware Investigation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL
Isaac B. Moore S&E-QUAL-PIR	453-1400	P. M. Hughes, Jr., S&E-QUAL-P

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Electromagnetic Compatibility Test Equipment

OBJECTIVE: To develop solid-state, automatic, electromagnetic test equipment for electromagnetic compatibility (EMC) tests on Shuttle.

APPROACH: The approach is to procure state-of-the-art solid-state electronically tuned receivers and integrate them into a high-speed computer controlled radio frequency (RF) automatic receiving and measuring system suitable for determining the RF spectrum from 14 KHz to 18 GHz.

The task is divided into three phases: (1) to procure 1 GHz to 18 GHz receivers, (2) to procure 14 KHz to 1 GHz receivers and, (3) to integrate receivers into a system.

STATUS: Technical Progress:

The 1 GHz to 18 GHz receivers obtained from Varian-Ryka Corporation, Sunnyvale, California, under Contract NAS 8-29000 were tested and verified to be in compliance with the contract specifications.

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Management Progress:

A proposal was made for sufficient funds to procure the 14 KHz to 1 GHz receivers (Phase II) and to integrate the receivers into a system (Phase III) under RTOP 976-30-01. The proposed RTOP was disapproved. Therefore, no further action is planned at this time.

Conclusions:

The 1 GHz to 18 GHz receivers met all specifications and satisfied Phase I of this task. Phases II and III could not be implemented due to lack of funds under this RTOP. Additional funds to complete Phases II and III were requested under RTOP No. 976-30-01. The funds were disapproved. The receivers will be retained in an inactive status until they are needed on a program that can provide sufficient funds to complete the effort.

No further reports will be made under this task.

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4. TITLE:

Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN W. E. Hill	3-1223	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Polyoxadiazoles for Structural Adhesive Applications

OBJECTIVE(S): To develop adhesive systems for structural applications at temperatures of 350°F for up to 200 hours.

APPROACH: Polyoxadiazoles based upon silicone containing monomers are being synthesized for evaluation of thermal and physical properties. Included in the high temperature screening program are experimental formulations obtained from outside sources.

STATUS: Technical Progress--A silicon containing cross-linking agent, the triacylchloride of phenyl-tris-4-carboxyphenyl silane, has been synthesized for curing low molecular weight polyoxadiazoles. The triacylchloride has been incorporated into initial synthetic sequences for polyoxadiazoles and has been tested as a cross-linking agent with some success. Work on this program is not in progress at present and no further reports will be issued.

Management Progress--None

Conclusions--No fully acceptable system has been developed which is better than known available systems.

Problem--The silane and siloxane monomers are difficult to prepare and polymer systems prepared from these monomers are not consistent in quality and physical properties

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Reports: Report each quarter since 1971 included in overall MNM Progress Report.

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (CONCLUDED): Causes of Problems-- N/A

Suggested Solution-- N/A

Forecast--N/A

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4. TITLE:

Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN L. M. Thompson	3-1223	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: "Design and Development of Polyphenylene Oxide Foam as a Reusable Internal Insulation for LH_2 Tanks", NAS8-27566 with General Dynamics Corporation/Convair Division.

OBJECTIVE(S): To develop information on polyphenylene oxide (PPO) foam and other materials required for a minimum weight internal insulation system usable in LH_2 tanks to a maximum outer surface temperature of 350°F. This effort, shall define a preferred lightweight PPO foam internal insulation system that will not be adversely affected by launch, flight, reentry, and landing, and will be reusable for up to 100 flights with minimum refurbishment.

APPROACH: To meet the objectives the following 13 task areas shall be performed: (a) effect of thermal cycling on mechanical properties and dimensional and weight stability; (b) materials and process specifications; (c) tank surface preparation; (d) methods for close-outs; (e) fabrication techniques for PPO foam; (f) techniques for making joints; (g) repair procedures; (h) techniques for surface rigidization; (i) physical properties thermal correlation; (j) geometric properties of foam. The following 3 task areas were added in Modification No. 1: (k) configuration screening on PPO foam samples;(l) properties of two additional PPO foam configuration and (m) fabrication and evaluation of close-out design.

STATUS: Technical Progress--All necessary physical properties of 72 PPO foam panels have been determined. Close-out adhesives gave been evaluated and repair techniques are about 90% complete. Substrate preparation procedures are under study. A

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

REPORTS: 26 Monthly and 3 Phase reports have been issued.

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (CONCLUDED): 100 inch test tank internally insulated with the PPO foam has sucessfully passed 100 fill and drain cycles using liquid hydrogen on a NASA Houston contract. A no cost contract extension to March 31, 1974 was necessary in order to test new PPO samples made in a Pilot Plant facility by an automated process. These sample were originally scheluded for delivery in Feburary 1973 and are now expected December 1973. The supplier has experienced many problems with mixing,extruding and curing the samples in this new facility.

Management Progress--N/A

Conclusions--All available test results indicated that PPO foam is an acceptable material for certain tank insulations. All test data were obtained for internal use in liquid hydrogen.

Problem--Pilot Plant scale-up problems have caused an unavoidable delay in finishing this contract. These are hopefully being resolved.

Causes of Problems--The scale-up involved in going to a batch process to a pilot plant operation.

Suggested Solutions--Contract was extended to March 1974 to allow supplier time for problem solution.

Forecast--Scheluded completion date is March 31, 1974.

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4. TITLE:

Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
ASTN J. M. Stuckey	2-1222	R. J. Schwinghamer

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: In house effort on Multilayer Insulation (MLI) Materials

OBJECTIVE(S): To evaluate the potential of materials and material composites as cryogenic insulation in terms of thermal performance, ability to withstand expected environmental conditions, and reliability. Efforts are directed toward supporting both internal and contracted programs.

APPROACH: Materials potentially usable for cryogenic insulation systems are evaluated for mechanical and thermal properties over their usable temperature range. Material composites are subjected to expected environments, including an aging program at KSC where high performance insulation concepts are exposed to ambient conditions. Studies include normal cryogenic insulation materials as well as high performance insulation materials.

STATUS: Technical Progress--No additional progress has been made in this area due to concentration of effort on developing an insulation/thermal protection system for the External Tank of the Shuttle. Thermal performance testing on MLI specimens was discontinued due to the transfer of personnel. The MLI ambient aging program at KSC was discontinued at the last inspection in July 1973. No significant change was found in any of the samples since December, 1972. Data is being assemblied for a final report on this effort.

Management Progress--None

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FIRST BENEFITTING PROJECT: Skylab

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STATUS (CONCLUDED): Conclusions--This aging program has shown that short term interruptions of dry gas purges on MLI systems stored in KSC type environment will probably have little or no adverse effect if the entry of bulk moisture is presented. Efforts to date also show that MLI systems usable at 350°F will probably be heavier than MLI systems that have been used or proposed for use at lower external temperatures.

Problem--None

Causes of Problems--None

Suggested Solutions--None

Forecast--A final report will be issued on the MLI ambient aging program at KSC. Since no additional effort is planned this will be the last report on this program.

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4. TITLE:
SPACE SHUTTLE CRYOGENIC TECHNOLOGY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
George M. Young	453-3854	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Zero-G Fluid Retention and Expulsion

CONTRACT: NAS8-27685, McDonnell Douglas/Western Division

OBJECTIVES: The objectives of this task include study and definition of an acquisition system for supplying LH_2 and LO_2 under in-orbit conditions. To provide specifics for the study, the following two design reference missions were identified: (a) cryogenic auxiliary propulsion system (APS) and (b) main propulsion for an Advanced Spacecraft Propulsion Module (ASPM). The ASPM requirements are representative of a vehicle such as the Space Tug. This effort concentrates on concepts that utilize the favorable surface tension characteristics of fine-mesh screens and will significantly advance cryogenic acquisition technology in general. The anticipated analytical and experimental results will provide a sound technology base for the subsequent design of cryogen supply subsystems for future space vehicles.

APPROACH: Phase I establishes parameters and component problem areas that should control acquisition system design and includes trade studies of variables influencing acquisition system design and interfaces with other systems. Phase II provides a design to meet each of the reference missions. Bench tests necessary to the design phase will be conducted. Based on these two designs, a ground test article(s) will be designed to demonstrate operational principles and hardware fabrication. Phase III will consist of fabrication of the test article(s) designed in Phase II. Phase IV will consist of supplementary studies and bench tests which are desirable to support the designs generated or to evaluate potential problem areas associated with the design.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MDC-G2562	"Study and Design of a Cryogenic Propellant Acquisition System" First Quarterly Report	G. W. Burge P. L. Klevatt	Oct 15, 1971
MDC-G2743	Second Quarterly Report	G. W. Burge P. L. Klevatt	Jan 15, 1972
MDC-G2940	Third Quarterly Report	G. W. Burge P. L. Klevatt	Apr 15, 1972
MDC-G3695	Fourth Quarterly Report	G. W. Burge J. B. Blackmon	July 15, 1972
MDC-G4271	Fifth Quarterly Report	G. W. Burge J. B. Blackmon	Oct 15, 1972
MDC-G4354	Sixth Quarterly Report	G. W. Burge J. B. Blackmon	Jan 15, 1973

FIRST BENEFITING PROJECT: SPACE TUG

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 908-52-37 PAGE 2 OF 3

STATUS: Technical Progress: The analysis and design phases of the contract are complete. Bench tests to evaluate screen properties have been conducted. Some of the more important findings which resulted from the bench tests are:

- Frictional pressure losses are reduced by including a coarse screen spacer between fine screen and backup material.
- Fine mesh screens can be successfully attached to steel plate by welding.
- Pleating of screens can be used to decrease pressure drop.
- Screen bubble point is not affected by repeated deflections normal to the surface.
- Preliminary tests suggest that screen exposure to warm gas may severely degrade the bubble point characteristic in liquid hydrogen.
- Vibration normal to a screen surface may have a degrading effect on bubble point.

Fabrication of test articles is underway and is about 90% complete. Those supplementary studies dealing with propellant settling and thermal effects have been initiated.

Management Progress: A two month, no-cost extension to the period of performance was granted due to vendor delays in hardware delivery.

Conclusions: A refillable start tank concept was selected for each of the reference mission designs. The differences in size and mission requirements between the two reference missions dictated considerable differences in the detail designs. These designs are illustrated and discussed in the quarterly reports.

Problems: No significant problems are anticipated.

Cause of Problem: N/A

Problem Solution: N/A

Forecast: Contract completion in 4th quarter of CY 73.

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4. TITLE:

SPACE SHUTTLE CRYOGENIC TECHNOLOGY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. Pratt	453-3854	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Feedline Geyser Suppression

CONTRACT: NAS8-29079, Martin Marietta Corp., Denver, CO

OBJECTIVES: Update existing geyser suppression technology to include non-vertical segments near the top and bottom of otherwise vertical lines. The existing feedline geyser correlation was developed for straight vertical lines. This effort considered complex feedline configurations with bends and angled line lengths.

APPROACH: Using subscale experimental hardware, evaluate line geometries applicable to Space Shuttle main propulsion system. Determine criteria for geyser suppression in non-vertical lines using existing correlation parameters such as heat flux, length-to-diameter ratio, and fluid properties. The test fluids were H_2O and LN_2.

STATUS: Technical Progress: The program has been completed and a feedline correlation has been developed for feedlines having complex configurations with various heat loads and contained fluids. This correlation differs from other approaches by considering the angled line segments of a feedline configuration.

Management Progress: The contract has been completed in a timely manner without any cost overrun.

Conclusions: This was a successful test program in which the objectives

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MCR-73-20	"Geyser Characteristics of Feedline Configurations Having both Vertical and Non-Vertical Sections"	T. J. Pharo J. E. Anderson C. S. Foster	March 1973

FIRST BENEFITING PROJECT: SPACE SHUTTLE

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were satisfied. There is additional effort which may be completed to expand the geyser correlation developed to include different cryogenic fluids, tank pressure cycles, and feedline materials.

Problems: None

Cause of Problem: None

Problem Solution: None

Forecast: None

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4. TITLE:

Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. Neill Myers	453-5707	G. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Develop "Zero Leakage" Separable and Semipermanent Ducting Joints NAS8-28159 Wilpac Manufacturing Co., El Cajon, Calif.

Objective: Develop engineering data and designs for zero leakage joints in two to 20-inch sizes for cryogenic and noncryogenic media. Produce reliable interconnect components for long-life and high reliability and an engineering handbook for applying developed design to specific joints.

Approach: Task I-Conduct literature search and select a number of candidate duct designs. Task II-Determine optimum design, prepare drawings, and fabricate ducting joint. Task III-Perform development testing, analyze results, prepare report and handbook.

Status: Task I-The literature search revealed that most work in the past was directed at the seal itself rather than the joint. Concepts that it was felt would show an overall joint improvement were concentrated on. Ten joint designs were submitted. Task II-One of the ten joint designs was selected for detailed study and test. This was a low profile flange design with a toggle action seal. This design incorporates the following advantages: Low sealing forces, protected sealing edges, compact, accept reasonable deflections prior to loss of seal, and low overhang. Further progress consisting of analysis with subsequent preparation of documentation was stagnant. Extension of the contract was not granted. A final report was then submitted which contained the material already submitted in Task I plus a brief stress analysis of the candidate joint seal.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Report	"Zero Leakage" Separable and Semipermanent Ducting Joints	H.T. Mischel Solar	May 72
Task I Prog. Report	"	"	Sept. 72
Task II Interim prog. Report	"	H.T. Mischel Wilpac Mfg. Co.	Apr. 73
Final Report	"	"	July 73

First Benefitting Project: Space Shuttle Ducting

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Work not Completed: Task II-A detailed analytical analysis of the design was to have been performed. Detailed drawings of the design were to have been submitted and the joint design was to have been fabricated. Task III-Development testing of the joint to determine its capabilities and limitations was to have been performed. The test results were to have been recorded, analyzed, and submitted. A final report containing all results and data was to have been submitted and a handbook was to have been prepared that could be used in designing specific joints of the type analyzed.

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Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. E. Engler, S&E-ASTN-ES	453-4050	G. A. Krol1

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Evaluation of Beryllium for Space Shuttle Components
NAS8-27739, Lockheed Missiles and Space Company

OBJECTIVE(S): To evaluate the potential for reduced structural weight by the use of beryllium in primary structure subjected to a flyback booster environment and to compare the lower cost beryllium structure to the comparable composite structures developed under other contracts.

APPROACH: The program was conducted in five separate overlapping phases. The first phase, Materials Evaluation, was based on the need for data at room and elevated temperatures for material claimed by the suppliers to be more ductile than what had been previously marketed. The second phase involved the development of design curves, i.e., buckling, post buckling, and crippling curves at room and 600° F., based on data obtained in phase I. The curves generated in phase II were used to design and analyze selected structural components, a concentrated load panel, a uniform load panel, a truss beam, and a shear beam. This work led to phase III, the development of a process technology plan and phase IV, the fabrication of a uniform and a concentrated load compression panel. Limited funds precluded fabrication of the beams. Finally the fabricated structures were to be structurally tested, and the results recorded in phase V. It was then anticipated that these results would be compared to those obtained from the testing of geometrically identical composite structures.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-D159319	Final Report for Evaluation of Beryllium for Space Shuttle Components	A.E. Trapp Program Mgr.	Sept. 30, 1972

MSFC - Form 350 (March 1973)

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STATUS: The contract was completed with the publication of the final report. The results originally planned were compromised when quotes were received greatly in excess of the available funds. Since thin gage beryllium (.01 thru .040) costs greatly exceeded the original estimates, an abbreviated scope of work was prepared omitting much of the materials testing and fabrication of structural specimens. A decision to fabricate only subscale and full-scale components of the compression panels followed. The subscale panels were tested by the controller, and excellent agreement between measured and predicted results were obtained. The testing of the full-scale panels was to be done in-house. Unfortunately, program priorities changed with the decision to eliminate the flyback booster, and consequently no results were obtained on the full-scale panels.

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Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. A. Hein	3-5706	G. A. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract NAS8-27504, Convair Division, Gen. Dynamics, San Diego, CA

TASK: Vacuum Jacketed Ducting Technology Investigation

OBJECTIVES: Improved vacuum jacketed ducting for space environment at liquid hydrogen temperature to provide minimum heat transfer, weight, and space envelope for 100 missions at 4 1/2 minutes per mission.

APPROACH: Two duct systems to be fabricated and tested: One state-of-the-art and one advanced design duct system for comparative testing; investigate heat cure adhesives for core reinforcement; investigate potting compound for stiffening honeycomb end structures.

STATUS: The state-of-the-art duct system has been fabricated and is being tested; a base duct segment of the advanced duct design has been completed,and tests will be completed in October; stress analysis is being conducted by Arrowhead on the advanced duct design ball-strut gimbal prior to fabrication; HT424, type II (foam-in-place) adhesive has been selected over the type I, HT424, a viscous adhesive, difficult to apply; potting compound for stiffening end structures was found to create high stress concentrations and abandoned except as a sealant; the advanced design duct system segment fabrications are scheduled for completion in December.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Monthly/Quarterly Reports	"Vacuum Jacketed Ducting Technology Investigation"	K. Leonhard, Gen. Dynamics, San Diego, CA	Jun 1971 Sept 1973
Interim Report #CASD-NAS 73-002	"	"	Jun 1973

First Benefiting Project: Shuttle Feedlines

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Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Kenneth G. Anthony	453-5701	G. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Long Life Valve Design Concepts
Fairchild Industries, Stratos Division, Manhattan Beach, CA
NAS8-28518

Objective: The purpose of this program is to develop fluid control component designs for use under conditions where long life and ability to withstand extreme environments are requirements. Operating life of 10 years with temperature extremes of +200°F to -423°F are the design goals.

Approach: Areas to be considered are analysis to determine vulnerable subassemblies, establishment of design criteria to preclude vulnerability, conceptual design of subassemblies, and breadboard development verification testing to confirm design criteria.
The effort shall consist of the following tasks:

a. Analysis and design criteria preparation.
b. Conceptual design.
c. Manufacture and perform breadboard testing.
d. Confirm and publish design criteria.

Status: Manufacturing is nearing completion and testing expected to begin by December 1.

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Monthly Reports	Progress Reports	J. R. Jones	Monthly

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Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. B. Wynn	453-3921	G. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Life Test Methodology
NAS8-27438 Battelle Memorial Institute, Columbus, Ohio

OBJECTIVE(S): Develop a methodology that permits ultimate component life assessment and/or verification for long-life Space Shuttle application.

APPROACH: Literature survey, establish environments imposed by extended space missions and determine environments affecting long-life components, establish most critical failure areas and determine wear and creep characteristics. Establish accelerated test program. Verify accelerated test program.

STATUS: Contract awarded on June 25, 1971, to Battelle Memorial Institute. Propulsion components and literature have been reviewed. Earth and Orbital environments established. Analyze aging on propulsion mechanical components. Creep and wear on nonmetallic parts are life limiting. Developed tests to determine wear and creeps characteristics. During next 3 to 4 months, perform tests to prove the long life of the components.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Interim Report	Development of Life-Test Methodology for Long-Life Mechanical Components Phase I: Development of Methodology	D. B. Hamilton et. al.	July 31, 1973

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Space Shuttle Cryogenic Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. Veitch, S&E-ASTN-EME	3-3925	G. A. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract NAS8-21133, Southwest Research Institute, San Antonio, Tex

TASK: Minimize Pressure Loss in Ducting Components and Flow Induced Vibration in Bellows.

OBJECTIVES: Provide design handbook which will include criteria for minimizing pressure loss in bends and bellows components; and mathematical procedures for performing design analysis on any annularly convoluted bellows for susceptibility to fatigue failure from flow induced vibration.

APPROACH: Investigate flow characteristics in bends and bellows; determine mechanism causing flow induced vibration in bellows; determine force equation; investigate factors influencing degree of bellows deflection and frequency, such as media, upstream bends, pressure and bellows convolute geometry; instrument test bellows with strain gages and perform static deflections for bellows spring rate and force-strain data; conduct resonant flow tests on a variety of bellows configurations with water, liquid and gaseous nitrogen, and Freon as media; determine effects of acoustic velocity on bellows; perform resonant flow tests on instrumented bellows to failure.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Monthly/Quarterly	"Minimum Pressure Loss in High Velocity Duct Systems"	C.R. Gerlach, Southwest Research Institute	Jun 67 - Jan 73
Int. Report #1	"	"	Jul 69
Int. Report #2	"Flow Induced Vibration of Bellows with Cryogenic Fluid Flow"	"	Aug 70
Presentation MSFC-Contractors/ Saturn	"Bellows Flow Induced Vibration"	"	Jun 68
Final Report	"Bellows Flow Induced Vibration and Pressure Loss"	"	Apr 73

Benefiting Projects: Sat IB/V - Provided mathematical procedures in determining conditions of failure in the following cases:

- J-2 Engine ASI flex hose failure (AS 502 flight)
- SII Prepressurization flex hose failure
- S-IVB Lox feedline gimbal failure (J-2S flow)

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STATUS: Final report (handbook release April 1973. Objectives met. Handbook provides evaluation of current bellows pressure drop equations; low pressure drop bend design criteria; evaluation of current spring rate equations for bellows; bellows liner designs mathematical procedures for determining flow induced vibration frequencies and stress levels in a bellows design; stress/cycle life curve for determining fatigue life of a particular bellows design; computer program structure for quick computation of bellows mode frequencies, lock-in range and stress values.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	908-52-39*	908-52-39

4. TITLE:

Aerothermodynamics I

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AAE Josh D. Johnson	205-453-2512	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Tasks: Water Impact Tests of Solid Rocket Motor Booster Models,
NAS 8-28985: Chrysler Corporation Space Division, New Orleans, LA 70129

Hydrodynamic Testing and Model Hardware Design for Space Shuttle Water Impact Tests,
H-92132A: U. S. Naval Ordnance Laboratory, Silver Spring, MD 20910

OBJECTIVE: Provide part of the water impact data that will serve as a data base to be used to design the solid rocket booster (SRB) structure and the SRB recovery system. Specific parameters to be investigated are pressure scaling effects, vertical impact velocity, and impact attitude. Horizontal drift velocity will not be investigated and only tail-first entry will be considered.

APPROACH: This will be a continuation of work that was initiated with other funds; therefore, an existing 0.08 scale will be modified for use in the tests. This model will be dropped into water at the U. S. Naval Ordnance Laboratory (NOL) Hydroballistics Tank. Accelerometers will be used to record total model impact loads and pressure transducers will be used to record local loads. High speed motion picture cameras will be used to record visual impact phenomena. Tests will be performed with ambient tank pressures and with reduced tank pressures.

Chrysler Corporation Space Division personnel will prepare for and perform the required water impact tests. They will also analyze the resulting data and prepare a test report. NOL will provide the test facility; NOL personnel will help prepare the test models and they will help perform the tests.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Northrop Services, Inc. M-230-1192	Test Results for Space Shuttle Booster Pressure Scaled Water Impact Tests (0.08 Scale Model)	W. F. Braddock	January, 1973

FIRST BENEFITING PROJECT: Space Shuttle

*Jointly funded by 908-52-70, 908-52-87, and 976-30-40

PROGRESS REPORT
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STATUS:

Technical Progress - Tests of an uninstrumented model were performed during October 1972. Results of the tests showed that, for vertical entry with an impact velocity that simulated a full scale impact velocity of 60 feet per second, the penetration depth was approximately one diameter deeper for tests with ambient atmospheric pressure. Results also showed that, for entry angles 30 degrees of vertical, the maximum penetration depth did not change when the atmospheric pressure was changed. One interesting result was that, for scaled atmospheric pressure, after each test the model floated in a vertical attitude. In contrast, after tests with ambient atmospheric pressure the model floated in an almost horizontal attitude.

Tests with an instrumented model were performed during February 1973. The model was instrumented with nine accelerometers and thirty-four pressure transducers. Data from these tests are currently being analyzed and CCSD will have a report completed by October 24, 1973.

Managment Progress - None

Conclusions - Under certain conditions, pressure scaling does effect impact penetration depths and floatation attitude after impact.

Problems - Test data were recorded on analog tapes. These tapes had to be digitized before the data could be analyzed. The MSFC Computation Laboratory agreed to digitize the data; however, the digitizing process took approximately four months to complete. Therefore, data analysis was delayed several months.

Causes of Problem - Computation Laboratory personnel stated that higher priority Skylab and Space Shuttle work caused the delay.

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4. TITLE:

Aerothermodynamics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AT Homer B. Wilson, Jr.	205-453-1163	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Ascent Base Heating Technology Study
NAS8-27090, Calspan Corporation
P. O. Box 235
Buffalo, New York 14221

OBJECTIVE(S): To develop new and improved capability for conducting short-duration Space Shuttle base heating tests. New instrumentation and methods of measuring heating rate are desired and an improved simulation of the orbiter engines and external flow will be required for the Space Shuttle.

APPROACH: New instrumentation capable of measuring gas temperature and other flow properties will be selected and evaluated by tests in typical base heating flow conditions. External flow simulation will be improved by extending the pressure temperature and Mach number range of the present facility.

STATUS: - Technical Progress - A hot wire resistance thermometer has been found through analyses to be potentially capable of measuring base gas temperature. Tests are planned to further prove this technique. The external flow facility is being modified to provide longer flow times (up to one-tenth second) and an external flow temperature up to 600 °F. Two new nozzles providing test section Mach numbers of 3.5 and 4.5 have been designed. These nozzles are being fabricated with funds provided by the Shuttle program. All of the results of this contract will be used in the Shuttle launch vehicle base heating tests being conducted by Rockwell International beginning in November.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (CONCLUDED)

Management Progress - This contract was modified September 13, 1973, to provide $47.7 K for nozzle fabrication.

Conclusions - None

Problems - None

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4. TITLE:

Aerothermodynamics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AAE Paul E. Ramsey	205-453-2517	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Experimental Aerodynamic Studies of Space Shuttle Concepts
H-74005A: Naval Ship Research & Development Center, Washington, D. C. 20034
NAS8-26701: Calspan Corporation, Buffalo, N.Y.

OBJECTIVE: Provide experimental, wind tunnel, static stability, drag, and control test data to support aerodynamic studies of Space Shuttle concepts in the subsonic/transonic regimes. The major study area of interest are launch vehicle ascent, booster reentry, and range safety areodynamics. Data obtained will be utilized to provide solutions to Space Shuttle aerodynamic problems which will enable efficient design of launch and booster configurations. Specific problems are: (1) Launch vehicle performance optimization while maintaining acceptable stability and control margins during ascent, orbiter position on booster, effectiveness of aerodynamic control during launch, geometrical shaping such as nose cone configuration and booster length to diameter ratio, drag reduction, booster engine locations, Reynolds number effects on static stability and control effectiveness, and interference loads on the launch vehicle components. (2) Booster reentry aerodynamics needed for recovery of booster components and high alpha aerodynamics for range safety.

APPROACH: The current Rockwell orbiter, external tank, and parallel burn SRB booster, will be used as the baseline configuration. The above problem areas will be studied experimentally in facilities supplied under contracts listed above on large scale models (1 to 1.5 percent) supplied by MSFC. During these studies, both pressure and force tests will be conducted to obtain loads data and static stability force data.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
HREC-6370-1 LMSC/HREC D225587	Interim Results of Parametric Studies of Space Shuttle Booster and Orbiter Concepts	Dale Bradley	May 4, 1972
HREC-6370-2 LMSC/HREC TR D306346	Summary of Results of Parametric Studies of Space Shuttle Booster, Orbiter, & Launch Vehicle Concepts	Dale Bradley Robert E. Buchholz	N/A

FIRST BENEFITING PROJECT: Space Shuttle

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APPROACH (CONCLUDED):
Facilities intended to be used are the Calspan 8-foot transonic and the NSRDC 7- x 10-foot transonic tunnels.

STATUS:

Technical Progress - All Shuttle investigations conducted in the Calspan and NSRDC facilities listed have been documented and the results summarized in the reports listed above. A base drag reduction study was conducted on a Shuttle booster concept in the Calspan 8-foot TWT. The methods used to attempt to reduce base drag were: (1) Base flaps were used to induce free stream air into the base region. (2) A vented base was employed to open the base region to free stream air. (3) Air was blown into base region. None of these methods were particularly successful in reducing base axial force. There was very little or no change for the base flap or base vent methods and a slight drag increase for the blown base method. The blowing base was unsuccessful because the nozzles were too localized and the flow velocity too high. Several tests were conducted in the NSRDC facility during the duration of this RTOP to study configuration geometry and engine location effects on static stability, control effectiveness and drag of a Shuttle booster. The results of these test programs are too extensive to mention here, but are discussed in past RTOP reports and above listed reports. These technology results on cruise stability and performance are currently being utilized by Rockwell International in definition of the orbiter ferry configuration. Plans to conduct large scale force and pressure tests on the latest SRB configuration at high alpha for reentry and recovery analysis have been delayed until small scale tests in the MSFC 14-inch TWT are completed and the configuration evolution becomes relatively stable.

Management Progress - None

Conclusions - None

Problems - Because of the procurement lead time of test model hardware for large wind tunnels and rapid Shuttle configuration changes, it has been difficult to form firm plans for conducting tests in the above facilities.

Causes of Problems - Long procurement time for large wind tunnel models and Shuttle configuration not yet stable.

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4. TITLE:

Aerothermodynamics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF John D. Warmbrod	205-453-0170	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Booster Aerodynamics Heating Test Support
NAS8-28115, Remtech, Inc.
2603 Artie Street, Suite 21
Huntsville, Alabama 35805

OBJECTIVE(S): To supplement the Space Shuttle contractor Shuttle aerodynamic heating work in the following important areas: (1) Aerodynamic heating test support, (2) develop rarefied flow regime heating rate correlations.

APPROACH: Provide engineering support for the formulation and conduct of experimental aerodynamic heating programs. Collect and correlate rarefied flow heating data for simple geometries (stagnation point, cones, cylinders, flat plates). Modify aeroheating program MINIVER to include the rarefied flow heating correlations that were developed.

STATUS: Technical Progress - Aerodynamic heating test on the MSC 049-2/156" Shuttle launch configuration was completed. Heat transfer data on the ET and SRB for the launch configuration were collected. These data were used by RI and MSFC to predict preliminary design flight thermal environments. Development of rarefied flow regime heating correlations for simple geometries has been completed and these correlations have been incorporated in the computer program MINIVER. Shuttle configuration data in the rarefied flow regime will be incorporated in these correlations later this year.

Management Progress - None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Remtech RTR 008-2	Aeroheating Correlations for Noncontinuum Hypersonic Flight	Dr. Carl D. Engle	N/A
Remtech RTR 008-5	MINIVER Computer Program Modification for Rarefied Flow Aeroheating	Dr. Carl D. Engle	N/A

FIRST BENEFITING PROJECT: Space Shuttle

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STATUS (CONCLUDED)

Conclusions - Currently RI and MSFC are using boundary layer concepts to generate thermal environments on Shuttle configurations. Preliminary results show that heating rates for certain areas on the ET are significantly increased using the developed methods for the rarefied flow regime. The impact on the ET Thermal Protection System (TPS) due to these increased heating rates could result in additional TPS weight. This effect is being investigated.

Problems - None

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	908-52-40	908-52-40

4. TITLE:

Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Jess H. Jones	205-453-0176	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Theoretical/Analytical Investigation of Critical Acoustic Environmental Trends During Space Shuttle Flight
NAS8-26919, Wyle Laboratories, Huntsville, Alabama

OBJECTIVE: The primary objective of this effort is to perform a critical analysis of the acoustic and fluctuating pressure environmental trends as a function of the complete flight envelope of the Space Shuttle.

APPROACH: Particular emphasis will be directed to the area of fluctuating pressure environments. Specifically, this work effort will consist of the following studies: (1) Perform a general review of the environmental acoustics associated with the operation of the Space Shuttle propulsion system. (2) Perform a critical analysis of the fluctuating pressure environmental trends associated with the Space Shuttle within the flight envelope. Establish the critical areas of the environmental trend.

STATUS: Technical Progress: The technical objectives of this effort have been satisfactorily completed. The results have been documented in the reports given below. This contract has expired.

Conclusions: The results of this study are of such a nature that it could be applied to any type of aerodynamic noise related problem area in order to obtain detailed characteristics of the fluctuating pressure characteristics associated with various aerodynamic flow regimes.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
WR 73-6	Predictions of Space Shuttle Fluctuating Pressure Environments, Including Rocket Plume Effects	Kenneth J. Plotkin and J. E. Robertson	N/A
WR 73-3	Prediction of Fluctuating Pressure Environments Associated with Plume-Induced Separated Flow Fields	Kenneth J. Plotkin	N/A
	Shock Wave Oscillations Driven by Turbulent Boundary Layer Fluctuation (Presented at the Sixth Fluid and Plasma Dynamics Conference of the AIAA, July 1973)	K. J. Plotkin	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 908-52-40	PRIOR NO.: 908-52-40

4. TITLE:

Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Jess H. Jones	205-453-0176	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Investigation of Jet Noise Theory and Application Utilizing the Pao Formulation
NAS8-28588, University of Alabama at Huntsville, Huntsville, AL

OBJECTIVE(S): The objective of this effort is to specify the critical Shuttle vehicle acoustic environment for a given vehicle configuration and propulsion engine characteristic. It is based on recent developments of an advanced aerodynamical noise theory first formulated by Pao in 1970. As a result of this formulation, important jet noise emission mechanisms in supersonic, high temperature jets relative to overall noise intensity, spectrum, and directivity have been rigorously defined. Computer programs developed using this approach are now available for the determination of nearfield and farfield noise predictions.

APPROACH: This effort includes investigations in two main areas: the existing computer programs shall be refined such that the sound pressure fluctuation environment for given Shuttle vehicle configurations can be predicted; secondly, theoretical analysis shall be performed in areas of fundamental importance to future advancements of technology in the identification of acoustical pressure loadings on the structure of the Space Shuttle and adjacent regions.

STATUS: Technical Progress: Final adjustments to the rocket noise prediction computer program have been made. This program has been written according to the full Phillips-Pao theory of jet noise radiation. Its layout contains four main portions:

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

The final report is in progress and it will be completed in October.

FIRST BENEFITTING PROJECT: Space Shuttle

STATUS (CONCLUDED)

the master program, the WKBJ transformation, self-noise calculation, and shear-noise calculation. In addition, there are subroutines for defining quantities such as turbulence intensity profile, turbulence structure, and special functions.

The calculation of the overall noise radiation from rocket exhaust flows is based on a "slice and segment" scheme. The exhaust flow is divided into 20 or 25 slices along the centerline of the flow. For each slice, characteristic spatial and temporal scales of the turbulence are defined. Each slice is further divided into approximately nine annular segments. Individual convection velocity and temperature are assigned to each segment according to the mean flow properties. For each slice, the WKBJ transformation is defined, and the self-noise and the shear-noise are computed according to the theory. The function of the master program is to execute such calculations for each slice, and to coordinate the bookkeeping and output of the accumulated noise radiation by the entire rocket flow.

In the checkout calculations of this program, the noise radiation characteristics are computed for individual slices. Some interesting trends have been observed. In the downstream quadrant, the noise is governed by both the shear-noise and self-noise, with predominately the contribution of shear noise near the axis of the jet. In the upstream quadrant, however, self-noise dominates. For noise radiation near the axis of the jet, the noise source is located mainly in the outer segments of the jet. Hence, sound intensity at these angles will be underpredicted if only one typical segment of the jet is chosen to represent the entire slice, which is commonly done for jet noise calculations. The directivity pattern as predicted by the current method agrees quite well with experimental results. Adjustments to the input constants have been made to improve the predicted accuracy for practical calculations.

Management Progress: Final report is in progress. This contract expires in October.

Conclusions: The theoretical results obtained to date are significant because they provide a means to obtain for the first time, a detailed evaluation of the basic noise characteristics of jet/rocket exhaust flows.

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MSFC	01 04 73 to 30 09 73	908-54-05	908-54-05

4. TITLE:

ELECTRICAL POWER

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W.J. Robinson, S&E-SSL-SG	453-0029	W. H. Sieber

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE(S): The objective of this program is to develop technology for transmission of electrical power over microwave and laser links through the feasibility phase and to investigate the practicality of transmitting power over microwave and laser beams between earth-orbiting satellites. The distances contemplated are 1 to 2 km, and the power levels are in the vicinity of 2 kw. Later the power level is expected to increase to the 50- to 100kw range if the nuclear reactor must be separated from the base station. The important parameters for use in planning earth orbital scientific programs are efficiency, distances, and power levels.

Background - The feasibility study of wireless power transmission at MSFC began in 1967 as a result of a need to transfer some 2 kw of electrical power between earth-orbiting satellites. A wireless power transmission system has a transmitter, beam-forming device, and a receiving device which captures the electromagnetic energy and converts it to dc power.

NASA technical memorandum report #53806 entitled "The Feasibility of Wireless Power Transmission for an Orbiting Astronomical Station" was published May 27, 1969, and is a report of the development of microwave and laser components which may be applicable to wireless power transmission systems. The investigation showed that component development in the microwave wavelength region was well ahead of that in the laser region. For example, transmitting devices in the microwave region were capable of some 400 kw of output, whereas devices developed in the laser region were capable of only about 10 kw output. Components for conversion of microwave and laser to dc electrical power were very poor in the microwave and nonexistent in the laser region.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
PT-2931	Free-Space Microwave Power Transmission Study, Phase I	W. C. Brown	June 1970
PT-3539	Free-Space Microwave Power Transmission Study, Phase II	W. C. Brown	Sept 1972

Background - Continued

A contract with Raytheon Company (Mr. W. C. Brown, Principal Investigator) was let in December 1969 to study the problem areas and improvements needed in microwave power transmission components.

In November 1970 a performance demonstration of a system using "off-the-shelf" components resulted in some 18% efficiency from a source of 60 Hz, 120V ac to the receiving antenna load. A performance demonstration is scheduled for February 1974 to show the results of the study effort over the past three years, and a system efficiency of some 50% is expected.

The in-house effort consisted of construction of three large receiving antennas for operation on the Astrionics Antenna Range to determine efficiency and power levels as a function of distance between transmitting antenna and receiving antenna. This effort is expected to be completed by December 1973.

APPROACH: The demonstration is scheduled at MSFC in February 1974 to show the results of the NASA-Raytheon joint effort in this program since 1969. The major improvement has been in the receiving subsystem efficiency.

System components in addition to receiving components of better efficiency have been assembled or purchased by the contractor for the demonstration. The system components will be shipped to MSFC and assembled in Building 4481. The system demonstration is expected to attain an overall efficiency of about 50%.The system efficiency value and other pertinent data will be published in a final report for distribution.

In-House Effort - This effort will utilize the three large receiving antennas which were built for range operation. A 5-kw, 2.45-GHz transmitter will be used as the microwave power source on the Astrionics Range to determine efficiency and power levels possible at given distances up to 120 meters. The results of the range tests will be included in the final report.

STATUS: All in-house activity is taking place on the Astrionics Antenna Range. Measurements are being made at distances from 15 meters to 120 meters.

The Raytheon contractor is assembling the equipment prior to shipment to MSFC for use in the second demonstration.

REMARKS: Because the extended program to build a 50-kw receiving antenna at MSFC has been transferred to another NASA Center, copies of all records and equipment built at MSFC should be transferred to the responsible NASA Center with the exception of the first receiving antenna, which should be offered to our space museum.

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MSFC	01 04 73 to 30 09 73	908-54-08	

4. TITLE:
Stabilization and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. M. Seltzer S&E-ASTR-A	453-4713	for Hans H. Hosenthien

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities): (NAS8-28358, U of CA)(NAS8-27799, U of Santa Clara)

OBJECTIVE:

1. To establish criteria for observability, controllability, stability, and performance of non-rigid spacecraft with active control systems having sensors and/or actuators attached to elastic portions of the vehicle.

2. Develop and apply multilevel methods for the analysis and design of complex attitude control systems.

APPROACH:

1. To begin with explicit determination of the desired criteria for relatively simple idealizations of flexible spacecraft, and proceed when possible to generic conclusions.

2. To investigate stability of a sample relatively complex control system by the modern decomposition-aggregation methods.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1	Regions of Absolute Ultimate Boundedness for Discrete-Time Systems (Paper presented at the 5th Asilomar Conference on Circuits and Systems).	D. D. Siljak S. Weissenberger	November 1, 1971
2	Boundedness Regions of Discrete-Time Dynamic Systems (Final Report).	D.D. Siljak G. J. Thaler S. Weissenberger	March 1, 1972
3	On Practical Stability (Paper Published in Int. J. Control).	Lj. T. Grujic	April 1973
4	Decomposition-Aggregation Stability Analysis of the Spinning Skylab (Final Report).	D. D. Siljak S. Weissenberger	June 11, 1973

FIRST BENEFITTING PROJECT: LST

MSFC - Form 860 (March 1978)

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7. Rept. No.:	Title:	Author(s):	Date Transmitted
AAS/AIAA Astro-dynamics Conference Presentation; accepted for publication in AIAA Journal	Mathematical Modeling of Spinning Elastic Bodies for Modal Analysis	Likins Barbera Baddeley	July 17, 1973 (presentation)
Accepted for publication in International Journal of Solids and Structures	Geometric Stiffness Characteristics of a Rotating Elastic Appendages	P.W. Likins	
UCLA-ENG-7329	Final Report, Vol. 1 Dynamics and Control of Advanced Space Vehicles	P.W. Likins	April 1973
UCLA-ENG-7329	Final Report, Vol. 2. Modal Analysis for Liapunov Stability of Rotating Elastic Bodies	Andre' D. Colin	April 1973

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4. TITLE: Stabilization and Control - Multilevel Analysis and Design of Attitude Control Systems for Space Vehicles

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL
Sherman M. Seltzer S&E-ASTR-A	453-4713	for Hans H. Rosenthien

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities): (NAS8-27799, Univ. of Santa Clara, CA 95053)

OBJECTIVE: Develop and apply multilevel methods for the analysis and design of complex attitude control systems.

APPROACH:

The purpose of the research is to investigate stability of the spinning Skylab control system by the modern decomposition-aggregation methods. Such an investigation is motivated by the fact that the mathematical model of the system is exceedingly complex and a straightforward analysis would become bogged down in the welter of detail requiring an excessive computer storage and time to complete the investigation. The multi-level decomposition-aggregation approach offers to solve the stability problems "piece-by-piece" and not only make more economical the computer use, but also reduce the liability of the errors in the analysis. Furthermore, by decomposing the system into parts that have important physical meaning, the decomposition-aggregation approach yields significant structural information about the behavior of the system, which is not generally available in a straightforward stability investigation.

STATUS:

The decomposition-aggregation method was applied to determine stability of the spinning Skylab. Linear equations of the Skylab motion, which include passive stabilization by extendable booms with tip masses were decomposed into two sets of equations describing the wobble motion and the spin motion. Then, two sets of equations were treated as subsystems which are interconnected by a coupling parameter representing the asymmetry in the booms setting. The

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1	Regions of Absolute Ultimate Boundedness for Discrete-Time Systems (Paper presented at the 5th Asilomar Conference on Circuits and Systems).	D. D. Siljak S. Weissenberger	November 1, 1971
2	Boundedness Regions of Discrete-Time Dynamic Systems (Final Report).	D. D. Siljak G. J. Thaler S. Weissenberger	March 1, 1972
3	On Practical Stability (Paper published in Int. J. Control).	Lj. T. Grujic	April 1973
4	Decomposition-Aggregation Stability Analysis of the Spinning Skylab (Final Report).	D. D. Siljak S. Weissenberger S. Cuk	June 11, 1973

FIRST BENEFITTING PROJECT: LST

decomposition-aggregation method was then used to determine stability region of the coupling parameter.

A meaningful optimization problem was formulated as the maximization of the coupling parameter constrained by the choice of the subsystem Liapunov functions. Computer programs are developed to solve the optimization problem and investigate the trade-off between the stability degree of the subsystems and that of the overall system.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 908-54-08	PRIOR NO.:

4. TITLE: Stabilization and Control - Control Systems for Advanced Space Vehicles

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. M. Seltzer, S&E-ASTR-A	453-4713	Hans H. Hosenthien

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities): (NAS8-28358, Univ. of California Office of Extramural Support, Los Angeles, CA)

OBJECTIVE:

To establish criteria for observability, controllability, stability, and performance of non-rigid spacecraft with active control systems having sensors and/or actuators attached to elastic portions of the vehicle.

APPROACH:

To begin with explicit determination of the desired criteria for relatively simple idealizations of flexible spacecraft, and proceed when possible to generic conclusions.

STATUS:

A. Technical Progress: As noted in the accompanying Milestone Schedule, our studies of the influence of sensor locations on observability, controllability, and stability of the system have been completed for the present. Explicit criteria have been generated for a rigid body with symmetrically attached appendages represented by both multiple-rigid-body and elastic body modes.

It is apparent that we must accept space vehicles that are neither fully controllable nor fully observable, and we recognize certain precautions that must be taken in sensor system design to assure the compatibility of the limited degrees of observability and controllability accepted in a given design.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
AAS/AIAA Astrodynamics Conference Presentation; accepted for publication in AIAA Journal	Mathematical Modeling of Spinning Elastic Bodies for Modal Analysis	Likins Barbera Baddeley	July 17, 1973 (presentation)
Accepted for publication in International Journal of Solids and Structures	Geometric Stiffness Characteristics of a Rotating Elastic Appendages	P. W. Likins	
UCLA-ENG-7329	Final Report, Vol. 1. Dynamics and Control of Advanced Space Vehicles	P. W. Likins	April 1973
UCLA-ENG-7329	Final Report, Vol. 2. Modal Analysis for Liapunov Stability of Rotating Elastic Bodies	André D. Colin	April 1973

FIRST BENEFITTING PROJECT: LST

MSFC - Form 350 (March 1973)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 908-54-08 PAGE 2 OF 2

The influence of sensor location on stability is significant and potentially dangerous, although for a spacecraft with known structural characteristics (mode shapes and frequencies in the control system bandwidth) this influence can be established and potential problems avoided.

The task of formulating equations for a complex structural system (the Hopkins work) continues to show only painful progress.

Procedures have been developed for simulating CMG's attached to a entirely flexible body. Equations are now being derived.

B. Management Progress:

(1) A proposal for extension of this study through calendar year 1974 has been submitted as Mod. 5 to this contract.

(2) Dr. Yoshiaki Ohkami has received permission from the Japanese government to remain at UCLA for another year to work on our MSFC contracts.

C. Conclusions: Our concern for the influence of sensor locations on control system performance for nonrigid spacecraft is justified.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	908-54-08	908-54-08

4. TITLE:

Stabilization and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-DOI Harry Buchanan	205 - 453-2475	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Integration Schemes for Equations of Motion
Contract No. NAS8-28833, Mississippi State University, Starkville, MS

OBJECTIVE(S): Adaptation of existing mathematical techniques to the specialized problem of simulating the dynamics of orbiting spacecraft. In particular, a formulation which utilizes the full potential of high-speed digital computers is sought. Present techniques have proved very uneconomical in computer time and thus cost for problems containing both high and low frequency components.

APPROACH: By considering a NASA/MSFC provided model of the dynamics and control equations for an orbiting vehicle under the influence of a variety of external torques, a specialized integration procedure will be developed. This integration procedure will allow both high frequency variables (structure and control system) as well as low frequency variables (gravity gradient and aerodynamic torques) to be handled economically within the same computer program.

STATUS: Technical Progress - An extensive literature survey was completed on available integration procedures. Many of these were applied to the integration of the equations of motion of an orbiting spacecraft and compared for running time and accuracy.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
EIRS-ASE-74-1	A study of Numerical Methods of Solution of the Equations of Motion of a Controlled Satellite under the Influence of Gravity Gradient Torque.	Joe F. Thompson, John C. McWhorter, Shahid A. Siddiqi, Samuel P. Shanks	N/A

First Benefitting Program:
Space Shuttle

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 908-54-08 PAGE 2 OF 3

Management Progress - The final report on the work under this contract has been received.

Problems - The amount of available literature and variety of integration techniques was underestimated initially. As a result, the literature survey took longer than planned and the desired integration scheme could not be formulated within the time and money constraints of the contract.

Conclusions - The literature search revealed a vast number of techniques that have been used for the integration of ordinary differential equations. Each of these methods has strengths and weaknesses and none was found to be clearly superior in execution time or accuracy. As a result of the vast number of existing techniques there were not sufficient time and funds to evaluate these and develop the desired integration scheme; however, the way has been cleared and the basic groundwork laid for its development.

Forecast - None

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MSFC	01 04 73 to 30 09 73	908-54-21	908-54-21

4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M.C. McIlwain S&E-QUAL	453-1435	R. M. Henritze

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Computer Enhancement of Radiographs
NAS 8-28521, Data Corporation, Dayton, Ohio

Objective(s): To develop a hardware and software system suitable for the automated scanning, and analysis of structural weld X-ray films. This involves the application of precision optical scanners and a computer suitable for performing the necessary enhancement, and analysis operations. Software packages consisting of executive, utility and enhancement routine are also required. The desired goal is to have a system which will permit the acceptance/rejection of radiographic film without having to rely on the skill of an X-ray interpreter.

Approach: Phase I - Feasibility Study: A literature search, conducted in 1968, indicated a rapidly increasing use of image enhancement as a means of improving the visibility and intelligibility of photographs taken by the Ranger and Mariner Spacecraft. Selected images of structural weld radiographs were processed by J. P. L. at the request of this Center to establish the technical feasibility of applying to MSFC radiographs, the image processing techniques developed for the J. P. L. programs. Phase II - Hardware and Software Definitions: Optimize hardware and software specifications in order to accurately determine operational constraints and future resources

(Continued)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
ESL-TM-213 (ESL, Inc.)	Development on Optimized Techniques & Requirements for Computer Enhancement of Structural Weld Radiographs	J.R. Adams, et. al.	Mar. 5, 1971
NASA CR-2213	Digital Processing of Radiographic Images	A. D. Bond & H. K. Ramapriyan	April 1973
MFR-73-3	Computer Enhancement of Radiographs	A. Dekaney, et. al.	July 15, 1973

First Benefitting Project: Space Tug.

requirements, the results to provide the necessary technical information on which to base a management decision regarding the implementation of such a system at MSFC. Phase III - Hardware and Software Procurement, and Phase IV - Program Implementation: Will follow.

Status: Technical Progress: Mead Technology Laboratories (formally Data Corp.) has completed their study and submitted the final report.

Management Progress: The overall study has been completed. Three reports have been published (see Section 7). This is the final report on this project.

Conclusions: A technology for digitally enhancing radiographs has been developed, which can be utilized for analysis of selected radiographs for enhanced definition of flaw characteristics. Complete automation of the radiographic interpretation is beyond the state-of-the-art for computer technology at this time.

Problems: None.

Forecast: None.

Publications: See Reports (Section 7)

Remarks: A spin-off of the technology developed under this study is being used to enhance earth resource photo interpretation.

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MSFC	01-04-73 - 30 09 73	909-51-02	909-51-02

4. TITLE:

Thermal Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Jack D. Loose	205 453-3824	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Deployable Heat Pipe Radiator; NAS8-29905, Grumman Aerospace Corporation

OBJECTIVE: Design and fabricate a heat pipe radiator panel and flexible heat pipe header which has deployment capability and can serve as an experimental research tool for investigating the control characteristics of: (1) variable conductance fin heat pipes used with a fluid loop header or single fluid heat pipe header, and (2) a variable conductance heat pipe header used with single fluid or variable condutance fin heat pipes. Panel to be approximately 4' x 6' and reject a heat load of 200 - 400 watts ar nominally 530°R. Heat pipe header to have minimum length of 7 feet and transport capacity of 400 watts.

APPROACH: The effort is divided into 6 phases:

1. Panel concept: Perform parametric studies to define radiator panel design/ performance specifications.
2. Flexible header: Develop flexible variable conductance heat pipe.
3. Design: Perform detailed analysis and engineering design.
4. Fabricate: Fabricate and assemble hardware.
5. Test: Prepare test plans/procedures and perform verification test. Ship hardware to MSFC.
6. Test plan: Prepare thermal vacuum test plan for testing in Government facilities.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

FIRST BENEFITTING PROJECT: Sortie Lab

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STATUS:

Technical Progress: Work initiated.

Management Progress: CPFF contract signed August 20, 1973, with Grumman Aerospace Corporation for 12 month performance period.

Conclusions: None

Problems: None

Forecast: Progress as scheduled.

Remarks: None

PROGRESS REPORT
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4. TITLE:

Thermal Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Kenneth E. McCoy	205 453-3824	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Heat Pipe Thermal Conditioning Panel; NAS8-28639 (MDAC)

OBJECTIVE: Develop a proven design concept and working model of a modular heat pipe thermal conditioning panel that has broad application of spacecraft thermal management.

APPROACH: Contractor shall develop the concept and hardware in five major phases as follows: Phase I - Formulation of Specifications: Investigate applications for panel and develop design/performance specifications for panel to provide maximum utility. Phase 2 - Analysis, Design, and Concepts Section: Develop alternative design concepts, analyze performance; and then select and design in detail optimum concept. Phase 3 - Fabrication: Fabricate selected panel of Phase 2. Phase 4 - Testing: Test panel under simulated application environments to verify analyses and achievement of performance specifications. Phase 5 - Second Panel: Repeat Phase 3 and 4 for a second panel built to the selected design or to a modified or alternative design. Both panels, with drawings, manuals, etc., will be delivered to MSFC for additional inhouse tests.

STATUS:

Technical Progress: During the current reporting period the following tasks were completed; fabrication and testing of first panel, design, fabrication and testing of second panel, and both panels delivered to MSFC.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MDC G 3155	"Quarterly Status Report, Heat Pipe Thermal Conditioning Panel"	J.S. Holmgren	October 1972
MDC G 4406	"	"	March 1973
MDC G 4416	"	E.W. Saaski	June 1973

FIRST BENEFITTING PROJECT: LST

MSFC - Form 350 (March 1978)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-51-02 PAGE 2 OF 3

STATUS: (Continued)

Management Progress: A one year contract with MDC was signed June 28, 1972, for $68,183. The contract was initially partially funded for only $30,000, which was expended by November 15, 1972. Work was stopped awaiting FY73 funds. The balance of fund became available February 15, 1973 and work was resumed after a 3 month delay. Contract was extended to September 12, 1973 on March 19, 1973 to compensate for time lost waiting on balance of funds.

Conclusions: Preliminary evaluation of design concepts indicate it is possible to use same design in both inhabited and uninhabited areas with only a fluid change. Aluminum/ammonia appears optimum in unpressurized areas and aluminum/acetone may be acceptable. Testing of the first panel revealed an excessive source to sink temperature difference at maximum heat load. Investigation revealed that this was caused by excessive gaps at the heat pipe/face sheet interfaces. Design changes incorporated in the second panel included using a square extrusion for the heat pipe, a higher conductivity bonding agent at the heat pipe/face sheet interface and closer heat pipe spacing. These changes reduced the source to sink temperature difference to less than the design goal of 15^{o}F at 300 watts total load.

Problems: None

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4. TITLE:

Thermal Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Jack D. Loose	205 453-3824	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Large Variable Conductance Heat Pipes; NAS8-27793, Grumman Aerospace Corporation

OBJECTIVES: Develop a high reliability, high performance, variable conductance heat pipe design which can be used as a header for heat transport and temperature control in ambient temperature spacecraft thermal management systems. Each pipe is to transfer and control a minimum load of 2 KW over an 8 foot length. Evaporator temperature at full load is to be 95°F, and the pipe is to be shut off at 50°F. A cold inert gas reservoir provides control. The design is to be suitable for use as a header on a nominal 50 square foot radiator.

APPROACH: Work scope has 5 phases

1. Perform parametric and design analyses for 2 self priming artery wick designs which exceed performance requirements.
2. Fabricate two designs serially such that, if problems arise in the first, the second is a backup.
3. Bench test under environmental conditions to verify analytical predictions and performance.
4. Deliver pipes and instruction manuals to MSFC for further testing.
5. Prepare final report and program plan for incorporating into a heat pipe radiator panel for testing.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1.	"Large VCHP-Spiral Artery Tunnel Wick, Design and Analyses," Grumman Tech Memo (HP-44)	J. Alario	8 July 1971
2.	"Experimental Performance of High Capacity Tunnel Artery Development Heat Pipe," Grumman Tech Memo (HP-46)	R. Hembach	29 Sept. 1971

FIRST BENEFITTING PROJECT: Space Tug

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PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

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STATUS:

Technical Progress: To Date: One 8 foot variable conductance pipe developed and tested by contractor. Transmitted 3200 W in single fluid horizontal mode, 1200 W in variable conductance mode. Limited variable conductance capacity due to degrading action of gas in artery. As variable conductance pipe, controlled evaporator temperature within 2°F over load range of 200 to 1200 W. Pipe delivered to MSFC, installed in test fixture, and inhouse tests initiated.

Second pipe was to have been built to demonstrate repeatability of performance. Since performance of first pipe was below contract specification, second pipe built as development tool to troubleshoot limited performance. Tried intercooling loop and artery bypass schemes to subcool returning artery fluid and increase performance. Latter scheme raised variable conductance capacity from 39% to 80% of single fluid capacity. A method of separating control gas from working fluid also proposed and cursory feasibility model developed and successfully tested.

During Current Reporting Period: Inhouse tests of single fluid performance were completed. Contractor's curve of power transmitted versus tilt repeated; however, at higher tilts, occasional drastic reduction of performance observed. Appears random gas entrainment in the artery causes depriming. Further inhouse testing halted by nonavailability of manpower.

Contractor's final report issued and distributed.

Management Progress: Contract signed June 28, 1971; current phase completed May 31, 1973. Response to RFP for sole source 10 month funded extension received and technically evaluated. Extension, designated "transverse header", is to further develop and optimize a radial heat pipe device allowing separation of the control gas and working fluid (see "Technical Progress"). Objective also to expand applications of the device. Disagreement over labor rates and hardware deliverability delaying final negotiation of extension.

REPORTING:	TITLE	AUTHOR(S):	DATE TRANSMITTED:
3.	"Transparent Heat Pipe", Grumman Tech Memo, HP-47	G. Knowles	25 October 1971
4.	"Large Variable Conductance Heat Pipe (VCHP) Temperature Control Analysis," Grumman Memo, HPM-1	J. Kutilek	12 November 1971
5.	"Thermal Test Plan for Large Variable Conductance Heat Pipe," Grumman report HPM-2	F. Edelstein	24 November 1971
6.	"Test Results of Large Variable Conductance Heat Pipe", Grumman report HPM-3	F. Edelstein	18 February 1972

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
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STATUS: (continued)

Conclusion: The heat pipe design developed under contract operates at higher capacities than any other known heat pipe design and provides excellent evaporator temperature control. The artery is, however, sensitive to entrapped non-condensible gas. Further investigation of this phenomena is warranted and is being fundamentally studied through ARC.

Problems: Limited pipe capacity (below contract specification) as discussed under "Technical Progress" and "Conclusion" headings. Limited manpower delaying further comprehensive inhouse testing.

Forecast: Resolve differences, complete final negotiation, and initiate effort on extension. Schedule enclosed assumes October 1 initiation.

Remarks: Since the contractor development of the 8 foot heat pipe has been completed, further reporting of the contractor effort will be discontinued. Future reports will address the "transverse header" extension and inhouse heat pipe test results.

REPORTING:	TITLE	AUTHOR(S):	DATE TRANSMITTED:
7.	"The Development of a 150,000 Watt-Inch Variable Conductance Heat Pipe for Space Vehicle Thermal Control," ASME Paper No. 72ENAv-14	F. Edelstein J. G. Roukis J. Loose	May 1972
8.	"Operating Manual for the Large Variable Conductance Heat Pipe (VCHP), Single Fluid Operation," Grumman Memo HPM-4	F. Edelstein R. Hembach	8 August 1972
9.	"Development of a High Capacity Variable Conductance Heat Pipe," AIAA Paper No. 73-728	R. Kosson R. Hembach F. Edelstein J. Loose	July 1973
10.	"Large Variable Conductance Heat Pipe, Final Report: Tunnel Artery Header," Contract NAS8-27793, Grumman Corp.	F. Edelstein	March 1973

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 909-51-02	PRIOR NO.: 908-51-02

4. TITLE:

EARTH ORBITAL SYSTEMS - THERMAL CONTROL

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. Wilkes, S&E-SSL-TR J. Trenkle, S&E-SSL-TR	453-3090	W. C. Snoddy W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE(S): (1) Problem - The optical properties of thermal control surfaces have been shown to be altered considerably under the space environments, including solar electromagnetic radiation and thermal vacuum. (2) Application - The thermal control surfaces used on long Shuttle mission payloads will be required to remain stable in their optical properties for up to a 10-year lifetime. This is a stringent requirement because of the harsh vacuum ultraviolet and particulate environment to which they will be subjected as well as the possibility of their being contaminated by the life support and operational functions of the vehicle. (3) Objective - To insure thermal control systems design, design engineers must have available all initial properties data on thermal control surfaces and the changes in these data which will occur during mission lifetime. The objective of this task is to generate the required design data for all candidate thermal control surfaces.

APPROACH: Thermal control surfaces will be tested in the laboratory to establish the effects of the simulated mission-environment on these surfaces. This will include vacuum and solar ultraviolet radiation as well as different types of contamination. The mechanisms of these damaging effects will be pursued so these effects could be minimized by special design, time-lining, orientation, material selection, etc. Accelerated testing rates will be used to provide the required 5-to 10-year tests.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Since the beginning of this task, monthly, quarterly, semi-annually and special reports have been submitted as required.

Since the facility has been finished and testing just begun, no report of results of long-term tests has been generated.

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STATUS: An in-house testing facility consisting of a clean vacuum system, 5-kw Hg-Xenon solar UV simulator, a 19-sample capacity substrate and manipulator system, and a unique computer-controlled spectroreflectometer has been designed and built. At present, environmental tests are being run and will continue to generate the required design data. When the thermal control problem was encountered upon Skylab deployment, this facility was used on an around-the-clock schedule to test the proposed thermal shield materials that were used in the Skylab "fix".

Problems - It has been difficult to obtain samples of candidate thermal control surfaces for testing. Other sources and agreements with present sources are being pursued to alleviate this problem.

Forecast - The present tests will be continued and mission-related tests (such as the Skylab tests) will be run as required.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	909-51-05	See Remarks

4. TITLE:

Earth Orbital Systems Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. B. Graff	453-4560	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Objective: To develop design concepts, techniques and criteria in the area of Electrical Power Generation by Solar Arrays.

Approach: This program is being conducted under separate tasks which will be individually summarized and discussed. The following tasks are in work:

- o Space Station Solar Array Development
- o Evaluation of Shallow-Diffused (Violet), High Efficiency Solar Cells

Status: Both tasks are contracted efforts using FY-73 and prior year funding. A status report for each task follows:

Remarks: See individual tasks for those previously reported under other numbers or other remarks.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
See individual Tasks.			

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 909-51-05	PRIOR NO.:

4. TITLE:
Earth Orbital Systems Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. L. Miller	453-4567	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Evaluation of Shallow-Diffused (Violet), High-Efficiency Solar Cells

Contract No: NAS8-29872, Centralab Inc.

Objective(s): To procure a quantity of the newly developed shallow-diffused, high-efficiency "violet" solar cells for performance evaluation purposes. During evaluation, emphasis will be placed on conversion efficiency, temperature coefficients (power, voltage, and current), and environmental degradation rate.

To gain knowledge of the general mechanism of the cell production line, especially predictions of yield and performance. To identify changes necessary for mass production, and to predict cost per unit in mass quantities. Also, the contractor's views regarding standardization of cells and/or submodules will be obtained.

Approach: A production line will be established, the cells will be tested for specified performance, and changes necessary for mass production will be identified.

Status: Technical Progress:

All materials and tooling required for fabrication of violet solar cells have been obtained. Initial studies have established the cell fabrication sequence. Studies have also been performed to try to establish production line check points and possible areas of cost reduction.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1	Monthly Progress (July and August, 1973)	P. A. Iles	Sept. 15, 1973

First Benefiting Project: All

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PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909–51–05 PAGE 2 OF 2

Status: (Cont'd)

Management Progress:

Contract with Centralab was signed, June 1973.

Conclusions:

None to date.

Problem Areas:

Problems have been encountered in the fabrication process in trying to scale up production of violet cells. The major problem encountered has been in maintaining the critical diffusion parameters required for large–scale production. These problems have caused a delay in the production of acceptable cells.

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4. TITLE:

Earth Orbital Systems Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. L. Crabtree	453–4567	R. M. Aden S&E–ASTR–E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Space Station Solar Array Development

Contract No: NAS8–28432, Lockheed Missile & Space Co.

Objective: Develop a long life, retractable, foldout, solar array using flexible substrates and incorporating modularization. Fabricate modules using standard and "violet" cells with welded interconnects and develop acceptance testing criteria.

Approach: The effort will be accomplished in five phases:

I. Establish materials properties and fabrication processes.
II. Establish design requirements; design and fabricate modules.
III. Environmental test and analysis of modules.
IV. Establishment of acceptance test methodology and criteria.
V. Development of array retraction method.

Status: Phase I, II and III efforts are progressing on schedule with thermal vacuum testing of 10 engineering evaluation modules complete. Based upon this testing and the materials information gathered in the early phases of the program, the primary module design has been selected. A secondary design also appears promising since no failures of this system occurred in the thermal vacuum testing. At present, fabrication of modules utilizing the selected and alternate design approaches is underway.

The Phase III presentation was given at MSFC in August, 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

A complete written report on Phases I, II and III will be distributed in October. Monthly letter reports received to date are as listed below:

March 1973
April 1973
May 1973
June 1973
July 1973
August 1973

First Benefiting Project: LST/Space Station

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Status: (Cont'd)

The schedule has been changed to terminate in June of 1974 due to lack of funds to continue beyond that date.

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4. TITLE:

Communications

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D.O. Lowrey, S&E-ASTR-IR	205-453-1578	O.T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Electronically Steerable Phased Array
NAS8-25847, Texas Instruments

Objective: To develop an electronically steerable microwave phased array that is capable of wideband communications and tracking simultaneously from space vehicles. The array will be capable of beam steering and contain transmit, receive, tracking and directional control of S-band and higher frequency signals. The array will be compatible with space relay satellites and ground receiving and transmitting stations.

Approach: The array design and construction utilizes 100 percent usage of active electronic circuits. Required inputs are d.c. power and data bit stream. Outputs are in the form of data and directional tracking information. The array utilizes 100 percent microwave integrated circuitry, microstrip techniques and integrated logic circuitry. Both in-house design and contractual fabrication and development are utilized. The system utilizes highly reliable, lightweight, high efficiency techniques to achieve a long life operational system.

Status: Technical Progress--- The prototype single layer array module was fabricated and testing was performed during this period. Design changes were incorporated for performance improvements. Improved microwave integrated circuits were fabricated and installed into the prototype module. Tests results indicated performance met the design specifications.

New layout drawings were made for fabrication of R.F. manifolds. The revised design

(Cont'd)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Airborne Electronically Steerable Phased Array, Final Report of Design Phase, Jan. 29, 1971		
	Antenna Array Efficiency and Efficiency Improvement Through Compensation, Technical Report No. 1		
	Solid State Microwave Source Development Program, Final Report June 1971.		
	Airborne Electronically Steerable Phased Array, July 1972.		

FIRST BENEFITTING PROJECT: CVT/Venus Pioneer

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incorporated change improvements to provide optimum performance for the single layer module.

The investigation study was continued during this time to determine the feasibility of adapting the present S-band array techniques to Ku-band operation. The available study results are being incorporated into the annual progress report which is now in preparation.

Management Progress: The contract for extension of the period of performance and increased scope of work was finalized.

Conclusion: The progress during this reporting period is on schedule.

Problems: None

Cause of Problems None

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4. TITLE:

Aerothermodynamics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AF John D. Warmbrod	205-453-0170	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Orbiter/ET Configuration Shock Interference Heating
NASA Defense Purchase Request Number H-99180A
Arnold Air Force Development Center
Arnold Air Force Station, Tennessee 37389

OBJECTIVE(S): Collect interference heating data on the Space Shuttle Orbiter/ET configuration at high Mach numbers and low Reynolds number.

APPROACH: Conduct a wind tunnel test program at AEDC VKF Tunnel F to collect interference heating data on the ET for simulated ascent conditions. Model heat transfer rates will be measured by slug calorimeters, coaxial surface thermocouples, and by a phosphorescent paint technique. Test results will be obtained on the Shuttle Orbiter/ET configuration at high Mach numbers (16, 19) and for a Reynolds number range of .05 - .15 million per foot. There are no existing data for this range of conditions for the Shuttle configuration. A pretest report has been documented.

STATUS: Technical Progress - Test is to be conducted January 1974.

Management Progress - None

Conclusions - None

Problems - None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
S&E-AERO-AT-73-30	Pretest Report for Test FH-10	Edwin B. Brewer	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:

Aerothermodynamics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AAE Kenneth L. Blackwell	205-453-2517	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Engine Plume Induced Effects on Ascent Aerodynamics
NAS8-26801: Lockheed Missiles and Space Company, Huntsville, AL
NAS8-xxxxx: REMTECH, Inc., Birmingham, AL

OBJECTIVE: To provide technology for wind tunnel simulation of prototype plume flow field and adjacent flow fields for Space Shuttle type vehicles and determine the best cost effective means for accomplishing test programs where plume interactions are significant during ascent flight.

APPROACH: Results of recent plume simulation analyses and wind tunnel tests indicate more extensive studies are required to investigate plume induced effects on ascent vehicle aerodynamics, orbiter aerodynamic control surface torques, engine hinge torques, vehicle base pressure and local impingement loads. A basic approach has been selected to attack the technology questions surrounding plume simulation requirements. A simple body of revolution was selected as the vehicle for the study to allow broader use of results and to make analysis easier. Areas of investigation will include plume simulation sensitivity to free stream mixing parameters, multiple nozzles, mechanical installation methods, Reynolds number sensitivity and two-phase effects on plume impingement loads. Knowledge gained from these investigations will be used to derive a set of simulation parameters for use in defining nozzles and test conditions for wind tunnel test models. This will be accomplished through analytical studies and wind tunnel tests in the MSFC 14-inch TWT and the ARC 2-foot wind tunnels. Basic plume simulation parameters will be investigated using single phase CF_4 and two-phase hot (products of combustion) "prototypes" and air as the simulant gas.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC/HREC TM D306631	Pretest Report for a Plume Technology Test Program in the MSFC 14-inch Trisonic Wind Tunnel	C. Donald Andrews C. E. Cooper	N/A

FIRST BENEFITING PROJECT: Space Shuttle

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STATUS:

Technical Progress - The CF_4/air tests at the MSFC 14-inch TWT have been completed and analyses of these data are underway. A second test series at ARC will be conducted to provide conditions over an extended range. Pretest analysis, model design and fabrication are underway for the "hot" tests to be conducted at MSFC and ARC.

Management Progress - The work under contract NAS8-26801 for conduction of the CF_4/air tests is proceeding adequately. The RFQ to Calspan has been withdrawn due to a change in approach for the "hot" tests. RFQ's were released to LMSC and REMTECH to do the "hot" studies. These contracts are expected to be activated during the next reporting period.

Conclusions - None

Problem - The necessary range of variables was not attained during the MSFC CF_4/air tests requiring additional tests at ARC.

Forecast - Analysis of CF_4/air data from MSFC tests will continue. The "hot" test at MSFC will be conducted. A target date of December 3, 1973, has been established for providing similarity conditions to the Shuttle program for use in March 1974 ascent tests.

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4. TITLE:

Operations, Maintenance and Safety - Space Shuttle Environment Area

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
George H. Fichtl, S&E-AERO-YA	205/453-3168	William W. Vaughan, S&E-AERO-Y

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Assessment of Atmospheric Relationships in Support of Space Shuttle Operations
Contract No. NAS8-29764, Texas A&M University, Dept. of Meteorology, College Station, Texas 77843

OBJECTIVE(S): Establish and provide analytical models on the relationships between significant features in the detailed ascent design wind profiles including wind speed and direction changes, wind shear and turbulence relative to the integrated ground and inflight wind to assist in the design trade-off status for Space Shuttle System relative to lift-off and ascent flight.

APPROACH: To establish the phase relationships between ground and inflight wind as a function of specific atmospheric conditions with respect to the operational constraints currently established for the Space Shuttle System.

STATUS: Technical Progress: Data samples of wind speed, direction, and temperature have been selected for analysis and additional ones have been requested from the NASA. These additional samples will be transmitted during the next reporting period. A literature survey of the appropriate subject matter has been completed.

Management Progress: Contract has been signed with Texas A&M - $15,000. Contract was initiated 17 04 73, full scale effort did not begin until 01 07 73. The contractor made a trip to MSFC to coordinate the work on the contract in August 1973.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Monthly Progress Reports			

FIRST BENEFITTING PROJECT: SRB

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STATUS (continued) Conclusions: None

Problems: None

Causes of Problems: None

Forecast: The work for the coming period will be concerned with an initial analysis of the wind profile data relative to merging the air flow near the ground (heights $\lesssim$150 m) with that at the top of the atmospheric boundary layer (heights $\sim$1-2 km).

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4. TITLE:

Operations, Maintenance and Safety - Space Shuttle Environment Area

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YT O. E. Smith	205-453-3144	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Engineering Atmospheric Model for Space Shuttle Reentry and Return Contract No. NAS 8-29753 (Modification 7-23-73). Georgia Tech Institute, Atlanta, GA

OBJECTIVE(S): Develop an engineering design model atmosphere for Space Shuttle design and operational analysis from orbital altitudes down to the earth's surface over the entire world. The monthly means and variations of pressure, temperature and density with respect to monthly reference periods are to be accounted for in the model. The objective(s) were amended 7-21-73 to include annual means and dispersions of pressure, temperature, and density and a derived wind model.

APPROACH: The MSFC 4-D Global Atmospheric Model which gives pressure, temperature and density versus altitude 0-26 km for any latitude, longitude and monthly reference periods and the MSFC Orbital Model which gives density as a function of time and solar activity for that volume of air above 90 km altitude are connected by a modelling pressure, temperature, and density from available high altitude rocketsonde measurements to form a continuous atmospheric model from orbital altitudes down to the earth's surface for any month, latitude, and longitude. The resulting engineering model will be in the form of a computer program for efficient application to Space Shuttle design and engineering problems. The wind model is derived from basic relationships of mean pressure gradients, i.e., the geostrophic and thermal wind equations.

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Required monthly letter type progress reports have been furnished by the contractor.

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STATUS: The modelling of the atmospheric parameters, pressure, temperature, and density has been completed and most work for the wind model. The computer program will be checked out in November at the MSFC computer facilities.

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4. TITLE:
Operations, Maintenance and Safety

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Leonard L. DeVries, S&E-AERO-Y	205/453-3108	William W. Vaughan, S&E-AERO-Y

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Potential Problems Due to Space Shuttle Operations
Contract No: NAS8-28294, The University of Michigan, Ann Arbor, Michigan 48105

OBJECTIVE: To examine the potential of Space Shuttle operations to contribute to upper atmospheric pollution, bound the problems if any of significance are found, and outline an investigative approach if necessary.

APPROACH: Several different aspects of potential Space Shuttle environmental effects are being simultaneously investigated by a scientific group representing disciplines including chemistry, botany, aeronomy, physics, atmospheric sciences, and cloud physics.

STATUS: The effluents of the Space Shuttle Solid Rocket Motors (SRMs) and orbiter engines have been established by altitude range. The law of conservation of matter has been applied to each element and they have been checked to assure the total mass of effluent equals the total mass of fuel.

A model of the interaction of Al_2O_3, HCl, and H_2O has shown that even for spherical, nonabsorptive Al_2O_3 particles, over one-half of the gas phase HCl concentration is removed. A new HCl scavenging model has been developed, in which all of the HCl has been apportioned among the Al_2O_3 particles in direct proportion to their spherical equivalent area. This approach is designed to supplement the NASA/MSFC diffusion model.

Every likely manufacturer of instrumental analytical equipment has been contacted concerning the detection of low concentrations of HCl and Al_2O_3. Development

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Reports NASA CR-129003	Assessment of Possible Environmental Effects of Space Shuttle Operations	R. J. Cicerone D. H. Stedman R. S. Stolarski A. N. Dingle R. A. Cellarius	June 1973
	The Effect of Gas Phase Chlorine on Stratospheric Ozone	R. S. Stolarski R. J. Cicerone	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (continued) of a chemiluminescent HCl detector, in which the sensitivity and fast response of the sensor appears very favorable, is underway.

An extensive literature search on the environmental effects of HCl and Al_2O_3 has been completed. This search has indicated a lack of information on long-term cumulative effects of continuous or frequent low level HCl exposures on humans. Research on the effects of SRM Al_2O_3 on the human lung indicates that the chances for exposure being severe enough to cause problems are extremely remote, in even the worst situations.

The possible stratospheric effects of SRM HCl are being investigated. Preliminary analyses indicate the possibility of ozone depletion by HCl through a catalytic cycle. The critical unknowns are the reaction rates of the various chemical reactions.

The localized effects of a single Shuttle re-entry on mesospheric odd-nitrogen have been modeled. Preliminary results indicate highly enhanced local concentrations of NO_x compounds. The duration of these effects depends critically upon the effectiveness of horizontal diffusion.

Chemical interactions of controlled vapor streams of HCl with known sizes and shapes of Al_2O_3 particles are being studied in the laboratory by use of a recently developed instrument by which differential light settling from a single particle is analyzed. In this manner, unambiguous data on the size, shape, and refractive index of various particles under all conditions of HCl/H_2O vapor can be obtained. These data can then be averaged over the size distribution of Al_2O_3 nuclei and the H_2O/HCl concentrations to yield an accurate parameterization for an HCl rain scavenging model.

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4. TITLE:

Operations, Maintenance and Safety

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Leonard L. DeVries, S&E-AERO-Y	205/453-3108	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Shuttle Engine Exhaust Emission Study
Contract No. NAS8-29033, H. E. Cramer, Co.
P. O. Box 9249
Salt Lake City, Utah 84109

Contract H92170A, U. S. Dept. of Commerce, ERL

OBJECTIVE(S): To develop an improved exhaust cloud dispersion model which includes the effects of chemical reactions of the exhaust by-products with the atmosphere, a more accurate prediction of the height and size of the initial stabilized ground cloud, and improved dispersion predictions.

APPROACH: The following tasks are being accomplished:

1. Make necessary modifications to the MSFC Multi-layer Diffusion Model.
2. Analyze special sets of atmospheric data for use in diffusion model equations.
3. Develop diffusion climatology for the KSC launch area from lower and upper atmospheric data.
4. Assist in the verification and assessment of downward diffusion estimates and field sample measurements by NASA.
5. Determine the initial and long-term chemistry of Shuttle engine exhaust compounds released in the atmosphere.
6. Identify improved methods to sample engine exhaust by-products in the near and far field by direct and remote sensors.

STATUS: Technical Progress: The NASA/MSFC Handbook for Estimating Toxic Fuel Hazards has been modified to permit use of the program in operation orientated projects. All

7. REPORT NO.:	TITLE: MONTHLY PROGRESS REPORTS	AUTHOR(s):	DATE TRANSMITTED
NASA CR-129006	NASA/MSFC Multilayer Diffusion Models and Computer Program for Operational Prediction of Toxic Fuel Hazards	R. K. Dumbauld J. R. Bjorklund J. F. Bowers	June 1973
	Prediction of Conenctrations Downwind from the Delta-Thor Launch of November 10, 1972	Same as above	N/A
	Prediction of Concentrations Downwind from the Scout-Algol III Launch of August 13, 1972	Same as above	N/A
	Development of Simplified Formulas for Estimating Worst-Case Ground-Level Concentrations Resulting from Normal Launches of Large Space Vehicles	Same as above	N/A

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STATUS: Technical Progress: source and meteorological data inputs required by the dispersion transport models are standardized and simplified.

A technical note "Prediction of Concentrations Downwind from the Delta-Thor Launch of November 10, 1972" was completed. This note describes the calculation of the ground exhaust cloud generated during the launch and presents predictions of HCl, CO, and Al_2O_3 downwind from the source.

A simplified formula for predicting maximum ground-level concentrations of rocket exhaust by-products resulting from worst-case meteorological conditions was derived.

A technical report describing prediction model estimates of HCl, CO, and Al_2O_3 concentrations downwind from the launch of a Scout-Algol III vehicle on August 13, 1972, at Wallops Island was prepared. Concentrations were calculated for ground level and at the height of the centroid of the ground exhaust cloud using the MSFC Multilayer Diffusion Program.

The MSFC Multilayer Diffusion Models were adapted for use on an IBM 7044 Computer. This adaptation was accomplished because of the difficulty in obtaining time on the 1108 Computer.

Calculations were made to determine "safe" heights for dumping potentially toxic fuels from the TUG vehicle to avoid exceeding allowable ground-level concentrations.

Profiles of ground-level concentrations of HCl, CO, and Al_2O_3 for normal Titan III launches for selected meteorological regimes were prepared. These predictions were used for planning a program for sampling concentrations from a Titan III launch in early November 1973.

A simplified version of Model 4 (Layer Breakdown Model) of the MSFC Multilayer Diffusion Model Computer Program for use on the Hewlett Packard Model 9820 A Calculator was prepared. This program was developed for preparation of real-time predictions for support of measurement programs.

Predictions were made of downwind concentrations of HCl, CO, and Al_2O_3 resulting from Titan III C launches at Kennedy Space Center and Vandenberg Air Force Base under 15 selected weather situations. These estimates will be used to assess the environmental impact of Titan III C launch operations under various meteorological regimes.

ITEM 7. (continued)

Report No:	Title: MONTHLY PROGRESS REPORTS	Authors:	Date Transmitted:
	Confidence Levels for Estimates of Safe Heights for Dumping Fuel from a TUG Vehicle	Same as above	N/A
TR-73-301-03	Downwind Hazard Calculations for Titan III Launches at Kennedy Space Center and Vandenberg Air Force Base	R. K. Dumbauld J. R. Bjorklund J. F. Bowers H. E. Cramer	September 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:

Operations, Maintenance and Safety

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
John W. Kaufman, S&E-AERO-YA	453-3159	William W. Vaughan, S&E-AERO-Y

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Atmospheric Scavenging of Hydrochloric Acid
Contractor: IIT Research Institute Contract No. NAS8-29668
10 West 35th Street
Chicago, Illinois 60616
Contract No. H2528B, AEDC, Arnold Air Force Station, Tenn. 37380

OBJECTIVE: To study hydrochloric acid reaction and combination processes with water vapor, sodium chloride, aluminum oxide, and various other elements and compounds emitted by solid rocket motors. Conduct laboratory studies to determine the degree that hydrochloric acid will be leached out of stabilized solid rocket engine exhaust clouds by rain.

APPROACH: Make a thorough review of past research on rain scavenging of aerospace engine exhaust by-products and other particulates emitted into the atmosphere. Conduct controlled environmental chamber tests to determine the degree of scavenging of HCl, Al_2O_3, CO, CO_2, and other materials by water vapor and droplets. Chemically analyze the gases, particulates, and moisture to assess the reactions, recombinations, acidity, and physical characteristics to lead to a proper determination of rain scavenging coefficients to use in available atmospheric diffusion models.

STATUS: The IIT Research Institute in Chicago, Illinois was chosen as the contractor to do the work. It is an eight month effort. The study and chamber tests will be conducted at the IITRI laboratories. Their 18 foot spherical, environmentally controlled chamber will be employed. Several sub-scale rocket motors and raw propellant will be fired to generate effluent compounds similar to that to be produced by the proposed Space Shuttle rockets and other solid rocket motors.

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Only monthly progress reports have been received to date.

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4. TITLE:

Electrical Power

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Herndon, R. H.	205-453-1508	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of High Temperature Flat Conductor Cable
In-House & NAS8-29076 Martin Marietta Corporation, Orlando, Florida 32805

OBJECTIVE: To continue in-house development and utilize a supporting contract for the design, development and testing of high temperature flat conductor cable (FCC). The contract effort shall include the design, fabrication, test and delivery of 3000 feet each of two sizes of high temperature (-65°C to 350°C) flat conductor cable having pre-insulated conductors. A process and procedure for stripping shall be developed and documented as part of the contract. The in-house effort will include testing, electrical characteristic measurements, termination hardware and process development, establishment of specifications and engineering application studies.

APPROACH: The contractual effort will be accomplished in two phases: Phase 1 - A prototype FCC using the selected materials and manufacturing method will be fabricated and evaluated to determine if the contract requirements are met and if the stripping method proposed and used is satisfactory. At least 30 feet of continuous FCC will be forwarded for evaluation which will be made simultaneously by the contractor and MSFC. Phase 2 - After the results of the tests have been evaluated and approved by MSFC, the fabrication and production of 3000 feet of each size of FCC will then begin. In-house effort will continue until the objective is accomplished.

STATUS: Technical Progress: After preliminary test and evaluation of various films, adhesives and construction processes; two methods of developing a high temperature FCC were considered. The first method was to prewrap the individual conductors by using

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Letter Report No. 14	"Design, Development, Fabrication and Testing of High Temperature Flat Conductor Cable"	Walter S. Rigling	20 September 1973.

FIRST BENEFITTING PROJECT: Space Shuttle or Space Systems

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TASK: Development of High Temperature Flat Conductor Cable .

STATUS: Technical Progress: (Continued)

polyimide film coated with FEP adhesive on both sides and overcoating with a liquid polyimide. The second method was to laminate the conductors between two layers of polyimide (Kapton) film coated with polyimide (Kerimid) adhesive. The second method was chosen because a FCC of this construction offered higher heat resistance, lower fabrication costs, better strippable characteristics and more compactness. Kerimid had not previously been used as an adhesive in a roll laminating process; therefore, it was necessary to develop a technique for this application. To allow time for this development, the contract was extended. Lamination of the twenty-five conductor and the three conductor cables was accomplished on September 28 and 29, 1973. Several approaches using combinations of rubber rollers and steel rollers were tried. The most successful cable fabricated was a twenty-five conductor version using two steel rollers at 350°F and two feet per minute.

Management Progress: Contract NAS8-29076 was awarded on June 30, 1972 for fourteen months duration. A six and one-half months extension has been granted at no additional cost to the Government.

Conclusions: Joint in-house and contractual efforts have shown that the Kapton films coated with Kerimid adhesive can be successfully laminated.

Problems: No major problems have been reported by the contractor.

Forecast: The contractor should complete Phase 1 of the contract in October 1973 and complete Phase 2 in March 1974. In-house effort should be completed in December 1974.

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4. TITLE:

Electrical Power

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Herndon, R. H.	205-453-1508	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Shielded Flat Conductor Cable In-House

OBJECTIVE: The major objective of this effort is to provide technology (methods, techniques, procedures, tools and equipment) for the fabrication of shielded flat conductor cable (FCC) systems which would effectively shield against RFI and EMI in applications where these interferences pose a problem in future manned and unmanned missions.

APPROACH: To meet the objective, in-house work must include preparation (stripping) of the cable ends for reliable and inexpensive termination, testing, electrical characteristic measurements, termination hardware and process development, establishment of specifications, and engineering application studies. This effort is being accomplished in five phases: (1) Development of an effectively shielded FCC which can be reliably and inexpensively terminated, (2) Testing and evaluation of prototype cables, (3) Development of processes and termination hardware, (4) Fabrication of prototype cables for engineering application studies, and (5) Prepare final report and documentation.

STATUS: Technical Progress: Basically, two types of shielded FCC have been developed: (a) An insulated copper foil laminated to the outer surface of the FCC. This method reduces the flexibility of the cable and presents a problem in stripping and termination of the cable. (b) A loose overlay of an insulated copper foil. This method requires a tie down of the shield at intervals along the length of the cable and care in handling to prevent damage to the shield. Stripping and termination is also a problem. A supplier is being sought for a ½ oz. copper foil with a 1 mil Kapton film bonded on one side using a chemically strippable adhesive with a heat resistance sufficient to with-

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No formal in-house report has been issued. In-house accomplishments are reported in the Weekly Notes.

FIRST BENEFITTING PROJECT: Space Shuttle, Tug or Space Systems

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TASK: Development of Shielded Flat Conductor Cable

STATUS: Technical Progress: (Continued)

stand the laminating temperature of Kapton/FEP insulated FCC (280°C). A shield of this composition could be added during the fabrication of the FCC. The Kapton and shield adhesive could be removed chemically and the FEP mechanically (FEP cannot be stripped chemically). A portion of the end of the shield, as well as the ends of the conductors, must be stripped for grounding to accomodate termination. Tests are being conducted on previously developed shielded FCC to determine the effectiveness of the copper foil as a shield against RFI and EMI.

Management Progress: Work continues on this in-house effort under a restricted manpower allocation and with no Advanced Development FY-74 approved funding.

Problem: The major problem which exists in the development of shielded FCC is in the area of stripping and termination.

Cause of Problem: The basic FCC construction is Kapton/FEP insulated. This cable may be stripped quickly, easily and economically using a stripping tool with a sharp steel blade which cuts through the Kapton and into, but not through, the FEP and stripping both away in one quick stroke. When an insulated ½ oz. soft copper foil is added to this construction, stripping becomes a major problem. The shield insulation and adhesive must be removed leaving the foil intact. The adhesive bonding the foil to the FCC, the FCC insulation film and its adhesive must also be removed. At the present time this operation is slow, tedious and quite expensive.

Suggested Solution: Locate a source for a ½ oz. soft copper foil insulated on one side with a 1 mil Kapton film laminated to the foil using a chemically strippable adhesive having a heat resistance capable of withstanding the laminating temperature of Kapton/FEP insulated FCC. This composite would then be laminated to the FCC during fabrication in a single operation. The foil insulation film and its adhesive could be removed chemically, the foil folded back and the Kapton/FEP removed with the cold blade stripper in the same manner as an unshielded cable is presently stripped.

Forecast: In-house work for Phase I should be completed in March 1974. This task should be completed in February 1975 with the delivery of the Final Report.

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4. TITLE:

Electrical Power (Flat Conductor Cable Systems for Future Missions)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Herndon, R. H.	205-453-1508	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Flat Conductor Cable Connector Spring Contacts Development
In-House & NAS8-30287 Astro-Space Laboratories, Inc., Huntsville, AL 35806 (Note *)

OBJECTIVE: The major objective of this RTOP is to provide technology (methods, techniques, procedures, tools and equipment) for the fabrication of flat conductor cable (FCC) systems which could be used for future manned or unmanned missions. This specific task is for the FCC connector spring contacts development and will include the investigation, analysis and development of spring contacts (BeCu spring investigation, failure analysis, fatigue, redundant contacts, etc.).

APPROACH: An in-house effort and a supporting contract are being utilized for this task. The in-house effort will include the configuration and materials study, preliminary design of contacts, prototype fabrication and tests and specifications. The contractor will use the recommended MSFC drawings for a redundant connector contact, MSFC tooling drawings and MSFC connector design drawings during his performance of the contract. The contractual work will be performed in phases: Phase I - Evaluation of redundant vs single contacts. Phase II - Tooling Design for Connector Parts. Phase III - Contact Manufacture and Tests. Phase IV - Manufacture, Assembly and Delivery of Connectors with drawings and specifications.

STATUS: Technical Progress:

In-House - Prototype redundant Beryllium Copper spring contacts have been fabricated and tested. This design was used to initiate a procurement request for the fabrication

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Report (August 16 through September 16, 1973), "Flat Conductor Cable Connectors", Basil W. Wheeler. (Note*)			

(Note * - Contract NAS8-30287 contains a Scope of Work for both the FCC Connector Spring Contacts Development and the Development of FCC Connector Body)

FIRST BENEFITTING PROJECT: Space Shuttle, Tug or Space Systems

MSFC - Form 350 (March 1973)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-05 PAGE 2 OF 2

TASK: Flat Conductor Cable Connector Spring Contacts Development

STATUS: Technical Progress: (Continued)

of a small production quantity of redundant contacts for evaluation tests and use by the contractor.

Contract - As of September 16, 1973, the contractor has completed about 30% of the work toward the completion of the redundant contact evaluation.

Management Progress: Contract NAS8-30287 was awarded on August 16, 1973 for an eight month period of performance. (See Note *)

Conclusions: None

Problems: None

Forecast: The four phases of the contract should be completed on the following dates: Phase I - September 27, 1973, Phase II - January 10, 1974, Phase III - January 10, 1974, and Phase IV - April 16, 1974. The in-house effort is expected to be completed in October 1974.

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4. TITLE:

Electrical Power (Flat Conductor Cable Systems for Future Missions)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Herndon, R. H.	205-453-1508	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Flat Conductor Cable Connector Body
In-House & NAS8-30287 Astro-Space Laboratories, Inc., Huntsville, AL 35806 (Note *)

OBJECTIVE: The major objective of this RTOP is to provide technology (methods, techniques, procedures, tools and equipment) for the fabrication of flat conductor cable (FCC) systems which could be used for future manned or unmanned missions. This specific task is for the development of an FCC connector body and will include the investigation and processing of various molding and potting materials (materials that will be abrasion resistant and meet the necessary requirements in MIL-C-55544A for space environment).

APPROACH: A large in-house effort and a supporting contract are being utilized for this task. The in-house effort will include the investigation of various molding and potting materials, material selection and tests, preliminary design of connector body, prototype fabrication and tests, connector assembly and specifications. The contractor will use the recommended molding and potting materials, MSFC tooling drawings and MSFC connector design drawings during his performance of the contract. The contractual work will be performed in phases: Phase I - Material Selection and Value Analysis (Submission to MSFC for final selection). Phase II - Connector Manufacture and Assembly Tooling (Design and manufacture or procure the tooling required for producing connector parts and for connector receptacle assembly). Phase III - 1.5 inch FCC Plug Termination Tooling (Deliver termination tooling and cable-to-plug assemblies). Phase IV - Manufacture and Assembly of Connector Receptacles (After acceptance testing is completed and approved, deliver required connector receptacles in three sizes - 1.0, 1.5 and 2.0 inch).

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Report (August 16 through September 16, 1973), "Flat Conductor Cable Connectors", Basil W. Wheeler. (Note *)			

(Note * - Contract NAS8-30287 contains a Scope of Work for both the Development of FCC Connector Body and the FCC Connector Spring Contacts Development)

FIRST BENEFITTING PROJECT: Space Shuttle, Tug or Space Systems

MSFC - Form 350 (March 1973)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-05 PAGE 2 OF 2

TASK: Development of Flat Conductor Cable Connector Body

STATUS: Technical Progress:

In-House - The selection and testing of materials has been completed. A glass filled epoxy material and a moldable polyimide material were selected for further evaluation. A preliminary design of the connector body was completed and will be discussed with the contractor. Materials, test data and pertinent information supporting the selection of materials are being reviewed in accordance with the contract.

Contract - The investigation of materials is about 65% complete. The contractor has completed about 50% of the work toward the completion of the connector value analysis. The contractor examined the shell design in light of several functional problems encountered in the current configuration and will discuss certain modifications with a tooling manufacturer. The contractor is evaluating the preliminary design of the connector body. NOTE - This is STATUS as of September 16, 1973 for Contractor.

Management Progress: Contract NAS8-30287 was awarded on August 16, 1973 for an eight month period of performance. (See Note *)

Conclusions: None

Problems: None

Forecast: The four phases of the contract should be completed on the delivery schedule dates: Phase I - September 27, 1973, Phase II - January 10, 1974, Phase III - January 10, 1974, and Phase IV - April 16, 1974. The in-house effort is expected to be completed in October 1974.

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Marshall Space Flight Center	01/04/73 - 30/09/73	CURRENT NO.: 909-54-07	PRIOR NO.:

4. TITLE:

Advanced Crew/Computer Communications

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Bobby Hodges	(205) 453-1385	Dr. W. K. Polstorff

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Advanced Crew/Computer Communications Techniques

NAS8-25701 McDonnell Douglas Astronautics Company
Huntington Beach, CA 92647

OBJECTIVE(S): Develop techniques, methods and system requirements for effective communications between man and computer. Develop, implement and demonstrate operational crew/computer communication systems. These demonstrations utilize a unique programmable command keyboard and display (PKD) terminal, structured vocabulary and software.

APPROACH: Part I -- Definition and development of a crew/computer communications system.

Phase A. Formulation of crew/computer communications system requirements.

Phase B. Requirements specification for crew/computer communications system major components and techniques.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR112712	Crew/Computer Communications Study	Mr. R. Joslyn Mr. G. Montoya	October 1972
	Bi-Monthly Technical Progress Report	Mr. R. Noulin	March 1973
	Bi-Monthly Technical Progress Report	Mr. R. Noulin	June 1973

Phase C. Implementation and demonstration of operational crew/computer communications systems.

Part II - Development of crew/computer communications system using speech recognition.

Phase A. Development and demonstration of 25-word Word Recognition System (WRS).

Phase B. Development and delivery of 100-word WRS.

Phase C. Integration of WRS with operational ground computer system.

Phase D. Integration of WRS with operational on-board computer system.

Part III - Development of crew/computer communication system requirements and techniques for specific applications.

Phase A. Development and demonstration of crew/computer communication techniques and system for spacecraft experiment performance.

Phase B. Development and demonstration of crew/computer communication techniques and system for ground checkout and launch system.

STATUS: Part I - All phases have been completed.

Part II - Phase A of Part II is complete. Phase B is 90-percent complete with delivery of the 100-word Word Recognition System planned for September 1973. Current word recognition accuracy is in the 90-95-percent range and work is being performed to improve this figure. Phase C has been initiated.

Part III - The technical approach for Phase A, the C/CC system for experiment applications, is complete. The design scenario has been completed and documented. Software is being designed and implemented and/or modified to include the experiment demonstration package within the existing framework of the demonstration implemented for Part I - Phase C.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Splawn, J. L.	205-453-0120	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Simulation Techniques and Capabilities In-House

OBJECTIVE: The major objective of this effort is directed toward the development of simulation equipment and improvement of techniques for performing engineering studies and evaluations in a simulated zero gravity environment with greater efficiency and safety.

APPROACH: In-house effort is being used to develop and update this simulation equipment, simultaneously conforming to the current space suit configurations, simulation test requirements and test hardware design.

STATUS: Technical Progress: Measurement of metabolic rate of space-suited subjects is being investigated. Work is being conducted to investigate large mass handling techniques under simulated zero gravity conditions. Continuation of work on other simulation techniques for free-flying platforms, rendezvous and docking, solar lighting conditions, etc., is dependent upon an additional allocation of manpower.

Management Progress: Additional funds and manpower allocation must be made available to maintain this capability for neutral bouyancy simulation. This requirement was proven during the Neutral Bouyancy Flight Support of the recent Skylab Problems. The fidelity of simulation tests must be continually up-graded to better simulate the actual flight conditions experienced while in orbit.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

No formal in-house report has been issued. In-house accomplishments are reported in Weekly Notes and in new releases to the Press, Radio and Television.

FIRST BENEFITTING PROJECT: ATM, Skylab, Space Systems, Space Shuttle

MSFC - Form 360 (March 1978)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-21
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TASK: Development of Simulation Techniques and Capabilities

STATUS: (Continued)

Conclusions: This improved effectiveness and safety of space simulation testing has resulted in allowing a greater number of astronauts, designers and engineers to gain first-hand information and training with regard to man/machine problems by actually performing tasks in space simulations.

Problems: None

Forecast: This in-house effort should continue until all simulation requirement have been completed. Skylab 4 crewmen (Astronauts Gerald Carr, Ed Gibson and William Pogue) are scheduled to complete their Neutral Buoyancy Training on October 10, 1973. The Skylab 4 backup crew (Astronauts Vance Brand, Don Lind and William Lenoir) are scheduled to complete their Neutral Buoyancy Training on October 12, 1973.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Taylor, R. A.	205-453-4870	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of a Computerized Welding Skate with CCTV Arc Guidance In-House

OBJECTIVE: The objective of this in-house effort was to develop a computer controlled welding skate with a newly developed closed circuit television (CCTV) Welding arc guidance tracking system for contoured and double contoured precision welding.

APPROACH: This in-house task included work to (1) evaluate the CCTV engineering model MK-1 in a welding program, (2) complete modifications to the automatic weld skate and conduct weld tests, (3) complete the design, fabrication and testing of an updated CCTV engineering prototype MK-2, and (4) integrate the skate and the CCTV Arc Guidance.

STATUS: Technical Progress: The Advanced Development work under this task was completed with the fabrication and testing of the updated CCTV engineering prototype MK-2. This program was transferred to the Space Shuttle External Tank welding program; therefore, additional work will be performed on the development of an MK-3 system.

Management Progress: Since funds and manpower allocation was not available for the continuation of this development, this effort is considered to be terminated and will be continued under the Space Shuttle Program.

Conclusions: Preliminary tests indicate that the final system will be capable of 3-axis automatic welding of contoured and double contoured parts while maintaining a weld speed accuracy of $\pm$ 3%, a torch angle accuracy of $\pm$ 1 degree and a tracking accuracy of $\pm$ 0.079 cm (0.031 inch).

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Support Contractor (Hayes) Report No. ED-9-70, "A Preliminary Study of the Computerized Weld Skate", Barber and Wunsch, June 30, 1970.

Support Contractor (Hayes) Report No. ED-17-70, "Progress Report on the Computerized Weld Skate", Barber and Wunsch, October 30, 1970.

(Related Program Funded - SCI Report No. 3362-M1-001/3, "Automatic Weld Skate Integration, Final Report", Leslie Gard, July 16, 1973.)

FIRST BENEFITTING PROJECT: Space Shuttle

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-21 PAGE 2 OF 2

TASK: Development of a Computerized Welding Skate with CCTV Arc Guidance

STATUS: (Continued)

Problems: None

Forecast: This task is considered to be terminated.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Simpson, W. G.	205-453-2670	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Adhesive Bonding Technology for Space Application In-House

OBJECTIVE: The objective of this task was to provide a quick, reliable means of attaching structural members, effecting repairs, or sealing inhabited space vehicles.

APPROACH: In-house effort was utilized in the design, development, fabrication and test of an adhesive bonding device which was later called a Stud Bonding Gun.

STATUS: Technical Progress: In compliance with a request by Mr. D. Harmon, Naval Weapons Center at China Lake, California, assistance was given to the Valaero, Inc., Valparaiso, Florida, during their redesign of the Stud Bonding Gun to allow operation under water at a depth of sixty feet. This effort included technical consultant assistance of design modifications and evaluating the contractor tests on a Stud Bonding Tool.

Management Progress: During this reporting period, funds for travel were furnished by the Naval Weapons Center. This task is considered to be completed.

Conclusions: This development also has commercial potential. A manufacturer was denied exclusive rights to fabricate and sell the items developed on this program.

Problems: None

Forecast: This task has been completed.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA Technical Brief 69-10009	by MSFC Technology Utilization Office		

FIRST BENEFITTING PROJECT: Space Systems & Space Station

MSFC - Form 350 (March 1973)

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Jackson, L. C.	205-453-4909	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Fabrication Technology for Electronic Circuitry Components In-House

OBJECTIVE: To continue development efforts on fabrication technology for electronic circuitry components. The present effort includes the development of a plated through-hole process applicable to two or more planes of circuitry for printed wiring boards used in both flight and ground support equipment circuitry. Specific requirements are for a deposit of copper that will not crack when subjected to repeated thermal shocks of molten solder application, low temperature and vibration environments. This would give a plated interconnect that is reliable without redundant wiring.

APPROACH: In-house work is being continued on the investigation and evaluation of various incremental aspects of electronic circuitry fabrication. The present effort will include work to (1) design and fabricate test samples of large colony from various types of copper plating baths under various operating conditions, (2) metallurgically evaluate each condition as deposited, (3) subject test samples to thermal shock, (4) metallurgically evaluate for cracks and defects, and (5) prepare test report and documentation.

STATUS: Technical Progress: In-house metallurgical evaluation of the first thermal shock samples has been completed. Additional tests are being performed. Some samples were eliminated from contention after the first thermal shock exposure. Incremental improvements in the mechanical fixturing and operating control parameters have been implemented.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
No formal in-house report has been issued. In-house accomplishments are reported in the Weekly Notes.			

FIRST BENEFITTING PROJECT: Space Shuttle or Tug

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-21 PAGE 2 OF 2

TASK: Development of Fabrication Technology for Electronic Circuitry Components

STATUS: (Continued)

Management Progress: Work continues on this in-house effort under a restricted manpower allocation and with no Advanced Development FY-74 approved funding.

Conclusions: Continued effort must be performed on the evaluation of the thermal shock effects and failure mechanisms before final requirements can be determined.

Problems: None

Forecast: To meet manpower restriction, all in-house work must be completed by the end of FY-74.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Jackson, L. C.	205-453-4909	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Process Development for Electronic Interconnection of Microcircuit Devices In-House

OBJECTIVE: To continue development effort on electrical interconnection techniques for assembly of microminiature devices. This effort will include the development of mounting and joining techniques for optimization of reliability for devices and interconnecting systems of microcircuit devices.

APPROACH: In-house work is being continued to investigate and develop conceptual methods of interconnection and evaluate for quality and manufacturability. The present effort includes (1) development of mounting and joining concepts, (2) development of lead bending, forming and trimming tooling, (3) assembly and evaluation of assembly techniques, (4) evaluation of concepts for optimum quality and reliability with minimum costs, and (5) prepare test reports and documentation.

STATUS: Technical Progress: Available manpower was utilized on higher priority work during this reporting period.

Management Progress: Work will continue on this in-house effort under a restricted manpower allocation and with no Advanced Development FY-74 approved funding.

Conclusions: Developed techniques show much promise for increased reliability and reduction in costs.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
No formal in-house report has been issued. In-house accomplishments will be reported in the Weekly Notes.			

FIRST BENEFITTING PROJECT: ATM, Space Systems, Space Processing

MSFC - Form 350 (March 1973)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-21 PAGE 2 OF 2

TASK: Process Development for Electronic Interconnection of Microcircuit Devices

Problems: None

Forecast: To meet manpower restriction, all in-house work must be completed by the end of FY-74. Evaluations and tool development for flat pack units will be dependent upon an allocation of manpower.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Blaise, H. T.	205-453-2005	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Maneuvering and Manipulating Units In-House

OBJECTIVE: This effort is directed toward the development of maneuvering vehicles and manipulating units. Items will be used for the purpose of demonstration testing in simulated space environments; such as air bearing surfaces and underwater, with final effort in support of EVA/IVA space activated simulations.

APPROACH: The approach taken to meet the objective included the following areas of work: (1) Develop Air Bearing Lift Pad and manipulating sub-systems. (2) Identify potential application. (3) Test and evaluate to determine technological problems. (4) Upgrade design and hardware. (5) Test and document for future application. (6) Develop multi-purpose Joystick Control for seven-degree-of-freedom master slave manipulator with rate control feature. (7) Develop Extendable Stiff Arm Manipulator (ESAM) for docking experiments. (8) Develop underwater maneuvering Free Flying Platform. (9) Develop analog controls for manipulators. (10) Develop Automatic Cable Management Gantry. (11) Conduct design study for exchanging End Effector Jaws remotely. (12) Develop Joystick/Analog control for ESAM manipulator. (13) In-house tests and evaluation.

STATUS: Technical Progress: The above items (1) through (7) have been completed and reported on in prior reports. Some of the developed items are now being utilized in the work being done for RTOP 970-63-20. Work continued on the following items: (8) Basic unit is complete. Underwater sub-systems (thirteen degrees-of-freedom

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Equipment Contract NAS8-29078 - Final Contract Report, "Development of an Automatic Cable Management Gantry, James R. Allen & Andrew Karchak, Jr., September 1973			

FIRST BENEFITTING PROJECT: Free Flying Teleoperator/Shuttle

MSFC - Form 350 (March 1973)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-54-21 PAGE 2 OF 2

TASK: Development of Maneuvering and Manipulating Units

STATUS: Technical Progress: (Continued)

Joystick Controller, control electronics, on-board power supply and circuits, etc.) were tested and operated satisfactory. U-CAMP man aboard and remote demonstration testing was documented on video tape. A test plan is being developed for evaluating U-CAMP compatibility to translate and maneuver a 1589 kg (3500 pound) dryweight mass underwater. Design specification for the radio control link was completed and design request action was taken. (9) Analog controller assembly and preliminary testing was completed. Tests indicated that the analog unit was too heavy and that the extend brake did not function as expected. Redesign of the controller has been completed and necessary modifications are being made. (10) The Automatic Cable Management Gantry delivered by R&D Engineering on Contract NAS8-29078 did not meet operational requirements. Modifications are being made which should resolve operational inefficiencies. (11) Design study for exchanging the End Effector Jaws remotely was completed and a working demonstration model was provided. Further development of the Terminator Kit Assembly (TKA) will be continued under RTOP 970-63-20. (12) R&D Engineering delivered the Joystick/Analog Controller. This model was functional tested by MSFC and met about 75% of the functional requirements. Improvements can be expected on second model. Draft copy of Final Report has been approved. Since funding and manhours are not available under this RTOP, the second model should be developed under RTOP 970-63-20. (13) In-house testing and evaluation is being performed under a restricted manpower allocation.

Management Progress: Work continues on this in-house effort under a restricted manpower allocation and with no FY-74 approved funding. Components purchased under Contracts NAS8-29218 and NAS8-29078 were delivered.

Conclusions: The Air Bearing Lift Pad and Underwater Model Maneuverable Units are expected to provide versatile test beds for Free Flying Teleoperator test and simulation studies. The ADAMS manipulator preliminary test indicates improvement of the Servo Control Unit and will provide a valuable manipulator system for various remote manipulator studies and simulation exercises. The 14-channel control and Joystick Analog Proportional Rate Control Unit provided a tool for trade-off studies of control units. The Automatic Cable Management Gantry will improve Free Flying simulation testing. The ESAM manipulators and Joystick/Analog Control will provide the equipment necessary to do simulated remote EVA grappling experiments.

Problems: Minor problem areas are stated under STATUS.

Forecast: Fabrication and testing must be completed in June 1974 to meet manpower allocation restriction.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
McCaig, J. C.	205-453-5088	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Process Development and Equipment Improvement for Electron Beam Welding In-House

OBJECTIVE: The objective of this in-house effort was to develop electron beam welding systems for the fabrication of space vehicle components and structures; to further improve applicability, joint efficiency and economy of fabrication; and to reduce weld distortion.

APPROACH: This in-house task included work to refine the out-of-vacuum electron beam welding equipment and to determine equipment requirements and processes for application in future NASA Programs.

STATUS: Technical Progress: The Advanced Development work under this task was completed with the investigation of the out-of-vacuum electron beam welding process for application with 2219-T87 Aluminum Alloy. This welding process will be investigated for use in the Space Shuttle Program.

Management Progress: Since funds and manpower allocation were not available for the continuation of this development, this effort is considered to be terminated and will be continued under the Space Shuttle Program.

Conclusions: Results of welding tests indicated that this welding equipment is not readily applicable with the aluminum alloys.

Problems: None Forecast: This task is considered to be terminated.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

No formal in-house report has been issued. In-house accomplishments are reported in the Weekly Notes.

(Related Report - Internal Note, S&E-PE-IN-72-1, "Non-Vacuum Electron Beam Welding for Shuttle Applications", dated July 13, 1972)

FIRST BENEFITTING PROJECT: Space Shuttle or Space Systems

MSFC - Form 850 (March 1973)

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Siler, H. L. (Alt. COR) (*)	205-453-5088	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Analysis of Thermal Stress and Metal Movement During Welding
NAS8-24365 Massachusetts Institute of Technology, Cambridge, MA 02139

OBJECTIVE: The major objective of this effort is to perform studies and a complete analysis of thermal stress and metal movement during welding.

APPROACH: A contract is being utilized to perform (1) mathematical analysis of temperature distribution, (2) analysis of stress distribution, and (3) prediction of metal movement.

STATUS: Technical Progress: Phase Report, 73-16, describes the work performed to June 1973. Appendix A of the report, which is the thesis entitled "Investigation of Thermal Stress and Buckling During Welding of Tantalum and Columbium Sheet" prepared by Mrs. K. Anne S. Hirsch, describes the work performed on Phase B and Phase D of the contract. Appendix B of the report, which is the thesis entitled "Analysis of Two-Dimensional Thermal Strains and Metal Movement During Welding" prepared by LCDR Jon J. Bryan, USN, describes the work performed on Phase E of the contract. Effort is being performed on the balance of the Scope of Work.

Management Progress: The original research contract on "Analysis of Thermal Stresses and Metal Movement during Welding" was initiated on May 15, 1969. The study was completed on October 14, 1970, and the final report of the study was published on December 15, 1970, as the NASA Contractor Report CR-61351. An extension of the contract became effective on October 14, 1970 with an appropriation of addition funds. In June 1973,

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA Contractor Report CR-61351	"Analysis of Thermal Stresses and Metal Movement During Welding"	K. Masubuchi	December 15, 1970.

Technology Utilization Office issued a NASA Tech Brief, B72-10333, "Analysis of Thermal Stress and Metal Movement During Welding", dated July 1972.

Phase Report, 73-16, "Analysis of Thermal Stresses and Metal Movement During Welding", T. Muraki and K. Masubuchi, June 21, 1973.

NOTE (*) Mr. R. M. Poorman, S&E-ASTN-MM, has been designated as COR.

FIRST BENEFITTING PROJECT: Space Shuttle, Space Systems, Space Station

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TASK: Analysis of Thermal Stress and Metal Movement During Welding

STATUS: Management Progress: (Continued)

the contract was again extended until June 30, 1974 with no additional funding and the program was further expanded to include Phase G, "Perform experiments on thermal stresses and metal movement in joining thin cylindrical shells", at no additional cost to the Government.

Conclusions: Although basic equations have been developed to analyze thermal stresses and metal movement in joining thin cylindrical shells, it is important to compare analytical solutions with experimental results. Efforts will be made to generate experimental data on cylindrical shells.

Problems: A major problem in the theoretical study is how to develop a computer program with satisfactory accuracy and reasonable cost. During the entire course of this research, persistent efforts have been made by the contractor to achieve that goal and computer programs have been modified many times.

Forecast: Contractual work is scheduled to be completed by June 30, 1974.

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4. TITLE:

Manufacturing and Inspection

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Holland, J. G.	205-453-1504	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Feasibility of Using the Weld Bond Concept for Space Vehicles In-House

OBJECTIVE: The major objective of this effort was to investigate and determine the feasibility of using the weld bond concept in the fabrication of heavy gauge materials for space vehicle components.

APPROACH: The limited funds were to be utilized for a study (in-house and supporting contract, if required) to determine the feasibility of using the weld bond concept for 6.4mm (0.25 inch) thick materials. Results obtained in the final report (LMSC-D282640) by the Lockheed Missiles & Space Company under Contract NAS9-12498 and from the in-house effort by S&E-ASTN were considered and utilized.

STATUS: Technical Progress: In-house effort was expended to determine a sound basis for performing this study completely in-house or on a contract. A feasibility sample of 7075-T6 Aluminum Alloy, 6.4mm to 6.4mm utilizing a capillary action weldbonding process, was received from Lockheed-Georgia. The procedure used for the sample was to clean, spot weld, chromic acid anodize, apply adhesive and cure. This procedure was different from that of the weld bond concept and was not considered acceptable. Since the weld bond concept did not seem feasible for joining 6.4mm thick materials, this study will not be continued.

Management Progress: Since the preliminary study and evaluation of available data indicated that additional funds and manpower should not be expended on the feasibility study, the funds were returned and this effort was terminated.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

FIRST BENEFITTING PROJECT: Space Systems

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TASK: Feasibility of Using the Weld Bond Concept for Space Vehicles

STATUS: (Continued)

Conclusions: The weld bond concept did not seem feasible for joining 6.4mm thick materials.

Problems: None

Forecast: This effort is considered to be completed.

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4. TITLE: MANUFACTURING AND INSPECTION

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-QUAL T. F. Morris	453-4519	R. M. Henritze

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Advanced Remote Visual Inspection Techniques

OBJECTIVE: This work will consist of the development of a remote visual inspection system with a color TV camera system, coherent fiberoptics and illumination sources for inspecting the inside of tubing, small tanks, components, injector plates, etc. The system will have the capability of detecting various defects such as cracks, fatigue stress, electrolytic action, metal transfer, corrosion and heat damage in areas normally inaccessible for direct visual inspection.

APPROACH: A black and white TV portable system has been developed and has been used for inspections of critical hardware and facilities. Progress has been made in the development of color TV's and ultraviolet fiberoptics. These advancements can be made applicable to this advanced remote visual inspection system.

The work is to be accomplished in three phases: (1) Color - development of color presentation; (2) Ultraviolet Light - development of an ultraviolet illumination system, and (3) Techniques - development and refinement of inspection techniques. Phase I will consist of two primary tasks: (a) procuring a low light sensitive color TV camera system; (b) adapting fiberscopes to camera. Phase II will be accomplished concurrently with Phase I and will consist of three tasks: (a) Procuring ultraviolet illuminator; (b) Procuring non-coherent fiberoptics capable of transmitting ultraviolet light, (c) Adapting fiberoptics to an operating system.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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STATUS: Technical Progress: A study has been completed to define the equipments that will be needed for this project. These have been prioritized and procurement actions initiated for the most critical items.

Management Progress: Funding has been approved in the amount of $30K and is being allocated to the purchase of top priority equipments. Manpower is being applied to this project at a rate of .5 man/year.

Conclusions: With the approval of funds, and the projected early delivery of equipment, the project should progress at a satisfactory pace.

PROBLEMS: None

FORECAST: Completion of procurement cycle. Adaptation of fiberoptics to TV camera system.

PUBLICATIONS: None

REMARKS: None

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MSFC Marshall Space Flight Center	01 04 73 to 30 09 73	CURRENT NO.: 909-54-22	PRIOR NO.: 909-54-22

4. TITLE:

Feasibility and Trade-off Study of Aero-Maneuvering Orbit-to-Orbit Shuttle (AMOOS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-DIR Jesco von Puttkamer	205-453-1260	E. D. Geissler

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Feasibility and Tradeoff Study of Aeromaneuvering Orbit-to-Orbit Shuttle Contract NAS 8-28586, Lockheed Missiles & Space Co., HREC, Huntsville, Alabama

OBJECTIVE: To study and assess the general feasibility and to conduct tradeoff studies of an aeromaneuvering orbit-to-orbit shuttle (AMOOS) vehicle with the goal of identifying one or more promising systems. After identification and selection of a range of appropriate concepts in the first study phase, those systems are now undergoing concept evaluation and concept design. As a highly maneuverable third stage for the Space Shuttle, the AMOOS will utilize atmospheric entry-and-exit passes for synergetic maneuvering, i.e., energy dissipation (braking) and/or orbit-plane rotation (lateral maneuvering) for return from high-energy orbits to Shuttle rendezvous orbits.

APPROACH: During Phase I (Concept Selection) the following tasks have been performed: Task I - Assessment of Range of General Feasibility; Task II - Preliminary Definition of Requirements and Mission Characteristics; Task III - Selection of Representative Configurations; Task IV - Preliminary Analysis of Flight Environments, including aero-thermodynamics, performance, and flight mechanics; Task V - Vehicle Design Data Parameters, to develop influence factors; and Task VI - Tradeoff and Optimization Studies. In Phase II (Concept Evaluation) the selected concepts are being analyzed in all problem areas, including aero-thermodynamics, heat shielding, performance, loads, structures, weights, and subsystems.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-HREC TR D304600 June 1973	Feasibility and Trade-off Study of an Aeromaneuvering Orbit-to-Orbit Shuttle (AMOOS)	C. Donald Andrews	N/A

FIRST BENEFITTING PROJECT: Payload for Space Shuttle.

APPROACH (CONCLUDED):
Trade studies are being conducted, and the operational aspects will be investigated. An economic analysis will be performed, and required technology will be identified. In Phase III (Concept Design), the system resulting from the preceding Phase will be conceptually designed to subsystem level. In-depth studies of guidance requirements, trajectory optimization, aerodynamics, and flight control will be part of this study phase. Wind tunnel testing will be conducted during Phases II and III.

STATUS: Technical Progress: During the reporting period, final results from Phase I (Concept Selection) were published. In general, it is concluded that AMOOS is feasible. Two specific configurations, each using an ablative thermal protection system (TPS), were identified as the more promising. These configurations, AMOOS 1 and AMOOS 5, were selected from seven candidate configurations studied and capable of performing the Space Tug baseline and alternate missions. These missions can be performed by the two selected configurations with a structural contingency of approx. 1000 kg each. The baseline and alternate B missions allow further contingencies of approx. 840 kg and 1240 kg, respectively. Further results are: The feasibility of performing a plane change with the aerobraking is marginal at best due to an L/D requirement of about 2 to perform 28° plane change from geosynchronous altitude, which would conflict with high drag and high volumetric efficiency required of AMOOS. - The number of atmospheric passes should be kept below 10 to ensure that the Space Shuttle on-orbit stay time of 7 days is not violated. - Light weight nylon-phenolic/microballoon ablative material was found to provide the best TPS. - The feasibility of a deployable, high drag device is contingent upon the development of a material substantially better than the current Goodyear AIRMAT, on a mass per unit area basis. - The mixed mode of operation (aerobraking plus propulsive) was found to be impractical. Propulsive maneuver phases in space can lower heating rates but this would not affect equilibrium temperatures significantly. For ablative TPS (as for radiative TPS as well), no significant mass savings resulted. The AMOOS vehicle is in general less sensitive to variations in I_{sp}, structural mass, and mission altitude than is the Space Tug. - Due to dimensional restrictions imposed by the AMOOS payload compartment, AMOOS can perform only 86% of the identified Space Tug missions. The possibility of repackaging or redesigning these oversize payloads was not investigated. Many of these oversized payloads do appear, however, to be arbitrarily set to the maximum allowable diameter of the Shuttle cargo bay. — Phase II effort has been devoted to date to improving the stability of AMOOS 1 and 5. A new configuration, designated HB, has been developed, based on a new forebody design to maximize drag at a given L/D. Structural mass for the HB is the same as for AMOOS 1. All three vehicles under consideration are statically stable. Early results of Phase II show that AMOOS 1, 5, and HB can achieve phasing orbit apogee after one pass through the atmosphere under extreme off-nominal design conditions (+100% and -50% density variation, 7 km target corridor width). Two limiting trajectories have been computed, - one resulting in the deepest atmospheric penetration, shortest stay time, and highest heating rate, the other requiring the longest stay time, yielding lowest heating rate, but possibly the highest heat loading. To calculate non-continuum heating rates to the stagnation point of a sphere, a computer routine has been written. A flap analysis for HB was also performed. --

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Management Progress: Final results of Phase I were reviewed in an oral presentation on 6/15/73. The Phase I Final Report (see 7., page 1) was published on 7/3/73 and distributed. Final AMOOS Phase I study results were also presented by the COR to the Space Systems Division (Arthur Henderson) of Langley Research Center on 7/20/73, and discussed in depth. - Phase II of the contract was negotiated and initiated with Lockheed. A second contract, NAS 8-28608, for Wind tunnel testing on the AMOOS vehicle, was negotiated with Lockheed and initiated. A working session was held with wind tunnel personnel of the Ames Research Center at Moffet Field.- The Cooperative Study Project with DFVLR/Germany (Dr. Ernst Dickmanns) is progressing as planned.

Conclusions: The objectives defined for the reporting period in the milestone schedule have been met on time. The tasks specified in a detailed time/task chart were accomplished as planned. Further study in depth appears justified by present results.

Problems: None.

Forecast: Work on Phase II of the study will continue on schedule. The aerodynamic geometry of vehicles 1, 5, and HB will be finalized. Flap effects on trim CG range and vehicle stability will be analyzed, and flap geometry will be finalized. Analysis and design necessary to support the model test program will be initiated; in particular, aerodynamic and thermodynamic loading will be considered. - The Cooperative Study will continue.

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4. TITLE:

Information Management System (IMS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. Garrett S&E-ASTR-CF	453-4070	C. N. Swearingen S&E-ASTR-C

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Space Ultrareliable Modular Computer

CONTRACT NO.: NAS8-24909, NAS8-25582, NAS12-2233, NAS8-29072, NAS8-29929

OBJECTIVE: To design a computer for Space Application which provides the capability, adaptability, and reliability to accomplish the requirements of the applications. The design shall:

Incorporate state-of-the-art technologies including large scale integration (LSI), complementary metal oxide semiconductor (CMOS), beam lead interconnection, and hybrid packaging.

Have universal application.

Be software compatible with existing commercial computers.

Be cost effective.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
S&E-ASTR-C-001	SUMC Microsimulator	S&E-ASTR-C	October 1972
S&E-ASTR-C-002	SUMC Microinstruction Assembler	S&E-ASTR-C	October 1972
S&E-ASTR-C-003	SUMC-BB Operator Guide	S&E-ASTR-C	October 1972
S&E-ASTR-C-004	SUMC-BB CPU	S&E-ASTR-C	October 1972
S&E-ASTR-C-005	SUMC Computers	S&E-ASTR-C	November 1972
	SUMC-DV System Manual	RCA	May 1972
N70-42890	Advanced Aerospace Computer Technology	H. Garrett	March 1970
IEEE 1971 Proceedings	Space Computer Technology	H. Garrett	March 1971
MSFC-Technology	SUMC an Approach to Flight Computer Systems	H. Garrett	February 1973

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APPROACH:

1. Perform System Architecture & Logic Design of a computer commensurate with the objectives.

2. Construct an engineering development breadboard for Logic Verification. Develop microprograming and demonstrate compatibility objectives.

3. Construct an engineering development model to demonstrate use of LSI CMOS and design automation techniques.

4. Construct a technology model to demonstrate validity of packaging technology including; beam leads, multilayer substrates, and hybrid subassemblies.

5. Perform development tests sufficient to verify the integrity of design approaches.

6. Construct a prototype model in final selected technology and demonstrate that the objectives of the design have been achieved successfully.

7. Perform design verification testing of the prototype unit.

8. Perform related software and reliability studies.

9. Expand the computer into a multiprocessor and evaluate.

STATUS:

Technical Progress - The system and logic design of the basic SUMC has been accomplished. An engineering development model was constructed and functional operation fully verified. In addition, compatibility with existing commercial computers (IBM System 360) has been demonstrated using the breadboard model.

An engineering development model of SUMC in LSI CMOS technology has been constructed and evaluated. This model employed the use of the design automation system developed for LSI CMOS under ongoing technology programs.

A technology model of SUMC has been constructed and fully verified. This model demonstrated the use of beam lead devices, multilayer aluminia substrates and hybrid packaging which are the technologies projected for SUMC use. In addition, this model was designed to be software compatible with a commercial computer (Honeywell 316) to demonstrate the flexibility of the microprograming feature.

Current and projected efforts include the development of a basic memory module (BMM) which can be used to implement main memory units (MMU), technology evaluations for applications in SUMC, partitioning studies, packaging and modularity evaluations, construction of a prototype SUMC in final technology design, evaluation testing and support software development.

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4. TITLE:

Information Management System (IMS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. Garrett S&E-ASTR-CF	453-4070	C. N. Swearingen S&E-ASTR-C

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Space Tug Requirements

CONTRACT NO.: NAS8-29749

OBJECTIVE: To define the functional, storage, physical, environmental, and reliability requirements for the onboard computer system.

To provide Space Tug with a reliable auxillary/mass memory capability. To perform development testing sufficient to have confidence in the computer in a Tug type application.

APPROACH: Assess the Space Tug Requirements and define the total requirements for the onboard computer system.

Evaluate the requirements against the Space Ultrareliable Modular Computer to determine areas wherein technology impacts exist.

Perform required development and testing to insure the requirements can be met.

STATUS: An effort has been initiated under Contract NAS8-29749 to accomplish the objectives stated above. A Space Tug Computer requirements document has been prepared and will be released in the near future.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
73W-0029	Space Tug Data Management Computer System Hardware Requirements Document	IBM	September 1973

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MSFC	01 04 73 - 30 09 73	909-55-01	909-55-01

4. TITLE:
Structural Design and Materials Evaluations (Tug)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Optimization of Structures Under Multiple Constraints
NCA8-71/72 Pennsylvania State University

OBJECTIVE(S): To develop a small-scale optimization program to demonstrate the feasibility of multiple constraint structural optimization which will serve as a model for a large-scale program.

APPROACH: The proposed work is an extension of the work already carried out at MSFC. The essence of the proposal is development of a computer program specially designed for experimentation with various optimization techniques. It is intended to limit the program to small structures, in order to conserve computational expense, but provide a maximum of flexibility in all other phases of programming. Provision would be made for constraints on stresses, displacements, buckling loads, and natural frequencies, applied either singly or simultaneously. The possibility of including flutter constraints will also be investigated. Some parts of the program have already been completed.

STATUS: Technical Progress--A computer program for minimum weight design with respect to constraints on natural frequencies has been completed. At this stage only 2-dimensional beam elements have been considered, but provision has been made for additional elements to be included at a later date. The results of the work accomplished to date are being prepared for publication.
Management Progress, Conclusions, Problems, & Forecast--None

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FIRST BENEFITTING PROJECT: Tug

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4. TITLE:

Structural Design and Materials Evaluations (Tug)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Solution Techniques for Nonlinear Structural Analysis
NAS8-29625 The Boeing Company

OBJECTIVE(S): The objective of this effort is to develop effective subroutines and criteria for solution of systems of nonlinear simultaneous equations that contain multiple roots as well as minimum and maximum points.

APPROACH: To accomplish this task, a two-phase program will be initiated. In Phase I, new methods will be developed, new and existing methods will be evaluated on ease of use, cost of solution (i.e., computational speed), and types of problems for which the method is effective. The subroutines developed for this effort will be written to be effective for the solution of problems in structural analysis. In Phase II, techniques will be developed for solution of problems with multiple roots, minimum points, and maximum points. The current techniques for solution of nonlinear equations are extremely inefficient for these types of problems. This phase is most meaningful for solution of buckling problems and nonlinear collapse since equations describing the phenomena can be written directly instead of making many simplifying assumptions which inadequately describe the phenomena as is the current practice.

STATUS: Technical Progress--Several technical papers have been reviewed on Koiter-related stability theory, involving techniques for tracing the fundamental equilibrium path, predicting the number and type of instability modes, and finally following each post-buckled path. These techniques generally require operations such as diagonalizing the system matrix, which are not practical for large size systems. We have concluded, therefore, that a practical analysis technique must employ initial imperfections

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STATUS: Continued
in load or geometry, and thus transform the buckling problem to one involving maximum and minimum limit points. Further efforts will be directed toward such techniques.

Management Progress--None
Conclusions--None
Problems--None
Forecast--None

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4. TITLE:

Structural Design and Materials Evaluations (Tug)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Combined Compression, Bending and Torsion Loads on Skinned and Unskinned Isogrid Cylinders NAS8-29671 McDonnell Douglas

OBJECTIVE(S): To develop an analysis for isogrid cylinders (with and without skins) subjected to combined compression, bending and torsion, and to verify the analysis by testing.

APPROACH: Analysis techniques for stress distribution and critical buckling loads will be developed. The theory developed shall be verified by scale model testing on Lexan isogrid cylinders. The test results and theory shall be summarized and incorporated into the Isogrid Design Handbook as a guide for future designs.

STATUS: Technical Progress--Work on this program during this reporting period was conducted on the design and analysis of the proposed test specimens; two basic isogrid sizes were analytically investigated, 1.612-inch and .750-inch node-to-node spacing. These sizes were chosen as the initial configurations because fabrication tooling exists for these sizes. The analytical study indicated that the .75-inch spacing would be best suited for this study.
Management Progress--None
Conclusions--None
Problems--None
Forecast--None

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4. TITLE:
Structural Design and Materials Evaluations (Tug)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Structural Test of Isogrid Conical Adapter
NAS8-29859 General Dynamics

OBJECTIVE(S): To perform a number of structural tests on a conical isogrid structure to obtain data to be used in the verification of analytical techniques.

APPROACH: A 10-foot-diameter isogrid conical adapter will be nondestructively tested for a number of load conditions to obtain structural response data for these types of loads. Upon completion of the nondestructive testing, the most critical loading will be selected and applied to the conical adapter to determine its ultimate strength. The test results will be summarized and incorporated in the Isogrid Design Handbook as a guide for future designs.

STATUS: Technical Progress--The conical adapter loading fixture and the conical adapter test specimen are being fabricated. The fixture is about 70 percent complete and the specimen about 95 percent complete.
Management Progress--None
Conclusions--None
Problems--Some machining and forming difficulties have been encountered in specimen fabrication. In some places the skins have been cut through, and in a few noncritical load carrying areas grid members have been cracked. The skins and grid members are repairable. The repaired specimen should have properties equivalent to that of an undamaged specimen. The know-how needed to avoid such damage in the future has now been acquired.
Forecast--None

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FIRST BENEFITTING PROJECT: Tug

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MSFC	01 04 73 - 30 09 73	909-55-01	976-30-40

4. TITLE:

Structural Design and Materials Evaluations (Tug)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. McComas	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Orbital Docking Dynamics - Structural Integrity Analysis
NAS8-26159 Martin Marietta Corporation, Denver Division

OBJECTIVE(S): The objective of this funded effort is to complete the development of the Orbital Docking Dynamics Program (A generalized digital computer program to predict preliminary docking loads) and to deliver and implement a working computer program. Demonstration of the program will be accomplished by performing analysis on a furnished Tug structural model and docking mechanism configuration to determine the impact and capture loads to verify the structural integrity.

APPROACH: The program will be developed by generalizing the equations of motion and providing a library of impact mechanisms and a routine that will describe the closing trajectory and predict the impact points until capture has been accomplished. Integration of the equations of motions will be performed to determine the flexible body loads versus time.

STATUS: Technical Progress--This contractual study is being developed in four parts. Feasibility study was completed. Phase I, development of the executive control, I/O, simulation framework overlays, and basic library of docking mechanism, was completed. Phase II, the development of the generalized kinematics section of the simulation overlay and the routines to establish constraint parameters and the implementation of user supplied constraint mode criteria, was completed June 1973. Phase III, (On-going) solution techniques for the nonlinear equation have been incorporated and checked out. A successful effort to date.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MRC 72-150	Orbital Docking Dynamics Phase I	Colt Park & David Warner	June 1972
MRC 73-146	Orbital Docking Dynamics Phase II	Same	June 1973

FIRST BENEFITTING PROJECT: Space Tug

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STATUS: Continued
Management Progress--None
Conclusions--None
Problems--None
Forecast--A no-cost extension has been verbally requested due to illness of the Principal Investigator.

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MSFC	01 04 73 - 30 09 73	909-55-02	909-55-02

4. TITLE:

Space Tug Thermal Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Jack D. Loose	205 453-3824	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Tug Thermal Control; NAS8-29670, Martin Marietta Corp. - Denver Division

OBJECTIVE: Define Space Tug thermal control system hardware requirements and specifications by analyzing Tug thermal environments and requirements and performing preliminary thermal control system design. Product to be recommended justified hardware systems which will be fabricated in a follow on effort and used for breadboard testing by MSFC to obtain advanced evaluation and optimization of Tug thermal control hardware.

APPROACH: Contract is divided into 5 subtasks:

1. Requirements: Catalogue equipment thermal requirements and constraints for all mission phases.
2. Environments: Compute and catalogue thermal environments for all mission phases.
3. Parametrics: Perform parametric thermal studies to define best methods for thermal control.
4. Systems Design: Prepare preliminary hardware systems specifications and designs and analytically demonstrate performance capability.
5. Hardware Plan: Prepare detailed plan including schedules and resources for executing follow on hardware systems fabrication/assembly.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1. MCR-73-220	Monthly Status Letter (MSL) and Program Schedule-July 73.	Terry Ward	6 August 73

FIRST BENEFITTING PROJECT: Space Tug

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STATUS:

Technical Progress: Equipment thermal requirements and constraints 90% compiled; computer cataloguing format completed. Program schedule documented.

Management Progress: Proposals received/evaluated. FFP contract signed with Martin Marietta Corporation-Denver on July 2, 1973, for $49,000. Performance period: 10 months. Initial planning meeting held July 12, 1973.

Conclusions: None

Problems: None

Forecast: Progress as scheduled.

Remarks: None

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN

1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 - 30 09 73	909-55-03	None

4. TITLE:

Tug Propulsion System - Main (MPS) and Auxiliary (APS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
F. W. Braam	205-453-3814	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Design Study of RL10 Derivatives, NAS8-28989, Pratt and Whitney Aircraft, West Palm Beach, Florida

OBJECTIVE: Examine a select number of possible RL10 engine derivatives containing various new features to increase performance and reduce vehicle weight. For each engine derivative, define in detail the engine system performance, weight and operational characteristics. Develop program plans and determine the associated development, production, and operational costs for each derivative.

APPROACH: Analyze in detail such performance improvement and vehicle weight reduction concepts as a two-position nozzle, tank head idle mode, and zero tank NPSH identified in study contract NAS8-29314. Conduct detailed design analyses to the component part level for no more than three engine derivatives or configurations selected by NASA. NASA's configuration selection will be based on results of critical design analyses and recommendations from the vehicle study contractors, the engine study contract, and MSFC in-house specialists. Develop detailed program plans for development production, operation, and flight support for each derivative. Based on these detailed plans, develop a cost breakdown for each configuration.

STATUS: Technical Progress: Engine configurations for the study have been defined and selected. Engine derivative IIA has a two-position nozzle, tank head idle mode, zero NPSH capability, and a maneuver thrust option. Engine derivative IIB has a two-position nozzle and tank head and pumped idle modes. These two engine configurations are derived from the current (RL10A-3-3)flight engine.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Design Study of RL10 Derivatives Monthly Progress Report		
FR-5699	No. 1	-	15 April 1973
FR-5756	2	-	15 May 1973
FR-5812	3	-	15 June 1973
FR-5875	4	-	13 July 1973
FR-5934	5	-	15 August 1973
FR-5593A	Program Plan (Revised)	-	30 April 1973
GP 73-114	Briefing Charts - 1st Review	-	1 May 1973
GP 73-161	" " - 2nd Review	-	27 June 1973
GP 73-217	" " - 3rd Review	-	30 August 1973
FR-5951A	Preliminary Interface Control Document		30 August 1973

FIRST BENEFITTING PROJECT: Space Tug

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 909-55-03

STATUS: Technical Progress: (Concluded)

A third engine configuration designated category IV is a completely new engine design maximizing the expander power cycle performance. Its features include a two-position nozzle, tank head and pumped idle modes and zero NPSH.

Design and development, production, and flight operation program definitions and cost analyses are complete for all three configurations. The highlights are given below:

Configuration	Isp	Weight	DDT&E
Derivative IIA	459 sec	513 lb	$44.5M
Derivative IIB	459	474	35.7
Category IV	470	424	71.8

Management Progress: Work began on February 15, 1973. Program reviews and data dumps occurred on May 1, 1973, June 27, 1973, and August 30, 1973. All technical work was completed on September 28, 1973. Preparation, review, and issue of the final report remain.

Conclusions: The program objective was met. The required engine data and costs were produced on schedule to support the Space Tug Vehicle System studies.

Problems: None

Forecast: The final report will be issued on December 15, 1973, in accordance with the schedule.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
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MSFC	01 04 73 - 30 09 73	909-55-03	113-31-12

4. TITLE:

Tug Propulsion System - Main (MPS) and Auxiliary (APS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. Miller	205-453-3816	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Low Speed Inducers for Cryogenic Upper Stage Engines, NAS8-29189, Rocketdyne

OBJECTIVE: Design, fabricate, test, and demonstrate the concept of using low-speed hydrogen and oxygen inducers for a Tug engine application requiring no tank pressurization. Select, design, and fabricate the optimum inducer drive system and test it with the inducers to demonstrate transient characteristics and mechanical integrity. At the conclusion of testing, refurbish the hardware and deliver to MSFC.

APPROACH: The program is to be accomplished in five phases. Phase I is a preliminary analysis including hydrodynamic analysis and configuration selection.

Phase II is the detailed analysis and design. Detail drawings and assembly drawings will be made.

Phase III is fabrication and includes purchasing, assembly, and inspection of the hardware.

Phase IV is the testing phase. Current plans call for an out-of-house testing laboratory to perform the work. Rocketdyne will monitor the work and analyze the test data.

Phase V is the refurbishment of the hardware as required prior to delivery to MSFC.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1.	Program Plan	J. A. King	6 Dec 1972
2.	Milestone Report Phase I	J. A. King	19 Jan 1973
3.	Milestone Report Phase II	J. A. King	7 Jun 1973

FIRST BENEFITTING PROJECT: Low Cost Cryogenic Tug

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 909-55-03

STATUS: Technical Progress: The Phase I Analysis and the Phase II Design efforts have been completed. The phase I analysis consisted primarily of selecting the optimum drive system from among turbine, hydraulic and electric drive methods. Based upon use with the RL-10 engine, the electric motor drive was optimum. Both oxygen and hydrogen inducers will utilize direct drive submerged motors. The oxygen inducer motor speed is 3000 rpm and hydrogen inducer motor speed is 14,000 rpm.

Phase II detail design consisted of motor/housing design and integration and detailed hydrodynamic calculations.

Phase III fabrication is now in progress. The motor has been subcontracted to Pesco Products Division of Sundstrand Corp. A variable frequency electrical inverter to drive both inducers is being fabricated by the General Electric Corporation.

Management Progress: A detailed design review of phase II was held on May 24, 1973. The test plan was reviewed and approved on August 30, 1973. The test program has been delayed until March 1974 due to a schedule slippage in the inverters.

Conclusions: An electric drive system was found to be optimum for this particular inducer application.

Problems: None.

Forecast: All inducer parts are scheduled for completion by November 1, 1973. Assembly will take place during November and no charges will be incurred by the program until delivery of the inverters in March 1974.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	909-55-05	See Remark Nr. 2

4. TITLE:
TUG Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. B. Graff	453-4560	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVES: To initiate and secure advances in the state-of-the-art in the Electrical Power area aimed at specific improvements in performance, weight and reliability of electrical components/sub-systems to permit attainment of performance compatible with TUG requirements.

Approach: This is being accomplished under various tasks and sub-tasks which are discussed and summarized separately. These tasks and sub-tasks are:

- o TUG Fuel Cell
- o TUG Component Development composed of such sub-tasks as Switch Gear & Circuit Protection, Power Conditioning & Analysis, Motors & Controls for Latching & Docking, Lightweight Cables & Connectors
- o Feed-Thru Electrical Connectors

Status: The Task "Rechargeable Battery Development" previously reported has been terminated due to changed requirements. A status report for each Astrionics Laboratory task follows.

Remarks: (1) The Task "Rechargeable Battery Development" has been terminated; this is the final report on this task.

(2) See individual Task Sheets for prior numbers.

(3) See individual Tasks for Problems & Remarks.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
See individual Tasks.			

First Benefiting Project: TUG

MSFC - Form 850 (March 1978)

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 909–55–05	PRIOR NO.:

4. TITLE:
TUG Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. Paschal/W. Britz	453–4562	R. M. Aden S&E–ASTR–E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Rechargeable Battery Development

Contract No: Not Awarded as yet.

Objective: Develop secondary Ag–Zn battery for use on TUG. This battery will be capable of meeting TUG Low Energy Mission Requirements. Battery will be capable of one to two years wetstand and 50 cycles operation at 50% depth–of–discharge.

Approach: Investigation, test and evaluation of cells constructed of organic and inorganic separators will be undertaken. Cyclic tests will be used to determine life characteristics of both types of systems. Separator and Zinc electrode deterioration will be analyzed.

Status: Since initiation of this task additional studies have been performed to develop TUG power source requirements. Weight, development costs, and power requirements were evaluated and it was determined that a Shuttle type fuel cell must be used to meet TUG requirements. Batteries could not be utilized to meet TUG objectives; accordingly, this task was terminated prior to release of battery procurements for cells constructed with inorganic separators.

Remarks: This task has been cancelled due to changed requirements. This is the final report on this task.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

First Benefiting Project: Space TUG

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
MSFC	01 04 73 to 30 09 73	CURRENT NO.: 909-55-05	PRIOR NO.: 909-55-05

4. TITLE:
TUG Electrical Power Systems Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. Morgan	453-2461	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: TUG Fuel Cell Development

Contract No: N/A, Not Selected.

Objective: Develop a fuel cell powerplant for Space TUG. Power requirements are 1.0 KW average and 2.0 KW peak. Minimum weight and cost are goals.

Approach: This is a new task directed towards modification of the Space Shuttle fuel cell technology base to meet TUG requirements. Major emphasis is to be on design modifications of Shuttle hardware to operate at the lower power levels of TUG. Low cost and lightweight are also major considerations. Basic R&D will not be addressed with this task as Shuttle program funding will carry this costing.

Status: This is a new task for this reporting period.

Technical Progress: Technical requirements are being defined.

Management Progress: A procurement covering the work scope for this task through FY-76 to accomplish a detailed design of a prototype TUG fuel cell powerplant is being prepared.

Conclusions: None

Problems: Selection of a vendor for this activity must be delayed until JSC selects a vendor for Shuttle fuel cell development, to reduce overall development costs

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NONE			

First Benefiting Project: TUG

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RESEARCH AND TECHNOLOGY OPERATING PLAN
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Status: Cont'd

Problems: (Cont'd)

and avoid duplication of efforts.

Forecast: None

Remarks: This is the initial report under this RTOP number.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
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MSFC	01 04 73 to 30 09 73	909-55-05	909-55-05

4. TITLE:

TUG Electrical Power Systems Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
B. J. McPeak	453-4652	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Feed-Thru Electrical Connectors

Contract No: N/A - Task 1, 2 & 4 are In-house. Task 3 will be contracted.

Objective(s): The overall objective of this program will be to develop and prove design concepts to establish a set of feed-thru electrical connectors sufficient for Tug LH_2 and LO_2 tanks penetration.

The proposed three-year lifetime Space Tug shows a configuration of thin wall LH_2 and LO_2 tanks. These proposals also show that there must be penetrations through this material for both coaxial and conventional connectors. We propose an investigation of these connectors since the long life, low leakage requirements will necessitate connectors that can operate over repeated cycles of ambient to cryogenic temperatures.

Maintenance of reliable connectors of electrical circuit penetrations of propellant tanks is aggravated by severe thermal shock and cycling with the cryogenic liquids involved. Pressure vessel integrity must be maintained to assure extremely low leak rates.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
N/A			

First Benefiting Project: TUG

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Similar electrical feed-thru connectors are used to penetrate the walls of propellant tanks and other pressure vessels of Saturn Vehicle Stages. Numerous problems were encountered with the feed-throughs used on Saturn. Difficulties were most severe with coaxial type penetrations.

Approach: It is proposed to conduct the investigation in four phases:

Task 1 - Assessment of requirements: Since both Tug structural design and electrical/electronic system design impose requirements on the feed-thru connectors the first task will be to develop for the connector a statement of performance, design requirements, to develop conceptually acceptable feed-thru connector configurations and to write performance-design specifications.

Task 2 - This task will be to carry out a detailed design of configurations selected in task 1, for further consideration. This task will include screening of already available components for modification to Tug-compatible configurations.

Task 3 - This task will consist of development and fabrication through contracted efforts, of required configurations as designed in task 2. The resulting hardware will be prototypes sufficiently similar to anticipated flight hardware to permit valid performance testing.

Task 4 - This task will be in-house testing of the prototype hardware to establish performance characteristics and issue test report.

The total effort is expected to require between 30 months and 48 months to complete. Tasks must be conducted, largely, in sequence.

Status: Effort has been completed to research and evaluate available data on cryogenic connector materials, manufacturers, users and problem histories. Many cryogenic connector users and manufacturers have been visited or contacted. Data obtained from users, describes problems and solutions as well as type of connector design used by each. Data obtained during the survey of manufacturers defines design, material, and environmental capabilities of each connector as well as the manufacturer's performance ability. Collected data analysis has been completed. Trades were made to determine extent of modification of existing cryogenic connector designs versus modification of standard multisource connectors to meet cryogenic applications.

A conceptual design approach has been established with modification of standard multisource connectors to meet cryogenic applications. A complete development specification, 40M38294, has been prepared and released. Tasks 1 and 2 are complete. A 404 Procurement request was submitted in April, 1973, to accomplish Task 3 of this effort. Some delays have been incurred since then but the RFQ should now be imminent. The PR was amended September 20, 1973, and $15,000 funding added for new total of $45,000.

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4. TITLE:

TUG Electrical Power Systems Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
B. J. McPeak	453-4652	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Lightweight Cable/Connectors

Contract No: N/A - In-house except for various procurements of piece parts.

Objective: The objectives of this effort are to review and assess the various methods (flat conductor cables, ribbon cables, etc.) available to provide lightweight, reliable cable and connector systems for Tug use, to identify those areas needing improvement in the state-of-the-art (e.g., connectors, terminations, shields, etc.) and to carry out the tasks necessary to improve the state-of-the-art to a level which will support Tug development.

Approach: This effort will be conducted in-house. Piece parts will be procured.

A program will be initiated in-house to layout electrical wiring harness configurations meeting Tug Configuration Requirements and to assess the design requirements. For each component run of the harness the advantages/disadvantages of the several possible wiring techniques (flat conductor cables, ribbon cables, individual wire cables) will be established in terms of weight, reliability, complexity, etc.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
N/A			

First Benefiting Project: Space Tug

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
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Evaluation testing of hardware and wiring harness layouts will be conducted in-house, and final design specifications prepared. Detailed harness design requirements will be prepared. Harness types not already included in the document "MSFC 40M39582, Harness Design Standard" will be documented for inclusion as applicable.

Status: Investigation has been conducted defining specific methods and hardware available to provide lightweight cable and connector systems. Ribbon cable configurations have been identified. Procurement requests have been submitted to purchase sufficient quantities of ribbon round wire cable for further detailed in-house MSFC test, analysis, and mockup for comparison with other candidate wire and cable systems. Connectors and other devices for terminating candidate wiring systems have been defined and procurement requests have been submitted. Some hardware deliveries have arrived at MSFC.

Further in-house effort will accelerate when sufficient quantities of hardware have been received.

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4. TITLE:
TUG Electrical Power Systems Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. R. Lanier, Jr.	453-4570	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Develop Motors and Controls for Latching or Docking

Contract No: N/A - In-house

Objective: Define the optimum motor(s) and control scheme(s) to be used for the latching or docking mechanisms required on the Space TUG vehicle. An optimum system will be defined as that system exhibiting the best approach after such parameters as weight, power consumption (efficiency), performance, reliability (maintenance) and cost are considered. Develop motor system; design and breadboard. Test and evaluate.

Approach: This approach will be accomplished in two phases which are broken down into sub-tasks as follows:

Phase 1 - Motor System Development
(a) Define Motor System Requirements.
(b) Select Motor Vendor and jointly perform tradeoff analysis of performance versus weight and/or reliability.
(c) Identify and prepare specifications.

Phase 2 - Motor System Manufacture & Test
(a) Design Prototype Motor System.
(b) Manufacture Hardware.
(c) Test and Evaluate.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

First Benefiting Program: Space TUG.

MSFC - Form 550 (March 1973)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-55-05 PAGE 2 OF 2

Status: Technical Progress:

Initial efforts have been concentrated at utilizing a linear induction motor (LIM) to accomplish latching and docking. Considerable time has been spent in familiarization studies with these motors. Test equipment was purchased and built. Off-the-shelf LIM's were procured and tested. Test results and a recent preliminary definition of motor requirements indicate that LIM's may not be the best approach to take. In addition to LIM's, MSFC is investigating the use of linear actuators which utilize a gear train (for mechanical advantage) and either AC or DC motor. Current plans are to procure some of these actuators and test and evaluate them for TUG applications. In-house design and build of a LIM is continuing. An interim report will be written following test and evaluation of the MSFC built LIM.

Management Progress: N/A

Problem:

Progress continues to be hampered by the lack of design details in the TUG Latching or Docking mechanisms.

Causes of Problem:

Insufficient design details on TUG Latching/Docking Concepts. A memo requesting these details has been submitted to Astronautics.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01 04 73 to 30 09 73	909-55-05	909-51-05

4. TITLE:

TUG Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. R. Lanier, Jr.	453-4570	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Power Conditioning Analysis and Development

Contractor: Teledyne Brown Engineering, NAS8-29770

Objective: This task will be conducted as in-house and contract in sub-tasks whose objectives are as follows:

Sub-Task 1 - Power Conditioning Equipment Dynamics & Stability Analysis: This effort will be to develop the necessary tools and methods to properly determine the stability and dynamic characteristics of switching mode power conditioning devices. Results will be verified by experimental tests with breadboard type circuits.

Sub-Task 2 - Standardization and Modularization of Power Conditioning Equipment: Efforts will be to develop a data base for the standardization and modularization of circuit designs and packaging concepts for power conditioning equipment. Effort will also include development of built-in test circuitry to check power conditioner performance; identify impending failures, or out-of-tolerance or failed conditions; and interface this diagnostic data with a data bus.

Sub-Task 3 - Power Conditioning Subsystem Circuit and Equipment Development: The objective of this effort will be to develop candidate power conditioning circuits and equipment. Power conditioning circuits capable of handling high power (25 to 250 KW) and high voltage (greater than 100 volts dc) or low voltage (3 to 9 volts dc) will be developed. A family of optimum key basic circuits will be developed and generated. This effort will use the developed circuits to produce working prototype equipment.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
No Number	1-Kilowatt SCR Switching Regulator	Sperry Rand Corp.	1/31/73
SP-243-0788	Investigation of Stagger-Phased Regulator	P. Harper	6/19/73
No Number	A Study of Power Conditioning and Power Distribution Components	M. A. Honnell	9/17/73

First Benefiting Project: Sortie Lab/Tug

Objective: (Cont'd)

Sub-Task 3 (Cont'd)

This equipment will then be tested to evaluate and assess their performance under typical ambient environment.

Approach:

Sub-Task 1 - Dynamics & Stability Analysis: An in-house effort will be conducted to develop transfer functions and mathematical models for all types of switching-mode studies to determine criteria, methods and tools for predicting dynamic characteristics and insuring stability of the devices. Results will be verified and demonstrated by experimental tests using in-house breadboard type circuits.

Sub-Task 2 - Standardization and Modularization of Power Conditioning Equipment: This effort will be a contract program conducted in five (5) phases as follows:

Phase 1 - Define power conditioning and built-in test requirements.

Phase 2 - Select candidate circuits meeting requirements, perform trade studies and select preferred circuitry.

Phase 3 - Identify subcircuit elements for thin or thick film microcircuit production.

Phase 4 - Design and develop a standard package and packaging techniques.

Phase 5 - Construct working prototype for testing and evaluation.

Sub-Task 3 - Power Conditioning Subsystem Circuit and Equipment Development: This effort will be accomplished in two phases which are further broken down into subtasks as follows:

Phase 1 - Circuit Development
- (a) Generate functional circuit block diagrams.
- (b) Generate parametric data for circuits.
- (c) Perform tradeoff analysis of performance versus weight and/or reliability.
- (d) Identify specifications for developed circuits.
- (e) Identify requirements for critical piece parts.

Phase 2 - Prototype Equipment Development
- (a) Purchase, analyze, and qualify piece parts as necessary.
- (b) Manufacture candidate prototypes of power conditioning.
- (c) Evaluate equipment by test in laboratory. The new equipment will be tested as separate items under various environmental conditions and then incorporated into a system type test. This testing will allow the use of various power sources and real or simulated so that all candidate power conditioning concepts may be evaluated. Operational response of the equipment will then provide inputs for necessary design modifications.

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 909-55-05

Status:

Technical Progress:

Sub-Task 1 - An effort was undertaken to parametically define the stability and dynamic characteristics of an existing switching regulator design. The final report of contract NAS8-26752, titled "A Study of Power Conditioning and Power Distribution Components," defines the results of this effort. Briefly, the results are that with considerable effort switching regulator characteristics and stability can be successfully reproduced and predicted for a specific design. However, attempts to extend these methods and results to regulator designs in general, as a before the fact procedure rather than after, have not been fruitful. Efforts are continuing to develop a simple, straight-forward method of predicting and defining switching regulator characteristics and stability.

Sub-Task 2 - The power conditioning requirements as ascertained in Phase 1 for future Earth Orbital Missions show the need for two families of standard power conditioners - a load center type with up to 300 W capability and a centralized type from 500 W up.

A load center type power conditioner meeting all requirements has been designed (Phase 2); the subcircuit elements have been selected for microcircuit production and production has been completed on the required number of units for the prototype (Phase 3); a standard, modular package has been designed (Phase 4); and construction of the prototype has begun (Phase 5).

The centralized type power conditioner is now in the design and breadboard phase (Phase 2).

Sub-Task 3 - Two circuit designs have been breadboarded and tested as candidates for both the high voltage and high power requirements. The first of these designs is a 1 KW SCR switching regulator operating with an input voltage of 100 to 130 Vdc. Regulation was held to $\pm$ 0.4 volts from no load to full load and over the input voltage range with an efficiency of 89%.

The second design is a stagger-phased regulator. Test and analysis performed on this design show that regulation, efficiency, and cost are about the same as the single phase switching regulator. However, for applications which do not require stepping into current, the stagger phase has a considerable savings in volume over the single phase.

Test and analysis on the two designs and other possible designs are continuing.

Management Progress:

Sub-Task 1 - None

Sub-Task 2 - A contract (NAS8-29770) has been awarded to Teledyne Brown Engineering for the fabrication of a prototype of the standardized load-center power conditioner.

Sub-Task 3 - None

Problems: (See next page)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-55-05 PAGE 4 OF 4

Problems:

Sub-Task 3 – Three contracts for required piece parts (high voltage transistors, high voltage Schottky rectifiers) have been cancelled because contractors could not deliver. This means a serious delay in the required piece part development and qualification phase of this task.

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MSFC	01 04 73 to 30 09 73	909-55-05	909-51-05

4. TITLE:

TUG Electrical Power Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Donald E. Williams	453-4653	R. M. Aden S&E-ASTR-E

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Switch Gear & Circuit Protection

Contractor: Selected Negotiation in Process

Objective(s): Component research and Breadboard development of high voltage solid state power controllers. Final results will be the development and MSFC qualification of solid state power controllers capable of flight applications. These devices will optimize current and voltage capabilities as determined by Breadboard development and semiconductor component availability.

Approach:

Phase A - Perform research of the availability of semiconductors etc. that have high voltage, gain and safe operating area (SOA) characteristics. Utilize the research to procure and fabricate a Breadboard model of a high voltage (output stage) power controller.

Phase B - Design, develop and fabricate 4 each solid state power controllers at 5 and 10 amperes. These devices are to meet the technical and functional requirements of the specification included in the contract work scope.

Status: Procurement request prepared and submitted to purchasing in mid-March, 1973. Proposal evaluation completed July, 1973. Negotiation is in process with successful bidders; due to contract protest, contract award is not expected until late September.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
N/A			

First benefiting project: TUG

MSFC - Form 360 (March 1978)

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MSFC	01 04 73 to 30 09 73	909-55-05	909-55-05

4. TITLE:
Tug Electronics and Avionics Research and Technology - Guidance and Control of Space Tug Vehicle.

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. D. Ellsworth S&E-ASTR-SG	453-4583	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Investigate the problems of calculation of the Space Tug's position in an inertial coordinate frame. NAS8-29852 Auburn University Research Foundation, Auburn, Alabama.

OBJECTIVE(S): The objective of this task is to investigate the problems associated with calculating the Space Tug's position in inertial coordinates. The problem areas to be investiagted will include periods when little or no measurable accelerations are present. Also to be investigated are the problems associated with updating the vehicle's attitude using onboard measurements in conjunction with ground or onboard computations. Measurement sensors will include sun sensors, star trackers and either gimballed or strapdown inertial measurement units.

APPROACH: The approach to be taken in this study effort will be to first identify the areas of concern. For each of these areas identified potential solutions will be identified and investigated both analytically and numerically. Techniques used to solve the problems will include Kalman Filtering, math modeling of forces etc. Attitude update techniques will be identified and sophisticated numerical procedures used to solve the problem in ground based digital computers. Techniques will then be used to simplify the scheme for onboard implementation. Onboard computer requirements will be established for the navigation and attitude update schemes above.

STATUS: Technical Progress: This effort is in the first month. No progress reports were received in the reporting period for this reason. A Kickoff meeting held on

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None			

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 909-55-05 PAGE 2 OF 2

September 9, 1973 at MSFC identified the study areas further. Areas of concern are the time periods when the Tug navigation system must rely on little, if any, information. These periods occur just prior to main engine burns.

Management Progress: This contract award was given on June 30, 1973. The personnel involved with this effort were at that time involved with another effort. For this reason, actual work on this effort was delayed. The first meeting was held at MSFC on September 10, 1973. It is expected that a contract extension at no cost to the government will be requested by Auburn University.

Conclusions: None

Problems: None

Forecast: None

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MSFC	01 04 73 to 30 09 73	909-55-05	

4. TITLE:

Tug Electronics and Avionics Advanced Development

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Herndon, R. H.	205-453-1508	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Light Weight Flat Conductor Cables and Connectors In-House

OBJECTIVE: The objective of this effort is to provide an improved light weight electrical power distribution and interconnect system for the weight-sensitive Space Tug. The effort will provide the necessary advancement in current flat conductor cable (FCC) technology in the areas of shielding methods, thin wall connector designs, high density miniaturized distributors and low-profile cable transitions which will meet specific Space Tug system design and environmental requirements.

APPROACH: This in-house effort will include the necessary tasks for component test and evaluation, full system studies, studies to establish optimum routing of FCC, installation and refurbishment procedures, new component design and hardware specifications which will support the Space Tug development. During FY-74 and FY-75, available funds will be used to purchase materials for in-house research, development, testing and evaluation tasks. These tasks will include any necessary work for the development of an improved light weight connector design, development of multiconnector distributor, FCC/shielding laminating techniques, etc. If additional funds become available, contracts could be utilized to conduct full system studies, prepare mock-ups for routing and installation studies and for the preparation of documentation and specifications.

STATUS: Technical Progress: Two sizes of an improved individually sealed contact connector are under development and are presently being tested and evaluated. The design of a prototype multiconnector distributor has been base-lined. Two types of a low-

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
No formal in-house report has been issued. In-house accomplishments are reported in the Weekly Notes.			

FIRST BENEFITTING PROJECT: Space Tug

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TASK: Light Weight Flat Conductor Cables and Connectors

STATUS: Technical Progress: (Continued)

profile cable transition are presently being tested and evaluated. An effort to evaluate the "TermiPoint" method for making terminations has been started. A general specification for FCC and FCC connectors is being prepared for the Space Tug, Space Shuttle and related OMSF Programs.

Management Progress: Procurement actions have been initiated for delivery of five types of flat conductor cables and for "TermiPoint" hardware and associated tooling.

Conclusions: None

Problems: None

Forecast: This in-house effort should be completed in June 1975.

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Marshall Space Flight Center	01 04 73 - 30 09 73	909-55-37	112-30-19

4. TITLE:

SPACE TUG CRYOGENIC TECHNOLOGY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Eric H. Hyde	453-3852	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study of Multilayered Pipe Penetration

CONTRACT: NAS8-26642, Lockheed Missiles and Space Company, Huntsville, AL

OBJECTIVES: The objective of this program is to provide thermal design data needed for the design of insulated stainless steel pipe penetrations extending through multilayered insulated blankets on cryogen tanks.

APPROACH: The study will be a three-phase program. Phase I will be devoted to parametric thermal analyses varying 11 variables. A general parametric study will be performed varying 7 parameters and generating a complex matrix of data. Phase II will be a test program designed to verify and complement the analytical portion of the program. Phase III will be a combination of tests designed to help understand factors that influence test results of Phase II, such as MLI outgassing, thermal acoustics, and MLI residual pressure.

STATUS: Phase I has been completed. Results of the study show that for most all cases conduction is the major mode of heat transfer through stainless steel penetrations. For fiberglass pipes, radiation heat transfer can be significant or dominate. For both materials, thermal acoustic oscillation can easily increase heat flow 10 - 100 times compared to the solid conduction rate. Efforts are now being made to define parameters that cause and sustain thermal oscillations. Penetration cryostat calibration tests are in progress. Some test results will be available next reporting period.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
D225403	Quarterly Progress Report	G. D. Reny	Sept 27, 1971
D225579	Quarterly Progress Report	G. D. Reny	Dec 23, 1971
D225792	Quarterly Progress Report	G. D. Reny	April 5, 1972
D306220	Quarterly Progress Report	G. D. Reny	Sept 27, 1972
D306392	Quarterly Progress Report	G. D. Reny	Jan 4, 1973
D306570	Quarterly Progress Report	G. D. Reny	April 2, 1973
D306680	Quarterly Progress Report	G. D. Reny	July 5, 1973

FIRST BENEFITING PROJECT: SPACE TUG

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Marshall Space Flight Center	01 04 73 - 30 09 73	CURRENT NO.: 909-55-37	PRIOR NO.: 908-52-37

4. TITLE:

SPACE TUG CRYOGENIC TECHNOLOGY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. E. Stonemetz	453-3854	A. L. Worlund

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space LOX Vent System

CONTRACT: NAS8-26972, General Dynamics/Convair

OBJECTIVES: To design, build, and demonstrate a prototype vent system capable of exhausting only vapor from an all liquid or two-phase mixture of oxygen under low or zero-gravity conditions.

APPROACH: A literature search and an analytical investigation of various liquid-vapor separator concepts will be conducted. The most promising concept, considering separation efficiency, weight, simplicity, and current technology, will be thoroughly analyzed. A system design will be made, including a parametric study showing overall system weight, efficiency, vented mass, etc., for specific design conditions. A prototype of the selected system will be designed, fabricated, and tested.

STATUS: A compact bulk heat exchanger vent system has been selected and designed as the best overall system to meet the requirements for a zero-gravity LOX tank vent system for 7 to 30-day missions. Individual component compatibility testing found the throttling regulator outlet pressure 5 psi higher than specification and was returned to the vendor. This problem and a delay in availability of the 87-inch test chamber, that is presently being used on contract NAS8-27419, have resulted in a no-cost contract extension to December 31, 1973. Component compatibility and system checkout tests in LO_2 are in progress.

REMARKS: None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
GDC 584-4-716	First Quarterly: Space LOX Vent System	J.A. Stark & J.R. Elliot	Oct 8, 1971
GDC 632-1-17	Second Quarterly Space LOX Vent System	J.R. Elliot, M.D. Walter, J.A. Stark	Jan 21, 1972
GDC 632-1-82	Third Quarterly Space LOX Vent System	J.R. Elliot, J.A. Stark	Apr 18, 1972
GDC 632-3-134	Design Phase Report Space LOX Vent System	J.A. Stark	Aug 10, 1972

FIRST BENEFITING PROJECT: SPACE TUG

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MSFC	01 04 73 - 30 09 73	909- 55-40	976-30-40

4. TITLE:
Aeroelasticity
Dynamics & Environment

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. McComas	543-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Curved Shell Finite Element for Space Tug (Continuation of Finite Element Modeling Optimization) NAS8-26284

OBJECTIVE(S): The objective will be to develop a curved shell finite element which will accurately determine antisymmetry shell vibration modes and dynamic response in a solution time effectiveness. The element or elements will be implemented into the MSFC NASTRAN program.

APPROACH: The approach will be to assess the curved shell finite element state-of-the-art and from the assessment results select the most promising element and implement the element into the NASTRAN program. After implementation, the element will be evaluated in its ability to model the Space Tug vehicle and produce accurate modes and responses.

STATUS: Technical Progress--The literary search has been completed (Monthly progress report number 2). Two candidates are under consideration (a) Triangle element developed by G. R. Cowper and (b) a isoparametric surface element.
Management Progress--The original scope of work of this contract was completed successfully and the final report accepted.
Conclusions, Problems, and Forceast--None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
2523-950001	Finite Element Modeling Study Using NASTRAN (Released thru STAR)	Stephen Jordan & David Brzezinski	April 73

FIRST BENEFITTING PROJECT: Tug

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4. TITLE:

Aeroelasticity (Dynamics)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Mario H. Rheinfurth	205 - 453-2470	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Space Tug Automatic Docking Control
Lockheed Missile & Space Co., Inc.
Contract Number NAS8-29747
P. O. Box 504, Space Systems Division
Sunnyvale, CA - 94088

OBJECTIVE: The study will be used to generate design requirements for the attitude system for autonomous docking and compare this mode with remote control. In addition docking sensor and hardware requirements will be specified.

APPROACH: Phase A. Literature search - The literature search will be accomplished by both manual and computer searching.

Phase B. Terminal Control Strategies and Sensor Requirements - The baseline docking control strategies, sensors, and hardware will be incorporated into the simulation. Data to determine the sensor requirements will then be derived by simulation and analysis.

Phase C. Influence of Docking Mechanism - Docking accuracy specifications for different mechanisms will be derived. The simulation will be run varying the noise, resolution, and bias of the sensors. End conditions of the simulation will then

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
N/A			

FIRST BENEFITTING PROJECT: Space Shuttle-Tug

APPROACH (CONCLUDED): be compared to the specification to ascertain the probability of a first attempt at successful docking.

Phase D. Effects of a Missed Docking Attempt on Tug Propellant Consumption and on the Payload Control System - The end conditions listed by the previous phase will also include the angular momentum imparted to the payload. In addition to knowing the Tug thrusters attitudes and separation from the payload, the angular momentum caused by impingement would also be calculated.

Phase E. Program Documentation - Complete user's documentation will be provided. In addition a one-day seminar and training session, using the program documentation, will be held.

STATUS: Technical Progress: The literature survey has been initiated by the contractor. The first screening produced only 7 NASA and 8 foreign titles that may be pertinent.

Management Progress: Contract was initiated on August 2, 1973 and orientation meeting held on September 19, 1973.

Conclusions: None

Problems: None

Causes of Problems:

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4. TITLE:

Aeroelasticity (Dynamics)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Mario H. Rheinfurth	205 - 453-2470	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Space Tug Recovery of Spinning Satellite
Northrop Services, Inc.
Contract Number NAS8-29627
6025 Technology Drive
P. O. Box 1484
Huntsville, AL - 35807

OBJECTIVE: Develop techniques for the recovery of free spinning satellites, requiring a minimum of modifications to Tug design. A desirable result would be a single recovery system capable of recoveringboth spinning and non-spinning satellites.

APPROACH: Phase A. Evaluation of Docking Mechanisms - Several docking mechanisms will be investigated for their applicability for recovery of spinning satellites. One or more mechanisms will be recommended which appears most feasible and requires the least Tug redesign.

Phase B. Capture Boundaries - Establish capture boundaries for retrieving spinning satellites in terms of initial misalignments and dynamic conditions.

Phase C. Stability Analysis and Dynamic Studies - Establish stability limits and perform dynamic simulations of all phases of the docking maneuvers including missed docking attempts.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
N/A			

FIRST BENEFITTING PROJECT: Space Shuttle-Tug

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RESEARCH AND TECHNOLOGY OPERATING PLAN
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APPROACH (CONCLUDED): Phase D. Sensor Requirements and Control Logic - Investigate requirements for, and implementation of, docking sensors. Establish translational and attitude control logic to accomplish initial capture and subsequent despin and hard docking. Logic includes action to be taken in the event of unsuccessful docking attempt.

STATUS: Technical Progress: Several docking mechanisms have been investigated. The McDonnell Douglas Docking System was selected as the most suitable for capturing spinning targets. Modifications of the system are contemplated with the aim of alleviating capture boundaries.

Management Progress: Contract has been initiated on August 22, 1973.
Conclusions: None
Problems: None
Causes of Problems: None

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01 04 73 to 30 09 73	909-55-47-00	908-54-22

4. TITLE:
Dynamic, Three-Dimensional Atmospheric Models

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Robert E. Smith	205/453-3140	W. W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Dynamic, Three-Dimensional Atmospheric Models. NAS8-28248, University of Alabama, Huntsville, Huntsville, Alabama.

OBJECTIVES: To develop dynamic, three-dimensional atmospheric models which are realistic representations of existing conditions. These models will be used for studies on trajectories, guidance, and heating of re-entering space vehicles. Emphasis will be on dynamic aspects of environment.

APPROACH: The short-term approach will be to analyze atmospheric variations in available data and to empirically model these variations to improve the representativeness of current engineering atmospheric models. The longer-term approach is to combine theories and observations to develop global three-dimensional atmospheric models based on available and future data and including all known energy sources, transport effects, and vertical and horizontal motions. Results of studies will provide direct inputs into air braking and related activities to permit relative assessment of pertinent design trade-off parameters and configurations.

STATUS:

Technical Progress: A program was developed to provide a capability for computing the drag of an ellipsoid-of-revolution shape. High and low values of speed ratios were tested with both results showing an increase in drag coefficient for all scattering angles except a perfect backscatter in which case the drag coefficient is independent of shape.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
N/A	Free Molecule Diffusion of Spherical and Cylindrical Particles	G. R. Karr	N/A
N/A	Dual Falling Sphere Determination of Density and Transition Flow Parameter	G. R. Karr	N/A

FIRST BENEFITTING PROJECT: TUG

STATUS: Technical Progress (continued):

The gas surface-interaction independent term of the drag coefficient for a sphere has been reported in previous progress reports for the limits of high and low speed ratios. This work has now been collected and a set of limiting expressions have been developed.

The density values between 80 and 120 km have been derived primarily from falling sphere data. In fact, the 1962 standard atmosphere was revised in this region in the 1966 Supplements based almost entirely on falling sphere data. Since this region of atmosphere is also of importance to the Aero-Maneuvering Orbit-to-Orbit Shuttle (AMOOS) study and the development of models of the atmosphere, a careful review of the falling sphere method of density determination was made. It was concluded that these measurements are likely subject to considerable error due to uncertainty in drag coefficient. Falling sphere data involve two regions of transition in aerodynamic drag; (1) transonic, from low to high Mach numbers, and (2) transition from free molecule to continuum aerodynamics. The second is of principal importance for the AMOOS since transition causes a factor of two change in drag coefficient.

The transition from free molecule to continuum aerodynamics has been studied both experimentally and theoretically with limited success. A major difficulty has been the lack of accurate experimental information in the free and near free molecule regime. This is of course the same reason that uncertainty exists in upper atmospheric density which is inferred from drag in the free and near free molecule regime.

Study of the falling-sphere density-determination technique combined with the recent work on drag coefficients has led to the conclusion that experiments should be conducted which will reduce the above mentioned uncertainties. These experiments are: Determination of the absolute values of temperature; Determination of transition flow onset and density; Determination of gas surface interaction parameters.

The above proposed two-sphere experiments should provide a wealth of information in the 80 to 120 km region of the atmosphere. Such experiments are feasible since two-sphere and three-sphere launches have been made by the University of Michigan group. The experiments would require the tracking of each sphere concurrently which was not done by the Michigan group.

The program to study the effect of satellite lift and drag on orbit decay in the atmosphere was successfully run during this period. An initial orbit of 35,900 km apogee and 80 km perigee was taken so as to compare with proposed AMOOS trajectories. With a drag coefficient of 2, a lift coefficient of 1, a mass of 1,000 kg, an area of 10 m^2,,and an angle of attack of 45°, a decay to less than 100 km occurred within 4 orbits. The orbit inclination was zero so no inclination changes due to wind motion were obtained.

The results for the above case and a second run with a perigee of 120 km seem to compare well with published values of similar cases. Improvements in accuracy are expected by employing double precision in the program.

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STATUS: Technical Progress (concluded):

The stability of a lifting satellite in free molecule flow has been investigated. In particular, the atmospheric influences of changes in gas and gas-surface interaction properties have been investigated. A change in gas composition or gas temperature can cause a change also in the gas surface interaction and speed ratio of the satellite. The study has presently concentrated on the influence caused by possible gas surface interaction changes. The study of the sensitivity to temperature changes is being considered.

The aerodynamic stability of a lifting body concerns the slope of the moment coefficient at the zero moment angle of attack. For a flat plate body in free molecule flow, the aerodynamic stability depends on the center-of-gravity location, the gas surface interaction, and the speed ratio. The stability derivatives have been tabulated and will be reported in detail in the interim report.

Management Progress: Contract was extended until September 1974.

Conclusions: Speed ratio and shape effects analysis needs to be extended. Falling sphere data may provide a valuable input not previously considered. Available data may be a good source of information on the transition flow regime and also the temperature of the upper atmosphere near 100 km.

Problems: Analysis to data has shown that many additional factors must be considered which will add to the complexity of obtaining accurate values of the ambient density from orbital decay histories.

Causes of Problems: More detailed and comprehensive analysis of available data than previous investigators has revealed additional complexities.

Forecast: Determination of effects of additional vehicle parameters on drag determined densities may become so involved and complicated that establishment of a model atmosphere containing all of the short period fluctuations may not be possible in the current time frame.

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MSFC	01 04 73 - 30 09 73	970-62-20	970-62-20

4. TITLE:

Food, Atmosphere, Water and Waste Management

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. E. Clonts	205-453-3828	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Analytical Methods for Evaluation and Control of Advanced EC/LSS
NAS8-28982 McDonnell Douglas Astronautics Company, Huntington Beach, CA.

OBJECTIVE: The objective of this study is to produce a mathematical model utilizing the G189A computer program that completely maps and determines the operating conditions and characteristics of the RITE Integrated Waste Management Water System.

APPROACH: For mathematical modeling, the RITE system will be divided into its constituent loops, low temp heating, flush water, air, solid waste, vapor, potable water storage, cooling and high temp heat source. These loops will be investigated to determine the compatibility with G189A. Any incompatibility will be corrected by devising new, or renovating existing subroutines. A mathematical model will be made of each loop, the loops will then be combined to form a cohesive and complete RITE system model. A performance analysis will be made and correlated, with experimental data to ensure model validity. This model will then be made compatibile and operational on MSFC's 1108 EXEC 8 system.

STATUS: Technical Progress - The investigation into the compatibility of the G189A program for use in modeling the RITE system indicated the need for programming of four new subroutines and renovation of one existing subroutine. These subroutines are for the RITE systems evaporator, condenser, pyrolysis unit, incinerator and tank with internal heating or cooling coil and have been checked out and integrated into the G189A computer program. A complete operational envelope including failure mode analysis utilizing this model has been

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1 thru 10	Analytical Methods for Evaluation and Control of Advanced EC/LSS	J. V. Coggi	10 thru 12, 1972 1 thru 7, 1973

FIRST BENEFITING PROJECT - Sortie Lab

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Technical Progress - Cont'd

made of the RITE system. This model is completely functional on MSFC's 1108 computer complex with the exception of the data plot package which is expected to be complete by 10-19-73.

Documentation and final reports are in progress.

Management Progress - A no cost extension has been granted until Nov. 1973.

Conclusions - Use of the G189A RITE mathematical model has identified the following areas that require further testing: (a) system effects arising from operating the RITE unit at coolant temperatures above test condition temperature ($32^{\circ}F$), (b) RITE system at present can reduce only 2.4 lb/day of waste. Skylab experience indicates this is too low, and (c) analysis of gas generation in the RITE system as pertains to overboard venting or gas storage requirements. These tests are now underway by General Electric under a separate NASA-AEC contract. This model will help to increase the efficiency of experimental testing and has improved program utility in its application to modeling of other life science systems.

Problems - None

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4. TITLE:

Food, Atmosphere, Water and Waste Management

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. L. Moses	205-453-3832	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Cryogenic Heat Exchanger for Life Support Systems
NAS8-28099, AiResearch, Los Angeles, CA.

OBJECTIVE: To provide technology required for design of a heat exchanger to remove varying cabin and electrical waste heat load by means of a cryogenic fluid heat sink. A heat exchanger of this type, for a cryogenic Shuttle, could replace several heat rejection systems that would be required for the various operational phases such as pre and post launch, ascent/reentry and on-orbit. Conventional heat rejection systems such as sublimators, air cycles and radiators work at only given altitudes.

APPROACH: The heat exchanger was studied analytically to investigate heat transfer characteristics and to identify the basic design and control concepts. The prototype heat exchanger was built and tested with GH_2 at 0 and -420°F and LH_2 at -420°F. The heat exchanger performance was predicted for O_2 by analysis only, as funds did not permit O_2 testing.

STATUS: Technical Progress - Heat exchanger has completed testing satisfactorily. Final report has been approved and received.

Management Progress - Contract has been completed. This is the last semi-annual report on this contract.

Conclusions - An 8 lb tube-shell heat exchanger was designed, built and tested which rejected 60000 BTU/hr (17.5 kw) of heat from Freon 21 to a H_2

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
73-9117	Study and Development of a Cryogenic Heat Exchanger for Life Support Systems	M.M. Soliman	March 23, 1973

FIRST BENEFITING PROJECT - Originally conceived of as Shuttle project.

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RESEARCH AND TECHNOLOGY OPERATING PLAN
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Conclusions - Cont'd

sink. Pressure drops and H_2 flowrates were acceptable. Prediction methods were verified. The heat exchanger was designed analytically to use O_2 as alternate cold fluid but due to fund limitations was not tested with O_2. The heat exchanger was tested under various load conditions but load conditions were not changed during individual test runs due to expensive facility modifications required. No freeze up occurred in the warm fluid. Minor pressure fluctuations were noted in the H_2 outlet. Fluctuations were on the order of .1 PSI and were not a diverging oscillation.

During the course of this contract the Shuttle concept was changed to eliminate on-board cryogens, thus the prime application of the heat exchanger disappeared. However, it is possible that this technology can find application on a future vehicle or on a ground application of LH_2.

Problems - None

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MSFC	01 04 73 - 30 09 73	970-62-23	970-62-23

4. TITLE:

Water and Waste Management

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. L. Moses	205-453-3832	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Vacuum Distillation/Vapor Filtration (VD/VF) Water Recovery System NAS8-27467, General American Transportation, Niles, Ill.

OBJECTIVE: To develop a system for reclamation of water from urine in a low gravity environment. System must reclaim 98% of urine, purify to levels prescribed by the National Academy of Science (NAS) and provide means of solids removal. Other design goals will be: weight of under 175 lb., power consumption less than 200 w, high reliability and minimum maintenance.

APPROACH: A prototype unit has been designed, built and tested on the ground. Further testing will be accomplished in low "g" aircraft flights. Work was accomplished in phases. First phase provided evaporator/catalyst and subsystem tests, second phase provided condenser/separator and systems tests. Third phase will provide low gravity testing.

STATUS: Technical Progress - Unit has been designed, built and tested in 1 "g", with production of water that meets NAS requirements, water recovery rates as predicted. Design for low gravity testing underway.

Management Progress - Contract for Phase III in effect.

Conclusions - VD/VF unit reclaims water efficiently with high degree of purity, exceeding NAS standards.

Problems - Schedule may slip due to loss of time involved in transfer of low gravity aircraft from Wright Patterson AFB to JSC.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1528	Design, Manufacture and Check-out Testing of an Evaporator for Water Recovery by Vacuum Distillation - Phase I	Honegger Remus Krug	April 1972
1528	Ditto - Phase II	Honegger Remus Krug	March 1973

FIRST BENEFITING PROJECT - Sortie Lab (Flight Experiment)

MSFC - Form 350 (March 1973)

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. W. Littles	205-453-3831	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Aircraft Flight Testing of Fluids in a Zero Gravity Experiment
NAS1-11735, General Dynamics, San Diego, CA.

OBJECTIVE: To flight test, at reduced gravity, in an aircraft an experiment in fluid management. The test results, along with results to be obtained at standard gravity on the same hardware, will be used to validate and update analytical models compiled under a previous contract.

APPROACH: Hardware has been fabricated which will be used to provide experimental data from laboratory and KC-135 aircraft tests on the gravity effects associated with the following flow phenomena: (a) two phase flow (b) inertial separation and (c) film transport and stability characteristics. The data will be used to validate analytical models for these fluid flow situations. The hardware is modularized so that the fluid flow sections can be replaced to provide the configuration required for a given flow condition. The power supply and instrumentation packages are in a separate module and are the same for all flow experiments.

STATUS: Technical Progress - Hardware has been fabricated and ground tests are to begin in October.

Management Progress - The contract has been funded.

Conclusions - None

Problems - None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
a. N/A	Sensor Studies	D. Heppher	April 1973
b. N/A	Objectives of the Prototype Experiment Program	J. Burnett	April 1973
c. N/A	Handbook of Instructions - Prototype Experiment System, Vol. II	J. Burnett	April 1973
d. N/A	Management Plan for Hardware Development - Prototype Experiment System	J. Burnett	May 1973

FIRST BENEFITING PROJECT - Sortie Lab (Flight Experiment)

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. Middleton	205-453-3828	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Radioisotope Water and Waste Management System
H-79269A, General Electric, Valley Forge, PA.

OBJECTIVE: Develop a complete system to process all waste products from advanced manned spacecraft with minimum human contact.

APPROACH: The current program is a joint AEC-NASA effort. The system processes the nominal 4 man quantities of waste: urine - 14 lb/day, trash - 1.2 lb/day, feces - 1.2 lb/day, wash water - 24 lb/day and condensate water - 20 lb/day. Using radioisotopes as thermal energy sources, these inputs are processed by evaporation/pyrolysis into distilled potable water and the solids by incineration into dry ash. The processed and stored water is maintained at 160°F until use to preserve sterility. The program has been conducted by means of analysis, component tests short duration (10 day) systems tests and a 180 day system verification test. Following the successful completion of the 180 day test, minor revision will be made to the system in the areas of shaft seal incinerator transport, etc., and a short test to confirm their operation will be performed. This test will only be for confirming component functional operation.

STATUS: Technical Progress - A breadboard and two 10 day system tests were performed to prove the conceptual design of the system. During these tests, the water met all National Academy of Science (NAS) and Johnson Space Center requirements for potable water except during short period (1-2 days) when certain mechanical components failed. When repaired the water quality met NAS and JSC specifications again. Following these successful tests, a 180 day demonstration test

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Monthly and Quarterly Progress Reports		

FIRST BENEFITING PROJECT - Sortie Lab (Flight Experiment)

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Technical Progress (Cont'd)

was scheduled to show the long term performance of the system. During this test, the water quality once again met NAS and JSC standards except when failure of mechanical sub-components caused explainable descrepancies. A slight air leak into the low pressure evaporator around a rotating shaft seal caused the Ph level of the water to be lower than desired. The 180 day test has been completed and accomplished the last major milestone of the original program and concept. Final report is being written.

Management Progress - None

Conclusions - The basic system concept and component designs accomplished the original performance goals of processing crew and spacecraft waste into potable water and dry ash as well as maintaining acceptable biological sterility of the mechanical components and processed water.

Problems - None

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. C. Clark	205-453-3828	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Bosch CO_2 Reduction System
NAS8-27276 Convair Division, General Dynamics Corp., San Diego, CA.

OBJECTIVE: Optimize operational parameters to effect a 50% reduction in power requirements and a 25% reduction in expendable weight. Conduct an indepth materials evaluation study to isolate materials which are non-reactive in the high temperature reaction zone area in order to preclude carbon precipitation in areas other than the catalyst cartridge. Redesign a power optimized variable speed control system for the re-cycle compressor. Investigation of use of the product carbon block as a filter medium. Investigation of the integration of the Bosch with the hydrogen depolarized cell CO_2 concentrator.

APPROACH: Determine operational parameters which most significantly affect efficiency and optimize for maximum performance capability. Select materials which are non-reactive based on in-depth study of reaction physics and chemistry. Determine filtration efficiency of the product carbon block, in a water system, with a broad spectrum of contaminants to be removed from wash water.

STATUS: Technical Progress - A small amount of additional system parametric testing was accomplished during this reporting period. Failure, due to internal carbon precipitation, on the regenerative heat exchangers preclude continuance of this effort. A procurement contract has been let with Metal Bellows Co., Los Angeles, for new heat exchangers manufactured from inconel 625, a very non-reactive material, with delivery expected in mid October. This should cause the carbon to react only in the catalyst bed.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
ADCA-DBD73-001	Bosch CO_2 Reduction System Development Interim Report	R.F. Holmes C.D. King E.E. Keller	January 1973

FIRST BENEFITING PROJECT - Sortie Lab (Flight Experiment)

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Technical Progress (Cont'd) - Material studies continue in an effort to isolate other alloys which are non-reactive in the Bosch high temperature gas stream. These studies are also being conducted to gain further insight into reaction mechanics which can be applied to improve reaction efficiency.

The motor/compressor/controls study has to date netted a 15% improvement in compressor power consumption. This was affected by increasing the tubing and fitting diameter of factory supplied manifolding on the compressor from 3/8" to 1/2". Power was reduced from 240 watts to 205 watts, on the average.

Management Progress - The contract was signed May 2, 1973. Two monthly progress and financial reports have been received.

Conclusions - None

Problems - Failure of regenerative heat exchangers due to carbon precipitation - new heat exchangers under procurement.

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. C. Clark	205-453-3828	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study/Integration of the Bosch CO_2 Concentrator With the Hydrogen Depolarized Cell CO_2 Concentrator (HDC)
NAS8-29623, Life Systems, Inc. (LSI), Cleveland, Ohio

OBJECTIVE: Determine whether or not the Bosch can be operated satisfactorily at the 1-3 PSIG discharge pressure of the HDC. Resolve pressure fluctuation problems associated with switch-over from one Bosch unit to the other, with resulting operational impacts on the HDC. Determine the amount of instrumentation communication required between the Bosch and the HDC. Confirm data outlined above with testing.

APPROACH: Both the Bosch and HDC will be mathematically modeled and computer analyses made to determine effect of Bosch operating characteristics on HDC. Test program to confirm analytical findings, suggested operating and control modifications to Bosch and HDC will be recommended.

STATUS: Technical Progress - Coordination meetings have been held between the Bosch contractors, General Dynamics Corp., and Life Systems to exchange operational data on the two systems, and to outline coordination effort required during the course of the contract. An outline of nominal, Bosch system operating parameters has been furnished to LSI for study in connection with the integration effort.

Management Progress - The contract for this effort was signed June 21, 1973. Two monthly progress reports and financial reports have been received.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITING PROJECT - Sortie Lab (Flight Experiment)

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Conclusions - None

Problems - None

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. L. Moses	205-453-3832	G. D. Hopson

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Advanced Life Support System Cost Study
NAS8-28377, MDAC-WD, Huntington Beach, CA.

OBJECTIVE: To develop and correlate costing and resource relationships to aid in estimating resource requirements for advanced flight type life support systems.

APPROACH: Subsystems to be studied have been identified and cost data collected on each subsystem. Systems investigated were: (1) water recovery systems, (2) CO_2 concentration systems, (3) oxygen regeneration systems and (4) atmosphere monitoring systems. Cost relationships for development of the system were obtained. The methodology for obtaining cost relationships has been developed under a previous contract. Basic data was obtained by review of cost data residing at the contractors Eastern and Western Division plants as well as what could be obtained from government and other contractor sources.

STATUS: Technical Progress - Data on selected systems has been collected. Cost comparisons between competing candidates have been made. Reports on systems have been completed. Due to the large number of experiments planned for Sortie Lab and other future missions, cost will be critical. Therefore a follow-on study is planned to investigate the cost of experiments including basic equipment and integration. In addition two life support subsystems not covered in the previous investigation will be covered in the follow-on. They are thermal control and waste management systems.

Management Progress - Statement of work for follow-on work has been published. Proposal is being awaited.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MDC G4031	Cost Analysis of CO_2 Concentrators	M. M. Yakut	June 1973
MDC G4032	Cost Analysis of Water Recovery	M. M. Yakut	June 1973
MDC G4033	Cost Analysis of Oxygen Recovery Systems	M. M. Yakut	June 1973
MDC G4034	Cost Analysis of Atmosphere Monitoring Systems	M. M. Yakut	June 1973
MDC G4030	Summary Report	M. M. Yakut	June 1973

FIRST BENEFITING PROJECT - Sortie Lab

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Conclusions - Cost escalates rapidly after construction of a typical non-qualified high fidelity prototype subsystem. Prototype cost is about 10% of the total program cost the rest is integration and qualification costs. In addition, due to changes, etc., design costs rise by 60% after "completion" of the design.

Problems - None

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Fred Zur Burg	205-453-4412	G. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Design Guidelines for Long-Life Mechanical Components
(Long life temperature control valve)

OBJECTIVE: Extend the useful life of temperature control valve (estimated to be 20,000 cycles) to 100,000 cycles.

APPROACH: The valve design shall emphasize material studies, wear rates, seat design, fatigue life, etc. Testing will be accomplished to verify design.

STATUS: Technical Progress - None

Management Progress - Proposal is being evaluated.

Conclusions - None

Problems - None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

FIRST BENEFITING PROJECT: Sortie Lab

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4. TITLE:

CVT EC/LSS Support Program

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
William M. Langston	205-453-3923	G. Kroll

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Design Guidelines for Long-Life Mechanical Components
(Pump failure anticipator)

OBJECTIVE: Develop sensors that will anticipate a motor or pump failure with sufficient time remaining that repair or replacement can be accomplished before failure.

APPROACH: Analysis of high frequency vibration spectrum will be utilized to provide diagnostic information to predict impending pump failures.

STATUS: Technical Progress - None

Management Progress - Proposals have been received from 3 contractors. The proposals have been evaluated and the results sent to purchasing.

Conclusions - None

Problems - None

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED

FIRST BENEFITING PROJECT - Sortie Lab

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MSFC	01 04 73 - 30 09 73	970-63-10	970-63-10

4. TITLE:
Requirements for Work Performance Design

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. W. Stokes, S&E-ASTN-SMH	205-453-3747	
P. T. Artis, S&E-ASTN-SMA	205-453-4373	T. P. Isbell

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Laboratory Configuration Development and Evaluation
NAS8-28512 University of Alabama in Huntsville, Huntsville, Alabama
NAS8-29777 Martin Marietta Corporation, Denver, Colorado

OBJECTIVES: Continue and consolidate the development, verification, and application of man/system integration criteria for maintainability, accessibility, and the various dimensions of habitability, as well as establishment of experiment integration criteria constraints.

APPROACH: A multilevel man/system assessment will be made during test operations in the Payload Carrier Simulator at MSFC. Logistics events such as supply transfers, stowage techniques, and maintenance activities will be coded and stored for subsequent analysis; utilization of the simulator will be determined via a program of direct observation of operating crewmen.

STATUS: Technical Progress: The Payload Carrier Simulator (PCS) Phase I Integrated Test has been completed including data reduction and analysis. The test was a success (ref. NAS TM X-64770, CVT/PCS Phase I Integrated Testing, R. O. McBrayer & J. D. Steadman, July 1973). The software for man/system data collection and analysis is complete. The Universal Stowage Module Concept Selection Review is complete. Final Design Review will be held in the near future. The goal of keeping the number of different restraints low is being met. Management Progress: The contract with University of Alabama in Huntsville is being completed. The Universal Stowage Module contract is on schedule. Conclusions: A viable program of experiment assessment

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final Report; Payload Carrier Simulator Man/Systems Program Integration	Dr. J. G. Rogers & Dr. R. E. James	July 1973
Monthly Progress Report: Universal Stowage Module for Future Space Exploration	Victor A. DesCamp & Michael W. Hussey	July 1973
Monthly Progress Report; Universal Stowage Module for Future Space Exploration	Victor A. DesCamp & Michael W. Hussey	August 1973
Monthly Progress Report; Universal Stowage Module for Future Space Exploration	Victor A. DesCamp & Michael W. Hussey	September 1973

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STATUS CONTINUED:

and man/system assessment of the Payload Carrier Simulator is under development. Problems: None. Forecast: The above efforts will be unified to produce an efficient design/development protocol for Space Shuttle payloads. Once established the protocol will be directly applied to payload outfitting.

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4. TITLE:
Requirements for Work Performance Design

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Jack Stokes, S&E-ASTN-SMH	205-453-3747	T. P. Isbell

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: On-Orbit Evaluation of Payload Man/Machine Integration Design
NAS8-26558 URS/Matrix Co., Man Systems Div; 4702 Governor's Drive, Huntsville, AL.

OBJECTIVE(S): Identify the tasks man will perform in the spacecraft environment.

Identify spacecraft hardware requirements utilized in man/systems zero and partial gravity flight testing for advanced systems design.

APPROACH: To review manned simulations.

To evaluate experiment protocols to be conducted in space.

To evaluate hardware which will allow the experiment protocols to be instrumented.

To conduct simulations on the ground, using one-G payload simulators as testbeds.

STATUS: Technical Progress: Majority of BETA hardware has been produced to be used in conjunction with payload simulators to monitor nonintrusively man/machine interfaces and to verify experimental protocol & data analysis techniques. A software package in conjunction with breadboard hardware being developed. Total effort proceeding according to plan. Management Progress: Planning and status meetings conducted. Test results summary meetings conducted. Conclusions: Testing was conducted as a part of payload carrier integrated test and again as a separate test demonstration feasibility of the system for nonintrusive testing.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Interim Report	BETA Flight Experiment on Work Performance	J. W. Stanfield	15 01 73

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STATUS CONTINUED: Forecast: No further testing will be conducted under the Matrix Contract. Effort will be directed toward a complete software package for non-intrusive data collection and analysis. The total package will be available on an as required basis for future payload testing.

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4. TITLE:

Requirements for Work Performance Design

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. B. Gardner S&E-ASTN-SM	453-3747	T. P. Isbell S&E-ASTN-S

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Experiment Crew Station Design Criteria
NAS8-25627 URS/Matrix Company, Huntsville, Alabama

OBJECTIVE(S): The development, verification and publication of man/systems design standards and criteria for application to shuttle payload control/display panels and crew stations.

The validation of 1-g simulation methods and techniques for use during the development cycle of payload control/displays, operating procedures, and workstations.

APPROACH: The objectives of this study are being accomplished by an on-orbit and ground evaluation of the ATM man/machine interface to identify design criteria, standards, procedures, and control/display hardware that can be used in the design of shuttle payload controls and displays and crew workstations. This effort is divided into two major phases as follows:

Requirements Analysis. The primary objectives of phase I were (a) prepare the ATM man/machine interface evaluation procedure, including ground data collection requirements, data analysis plan, and a list of the ATM interfaces to be evaluated, (b) prepare a listing of all Skylab on-orbit telemetry data to be used in the analysis.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
PRL-308	Phase I Report An Evaluation of the ATM Man/Machine Interface (Definition Study)	E. C. Pruett	2/6/73
PRL-308	Monthly Progress Report	E. C. Pruett	4/10/73
	Monthly Progress Report	E. C. Pruett	5/10/73
	Monthly Progress Report	E. C. Pruett	6/10/73
	Monthly Progress Report	E. C. Pruett	7/10/73
	Monthly Progress Report	E. C. Pruett	8/10/73
	Monthly Progress Report	E. C. Pruett	9/10/73

FIRST BENEFITTING PROJECT: SPACE SHUTTLE

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APPROACH (CONTINUED): Data Collection. During Phase II baseline ground data is being collected on the setup and operation of the ATM experiments using the ATM Dynamic Control/Display simulator located at MSFC. Data collection is being accomplished using closed-circuit video cameras, observation, a strip chart recorder and an analog computer. The ground simulation tasks closely duplicate those tasks for which on-orbit telemetry data will be available. During the SL-2 mission telemetry data on the operation of the ATM experiments was collected by MSFC. An examination of these on-orbit data has indicated that all requested data were collected.

Data Reduction and Analysis. The data collected in phase II is being reduced and analyzed. Data reduction is currently 60% complete. Data analysis will begin when all SL-2 data has been reduced. On-orbit data will be compared with baseline ground data for the purpose of validating 1-g simulation techniques and the identification of man/systems design standards, criteria, and control/display hardware that can be used in the design of future payload control/displays and crewstations.

Preparation of Design Criteria Handbook. When data analysis is complete the results will be integrated into a control and display panel design criteria handbook for shuttle payload designers. This will include all design criteria developed during this study.

STATUS: Technical Progress. An evaluation of ATM C&D panel design was completed including a comparison with MSFC-STD-267A and MIL-STD-1472-A human engineering design standard documents. All deviations of the ATM C&D panel design from the standards were recorded. The 19 major deviations are described in the 70 page phase I report (February 6, 1973). A plan was completed for collecting ground baseline data (Monthly Progress Report 6/10/73). Data reduction and data analysis flow diagrams were also prepared which identify the activities required for processing the on-orbit and ground data. Ground data collection and SL/2 data reduction are in progress. Management Progress. The original Scope of Work was expanded to include preparation of a Control and Display Panel design criteria handbook. This modification was incorporated 8/22/73. Conclusions. The ATM C&D panel violates 19 major design standards identified in MSFC-STD-267A and MIL-STD-1472. The effect of these deviations will be evaluated when the Skylab data analysis is completed in Phase II. Problems. Presently there are no known technical problems that might impede or prohibit successful completion of this effort. Forecast. None. Remarks. None.

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4. TITLE:
Teleoperator Control and Manipulation

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. H. Clingman	205 453-3465	

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task 50: Earth Orbital Teleoperator Systems Analysis and Experiment/ Demonstration Definition
NAS8-29153 - Bell Aerospace Company, Buffalo, N. Y.
NAS8-29904 - Martin-Marietta Corporation, Denver, CO

Objectives:

1. Analyze teleoperator systems and man-machine applications to NASA Space Shuttle, Tug, and Payload Missions.
2. Analyze and define teleoperator system interfaces and man-machine requirements with the Space Transportation System and future payloads.
3. Provide the definitions of experimental Free-Flying Teleoperator Systems which can meet NASA's mission model flight dates.
4. Produce teleoperator prototype systems and define interfaces with Shuttle/Tug/ Payloads for engineering evaluation or proposed demonstration orbital flights.

Approach:

The objectives of this task will be accomplished through study contracts with industry.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
D7425-953004	Shuttle Free-Flying Teleoperator System Experiment Definition	Bell Aerospace	June 1972
D7425-953008	Shuttle Free-Flying Teleoperator System Experiment Definition	Bell Aerospace	February 1973
MCR-73-263 (Mid-Term Report)	Shuttle Remote Manned Systems Requirements Analysis	Martin-Marietta	October 1973

FIRST BENEFITING PROJECT: Shuttle

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Status: Technical Progress: Two preliminary system level contracted studies have been completed. The general justification of the Free-Flying Teleoperator concept has been made. A typical experimental Free-Flyer system has been defined. A typical early Shuttle demonstration and data gathering experiment has been defined. Preliminary requirements of Remote Manned Systems are fifty percent completed.

Management Progress: Contract NAS8-29153 has been completed with final report and review submitted. The mid-term review of Contract NAS8-29904 has been completed and the contractor is producing the desired results.

Conclusions: The Free-Flying Teleoperator will add meaningful benefits to the Shuttle/Tug/Payloads and their earth orbital operations.

Problems: None

Forecast: None

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4. TITLE:

Teleoperator Manipulation and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-MS Wilbur G. Thornton	205/453-5530	J. Boehm, S&E-ASTR-M

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Objective: To investigate and establish component and integrated systems technology and define design criteria for free flying teleoperators applicable to shuttle, tug and satellite missions in earth orbit. The goal is to provide design criteria for manipulator, visual, remote vehicle control subsystems and man system interface in 1976 time frame.

Approach:

1. Conduct feasibility studies and design investigations on: advanced manipulators, controllers, end effectors, and their interfaces with supporting systems; remote control of free flying mobility units and interfacing systems; visual system sensors, communications, and displays.

2. Evaluate man-machine integration methods applicable to free flying teleoperators.

3. Define and develop systems for experimental and demonstration flights on early shuttle missions.

4. Investigate advanced methods in manipulators, visual systems, and computer sciences for application to later missions.

Status: This RTOP consists of several tasks. Each will be reported separately.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: Free Flying Teleoperator

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4. TITLE:
Teleoperator Manipulation & Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Wilbur G. Thornton S&E-ASTR-MS	(205) 453-5530	J. Boehm, S&E-ASTR-M

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task 11: Development of Advanced Manipulator Systems

Reference: This task consists of the following tasks from prior years:
FY-72: RTOP 503-24-01, Terminal Tools for Teleoperators
FY-73: RTOP 970-63-20
Task 10. Manipulator Systems Simulation & Evaluation
Task 11. Study & Development of Remote Manipulators
Task 12. Design Studies in Satellite Retrieval Systems

Contracts:
1. In-House Simulations
2. Ames Research Center, Moffett Field, CA
3. NAS8-27073. Univ. of Mass., Amherst, MA
4. NAS8-29188. Rancho Los Amigos Hospital, Downey, CA
5. NAS8-27013. URS/Matrix Co., Huntsville, AL
6. NAS8-28055. MIT, Cambridge, MA
7. NAS8-29724, Draper Labs, Cambridge, MA
8. NAS8-29631, United Shoe Machinery, Wakefield, MA
9. NAS8-30266, Martin Marietta Co., Denver, CO
10. NAS8-29632, Univ. of Tenn., Knoxville, TE
11. NAS8-28760, URS/Matrix Co., Huntsville, AL

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
URS/Matrix PRL 321	Teleoperator Systems Performance Requirements	Saenger & Pedgen	11/72
URS/Matrix PRL 360	Design of Terminal Pointer Hand Controller	Saenger & Woltosz	6/72
USM Corp.	Engineering Analysis of Pre-Stage Planetary Gear Trains	R. N. Morris	6/72
MIT DSR 72-73784	Optimal Trajectory Generation for Mech. Arms	J. Iemenschot	9/72
MIT DSR 73784-2	Experiments in Video Camera Positioning With Regard to Remote Manipulation	J. Mackro	2/73
MIT DSR 73784-2	Vibration Considerations in Manipulator Design	W. Brook	2/73
MIT DSR 73784-4	Summary & Conclusions	D. Whitney	2/73

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Report No.	Title	Author(s)	Date Transmitted
Univ. of Mass.	Monthly Letters on Technical Progress	F. R. E. Crossly	4/73 to 9/73
Univ. of Tenn.	Monthly Progress Reports	J. C. Hung	6/73 to 9/73
Univ. Of Ala.	Study of a Manipulator Arm Concept.	L. Kersten	8/73

First Benefitting Project: Free Flying Teleoperator

Objectives:

1. To identify and apply appropriate aerospace technology to the design of manipulator arms, actuators, end effectors and sensors.
2. To develop viable control schemes which will most effectively utilize the capabilities of man as the primary source of control signals.
3. To evaluate existing and new designs in laboratory conditions and generate requirements for a space design manipulator system.

Approach:

1. Perform trade off analyses and design studies of all design factors and performance functions of the manipulator including actuators, joints, end effectors, and sensors. Design, procure and test an advanced experimental manipulator and components applying space technology.
2. Develop candidate control schemes which offer maximum flexibility and ease of control for the human operator and evaluate these on computer simulations and actual hardware.
3. Using existing hardware where possible prepare a laboratory which will provide a simulated operating environment for the investigation and development of remote controlled manipulator systems. Included will be task boards, communication links, computer, visual equipment, lighting, control and display, etc. Provision will be made for investigating such effects as: manipulator control schemes, manipulator configurations, light, communication link degradation, time delay, etc. Flexibility for use of different manipulator/controller/display combination will be provided. This simulation will provide means of evaluating the man-machine interactions.
4. Utilizing the results of studies performed under contracts NAS8-27021, NAS8-27895, NAS8-29153, NAS8-29024, NAS8-28298, NAS8-28055, and others as appropriate perform a preliminary design of a manipulator system applicable to the free flying teleoperator system. The study would consider configurations, controllers, control modes, end effectors, actuators, sensors, displays and the interaction of the manipulator system with other teleoperator systems.
5. Generate preliminary design criteria.

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Status:

1. Manipulator System Simulation & Evaluation

a. During the past several months the simulation area has been undergoing a facility change consisting of the installation of a raised floor and air conditioning. This will be completed in October.

b. The hardware for the measuring equipment has been assembled and preparations made for installation in the laboratory. Telemetry has been checked out and installed.

c. Interconnections between the computer and manipulator have been installed and preliminary runs have been made to check out the system.

d. A set of high performance operational servo amplifiers were removed from the warehouse to determine if they could be used to replace the servo amplifiers which came with the Rancho RAM.

e. Programming of the Terminal Pointer Control Equations is continuing but was slowed at the beginning of the FY because of manpower cutbacks.

2. Manipulator Design & Control

a. Modular Manipulator Kit System

Design study for providing a semi-anthropomorphic like manipulator slave unit is complete, design detailing is underway. A wooden mock-up was manufactured for flat conductor cable routing study. The detailed design is scheduled for completion in Mid-November.

The design of the ADAMS III hand is complete. All items are being manufactured. The gear assembly to be furnished by Illinois Gear will be shipped in December.

Preliminary listing of the ESAM (Multipurpose) Mechanical Joystick Analog Controller is complete. Testing indicated a need for redesign of the marginal working extend brake and overweight forward unit assemblies. Redesign is being taken.

The engineering analysis and design of the Harmonic Drive Planetary Gear Assembly is complete. Manufacturing and assembly is 80% complete. Proof testing and delivery is expected by October. Phase I report (Engineering Analysis) has been published, (NAS8-29631).

b. Advanced Manipulator (In House)

The conceptual design and feasibility study have been completed. The manipulator concept is based on the use of concentric tubes and differentials to transmit the motion from the actuator to the displacement element. It will be a light weight general purpose device with all actuators for the first six degrees of freedom located at the shoulder.

c. Advanced Design and Control (NAS8-28055)

A technique has been developed to quantify and measure the performance of multi-degree of freedom open loop systems such as a man controlling a manipulator. Dissimilar data are normalized and parameters of performance are identified.

Mixed lumped distributed parameter models of vibrating arms are included in the dynamic analysis. The effects of motors, gear boxes, flexible shafts, etc., are included.

d. A simplified version of the MIT "Resolved Motion Rate Control" (RMRC) for manipulators has been developed in-house. The simplified version applies the RMRC techniques to the three degrees of feeedom applied to the translational motion of the manipulator while direct rate control is applied to the manipulator joints providing orientation of the end effector. Simplified RMRC has been developed for the extendible stiff arm manipulator (ESAM) and the concept will be tested with the isometric six DOF hand rate controller from the Draper Labs (NAS8-29724). The controller is to be delivered in October, 1973.

3. Configuration & Design Study of Manipulator Systems Applicable to the Free Flying Teleoperator. (NAS8-30266).

The purpose is to investigate the design concepts of manipulator system applicable to a Free Flying Teleoperator operating in conjunction with the Shuttle and Tug and to provide design trade-off data such that the most optimum selections can be made for specific applications.

Specific Objectives are:

a. An evaluation of existing manipulator components and subsystems for space use and a forecast of technology to be available in the 1980 time frame.

b. Provide a preliminary requirements analysis for the manipulator system.

c. Provide conceptual designs with supporting engineering analysis for the selection of the most promising concepts for further consideration.

d. Provide preliminary designs together with trade-off data of those concepts suggested in C.

e. Provide a preliminary specification for the manipulator system.

Conclusions:

1. The simulation of a complete remotely controlled manipulator system is a complex task. The complexity of the interaction of the many degrees of freedom of the manipulator connected by a computer system has not been fully realized in any work described elsewhere. However, if successful the system will make it possible to attack a wide variety of problems inherent in Remotely Manned Systems.
2. The use of the computer to calculate the transformations from the end effector to the controller is desirable in that it makes the systems more flexible. However, both mathematical and physical singularities are encountered in the general case and are difficult to overcome. Several methods have been advanced:
   a. Design the arm configuration such that the singularities are minimized or known.
   b. Use a calculation scheme which gives unique solutions such that mathematical singularities are eliminated. The use of Quarternions has been suggested.
3. The technical area requiring added effort is in the control scheme analysis and the design of control electronics. No quantitative information exists on these with respect to a remotely controlled manipulator.

Problems:

1. The restrictions on manpower have caused a delay and also uncertainty on making progress.
2. The reduction of in-house fabrication facilities together with restricted manpower allotments in that area will restrict the effort in-house because of the additional cost associated with outside procurement.
3. Facility changes in the manipulator laboratory and the mobility unit area have caused delays of about 4 - 6 months.

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Management Progress:

1. A contract was negotiated with Martin Marietta Company on the Configuration and Design of Manipulator Systems Applicable to the Free Flying Teleoperator. It began September 14, 1973, and runs for 10 months.
2. NAS8-29073 was extended until November 1973 at no cost to the Government.
3. NAS8-29188 was extended until October 1973 at no cost to the Government.
4. NAS8-28055 was inactive from February through April due to the fund freeze. It was extended May 1973 for a period of seven months.
5. NAS8-29724 was extended for one month because of a fabrication mishap. The controller will be delivered in October 1973.
6. NAS8-28361. The final report has not been delivered as required. Therefore, the final payment of contracted funds has been held up by Procurement Office.

Forecast:

1. The Terminator Kit Assembly hardware will begin man/machine testing in November, 1973.
2. Test and Evaluation of the Rancho RAM will begin next quarter dependent on the facility change.
3. Testing of the Draper Lab 6 DOF Controller with the ESAM will begin in October.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	970-63-20	970-63-20

4. TITLE:

TELEOPERATOR MANIPULATION AND CONTROL

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. Dwight Johnston/S&E-ASTR-GC	205-453-0792	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

PRIOR CODE: Task 12, FY-1972

TASK 20: INVESTIGATIONS ON REMOTE CONTROL OF TELEOPERATOR MOBILITY UNITS (INHOUSE)

OBJECTIVES:

1. To identify guidance, navigation and control subsystems required for free-flying teleoperator on Space Shuttle payload mission.

2. To determine minimum adequate hardware performance requirements for G, N, & C subsystem for a free-flying, remotely controlled teleoperator to affect launch from Shuttle; rendezvous, docking, controlling, and/or operational positioning with respect to an orbiting spacecraft; and the retrieval of the spacecraft.

3. To determine minimum adequate requirements for the remote control and display station applicable to the G, N, & C functions.

APPROACH: (Design, Fabricate and Test)

1. Remote controlled vehicle with attitude control systems and/or small CMG's necessary for docking. System will be equipped with air bearings to provide low friction rotations about two or three axes and translation in a plane capable of providing information on the G, N, & C functions necessary for rendezvous.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
S&E-ASTR-G-WP-7-73	Free-Flying Teleoperator Breadboard Vehicle	W. C. Mastin	July 3, 1973

FIRST BENEFITTING PROJECT: Teleoperator

MSFC - Form 860 (March 1978)

(Approach) (cont.)

2. A test bed of super smoothness (enclosed in a featureless opaque non-reflective flack cloth room) to provide low friction operation of the air bearings necessary for flotation of the above vehicle.

3. Control console and station to allow for remote control and monitoring of the above mentioned vehicle and test bed, and will include equipment to enable an in-depth study into the effects of time delays, data processing and handling requirements, communications, image displays, controllers, man-machine interaction, etc.

4. Perform studies on attitude control, docking and retrieval.

STATUS: Technical Progress:

1. The following designs have been completed, fabricated, tested and installed:

a. Rate gyro package and electronics necessary for stabilization, including determination and calibration of loop gain.

b. Mode circuitry for both station and mobility unit.

c. The passive unit, with drogue for docking test.

d. Test bed surface including flatness checks. Due to a non-uniform cure in the epoxy surface, four coats of epoxy paint were added to floor to eliminate some minor anomalies.

e. A high pressure gas line in test area for charging flotation and thruster supply tanks.

2. Since becoming operational in the closed loop mode, the mobility unit has been modified by (a) adding more gas bottles to permit longer operation between gas replenishment and (b) adding more rigid supports to eliminate pendulous effect.

3. The design of a 12-inch flotation air bearing has been completed but completion of fabrication has been delayed due to relocation of the manufacturing facility.

4. A digital rate integrator has been designed and is approximately 60% complete in assembly.

5. A catwalk for supporting an overhead T. V. camera (provide X-Y information for position and attitude system) has been designed and built; however, due to Center Management's decision to relocate the Teleoperator Test Facility, installation has been delayed.

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(Status) (cont.)

Conclusions: None

Problems:

1. Due to a non-uniform cure in the epoxy surface, it was necessary to add four coats of epoxy paint to the floor to eliminate some minor anomalies.

2. The completion of the Ranger Radar has been delayed due to manpower changes.

3. Due to the decision to close the building in which the facility was located many activities and studies that were planned to have been conducted by this date have been delayed. The relocation process will cause another delay of about six months.

Management Progress: None

Forecast: The program will be delayed about six months.

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MSFC	01 04 73 to 30 09 73	970-63-20	970-63-20

4. TITLE:

Teleoperator Manipulation and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. T. Huggins	453-5612	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task 30: Study and Development of Teleoperator Viewing System
NAS8-29024, Martin Marietta, Denver, Colorado

Objectives: (1) Determine the preferred type viewing system required for remote manipulator operation. (2) To examine and evaluate methods of determining range and range-rate by remote viewing through a television system. (3) Evaluate a combined mono and stereo viewing system. (4) Evaluate the use of color in the remote viewing system. (5) Determine the effect of fixed and variable delays between a video sensor and the display. (6) Perform studies for actual docking of the teleoperator to a target vehicle by remote viewing through a television system. (7) Write system requirements and limitations. (8) Develop a breadboard model and finally an engineering model for design criteria. (9) Apply image enhancement techniques to remote manipulator operations.

Approach: (1) From previous in-house experience, simulations and studies, the system requirements for teleoperator control have been determined and have been used to broadly define a teleoperator viewing system. Based on this definition, simulations are being developed to evaluate the performance capability of the man and the visual system. The Astrionics Visual System Test and Evaluation Laboratory is being used for this testing. Conduction of the tests and analysis of the results are being done by Essex Corporation under Contract NAS8-28298. (2) A contract for conceptual design and preliminary design of a teleoperator viewing system has been completed in 1973 by Martin Marietta under Contract NAS8-29024. The results of the conceptual design phase have been compared with in-house engineering data and a decision, based on both, has been made on the type breadboard system for use in the manipulator/visual system tests. (3) A study contract will be negotiated with a company in the first half of FY 74 for the testing of rendezvous and docking of a teleoperator with a target using only television. (4) Continue work utilizing concepts from computational linguistics to enhance images by

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MCR-72-276 NAS8-29024	Conceptual Design Study for a Teleoperator Visual System, Phase I	Martin Marietta	December 1972
MCR-73-96 NAS8-29024	Conceptual Design Study for a Teleoperator Visual System, Phase II	Martin Marietta	April 1973
Report #1 NAS8-28298	Earth Orbital Teleoperator Visual Systems Evaluation Program	Essex Corporation	March 1973
#1	Image Enhancement Progress Report	Dr. R. C. Gonzalez	February 1973
#2	Image Enhancement Progress Report	Dr. R. C. Gonzalez	March 1973
#3	Image Enhancement Progress Report	Dr. R. C. Gonzalez	April 1973
#4	Image Enhancement Progress Report	Dr. R. C. Gonzalez	June 1973
#5	Image Enhancement Progress Report	Dr. R. C. Gonzalez	August 1973

First Benefiting Program ----- Free Flying Teleoperator

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 970-63-20 PAGE 2 OF 2

selectively accentuating frequencies of interest. This procedure will be formulated so that it can be used by the operator with minimal insight and experience. This work is being done by Dr. R. C. Gonzalez, University of Tennessee, Knoxville, Tennessee, under Contract NAS8-29271.

Status: Technical Progress: (1) The open loop visual investigations which began in February 1972 are continuing and are described in Task 13. The results have so far indicated, for example, that certain tasks will require the operator to use a 3D TV system, and that brightness ratios will be extremely important where the objects would normally tend to blend without a high brightness difference. The use of color may help the brightness problem. Color testing is planned during the second and third quarters of FY 74. (2) Technical support to Essex Corporation is being carried out for visual system design, layout and maintenance for both the visual system test lab and the upcoming manipulator tests. (3) Contract NAS8-29024 with Martin Marietta has been satisfactorily completed. This work took a look at all the following subsystems of a remote manned system's visual system: sensors, illumination, deployment/articulation, displays, telecommunication, and controls and display integration. The basic visual system recommended from this work is a hybrid-monoscopic-stereoscopic TV system. This approach, inherently simple, appears to provide considerable operational flexibility and visual coverage adequate to accomplish all the anticipated RMS activities. (4) Circuit design of the teleoperator docking simulator X-Y coordinate system readout has been completed. The system derives X-Y coordinate data from a TV picture of the remotely controlled teleoperator, and stores this data on a 7-track tape for computer processing. This data is in digital format, coded as to X or Y data and vehicle orientation. The computer maintains a running time base reference. The breadboarded model is ready for dark room test as of this reporting date. (5) Phases I and II of the image enhancement contract with University of Tennessee are complete. The development of the necessary basic software for the PDP-11 digital computer, such as the programs to control information transfer and the Fast Fourier Transform programs, have been completed and are operational on the equipment. Initial tests on the effects of filter primitives and lighting on test images have been completed. Test images have been processed through the computer and displayed on the TV monitor. The development of automatic enhancement techniques is underway.

Management Progress: RFQ's are being prepared for two separate support studies. One is a test series to determine under what conditions, if any, an operator cannot rendezvous and dock a RMS with a satellite using only stereo TV and no ranging. The second is for determining the anticipated delays which will be encountered between a RMS control station at various locations and a satellite in low and geosync orbits. A computer program will be written to be used in controlling the variable delay between the controller and the RMS as a function of time and orbit position.

Conclusions: Objectives under Contract NAS8-29024 have been met.

Problems: None.

Forecast: (1) Due to long procurement cycles, the mono-stereo visual system will not be ready for lab tests before November 1973. The anticipated date to install it in the manipulator lab is March 1974. (2) Color testing also has been delayed. It should be complete by February 1974. (3) Motion simulations in the visual systems lab are expected to be completed by January 1974. (4) Improved enhancement picture quality can be expected, upon completion of the installation of some new equipment by the University of Tennessee at Knoxville.

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4. TITLE:

Teleoperator Manipulation and Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Wilbur G. Thornton S&E-ASTR-MS	205-453-5530	J. Boehm, S&E-ASTR-M

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task 40 RMS Man-Machine Integration Requirements
NAS8-28298 Essex Corporation, Alexandria, VA
NAS8-29914 Essex Corporation, Alexandria, VA

Objectives:

1. To determine, analyze, and integrate the human factors design requirements for manipulator, remote vehicle, and visual systems.
2. To analytically and empirically develop man-machine interface criteria
3. To investigate perceptual motion cues required for moving base vehicle simulation techniques.

Approach:

1. Plan and Conduct open loop visual system tests to determine performance of visual tasks using video systems and display aids.
2. Plan and conduct closed loop visual tests of performance in final approach and docking.
3. Plan and conduct man/machine interface evaluation for manipulator systems including manipulator, effector, controller, and visual subsystems.
4. Plan and conduct man/machine interface evaluation for remotely manned systems maneuvering and docking subsystems.
5. Perform analytic assessment of human factors design requirements to support empirical operator/system performance testing and system design decisions.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
H73-32	Manipulator Subsystem Evaluation Criteria	T. Malone	9/19/73

FIRST BENEFITTING PROJECT: Free Flying Teleoperator

MSFC - Form 350 (March 1978)

Approach: (Continued)

6. Plan and conduct empirical studies of acceleration and deceleration thresholds and changes in thresholds due to visual motion cues.

7. Incorporate threshold data into washout techniques which minimize detection of invalid platform motion required by moving base system travel constraints.

Status:

Technical Progress:

1. Open Loop Visual System Tests

Three visual system tests were conducted during the reporting period. These dealt with judgment of non-alignment of a satellite model with respect to the camera viewing axis and detection of relative motion (range rate) between a satellite model and the camera. The test of non-alignment detection was designed as a follow-on to experiment 10 reported in Ref. 1. The latter showed a strong dependence of non-alignment detection performance on the angle light source (sun)-camera-satellite. The test conducted during the reporting period served to more adequately quantify this effect and analyzed the ability of an artificial light source to compensate for this effect.

The range rate detection experiments were conducted to test reticle designs and effects of visual system transmission parameters on rate detection performance. Subjects were shown a brief TV view of a satellite model which was either stationary or receding or closing at one of a set of rates. The data from the three open-loop tests are currently being analyzed.

An analysis of optical range and range rate estimation methods was conducted. A potential method was identified using moving cursors which are electronically generated on the display. The operator is given rate-proportional control of the distance between these cursors and tracks the satellite as range changes by keeping the cursors aligned with the image edges. Range and range rate may then be estimated by:

$$R = \frac{KT}{W} \qquad \text{and} \qquad \dot{R} = \frac{-R\dot{W}}{W}$$

where

R = range

K = visual system parameter

W = between-cursor rate

$\dot{R} = dR/dt$

$\dot{W} = dW/dt$

T = target dimension

These calculations could be performed by a computer using W, $\dot{W}$, T, and K as inputs. T would be known from satellite dimension data and K would require zoom mechanism encoding.

The moving cursor system was fabricated by MSFC personnel during the reporting period. As currently configured, however, the control system is position proportional and no mechanism for computing $\dot{W}$ has been developed. Consequently, a preliminary test using the cursor to estimate range alone is being conducted.

2. Closed Loop Visual System Tests - Approach and Docking

Efforts completed during the reporting period include definition of dependent measures, run schedule preparation, specification of initial translation and attitude of tests within the constraint that the satellite always is within the field-of-view at run initiation. Reticles for use by operators were prepared and final checkout was carried out. Currently, subject selection and training have been completed and data collection is in progress. Runs completed thus far have been designed to measure the operator to match the motion of a nutating satellite.

3. Manipulator Man/Machine Interface Evaluation

Updated manipulator criteria were developed during the reporting period. This effort was devoted to identifying a common methodology for comparative evaluation of manipulator/controller combinations holding task, operator skill, and ambient conditions constant. Based on the general manipulator evaluation methodology, a set of specific tests was derived. These tests measure system performance in a variety of remote satellite servicing functions.

A test plan for the conduct of the selected tests across a range of manipulator/controller configurations was prepared. This plan provides independent variables, control conditions, test operational sequences, and data recording requirements for all tests. The experimental plan will support conduct of these tests in the MSFC Manipulator Laboratory during CY 1974.

4. Mobility System Man/Machine Interface Evaluation

During the reporting period, a test plan was prepared for the conduct of investigations using the MSFC Mobility Laboratory facility. The planned tests include handling qualities, satellite grappling, and satellite circumnavigation investigations. Essex personnel also participated in the design of a vehicle position measuring device which permits quanitfication of translation control accuracy during the approach to the satellite.

5. Analytic Studies of Human Factors Design Requirements

Analytic efforts conducted in this area include investigation of range and range rate estimation methods, utility of color coding and color TV in satellite servicing operations, and frequency of joint useage of controls and displays based on operational sequence diagrams for remotely manned system operation. These analyses were partially completed during the reporting period and are currently continuing.

6. Motion Threshold Investigations

During the reporting period, general test planning was completed and a plan for the first threshold study was prepared. This test will measure nonvisual (vestibular) acceleration and deceleration thresholds in the fore/aft axis. The problem being addressed is one of washing out fore/aft rates of travel using non-detectable decelerations and returning the platform to its center position with non-detectable accelerations.

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6. Motion Threshold Investigations (Continued)

Motion profiles, run schedules, and data collection procedures have been prepared.

Conclusions:

1. Results of the non-alignment detection test indicate that the pronounced failure of subjects to detect non-alignment of a satellite model under certain sun angle conditions can be compensated for by suitable artificial lighting.

2. Preliminary results from the range rate detection tests show that using a suitable reticle, no TV system degradation, and a 20° field of view, simulated range rates of approximately .12 ft./sec. are detectable in 95% of cases for a satellite model corresponding to a Biological Experiment Satellite at a range of 20 ft.

3. Preliminary results of the closed loop simulation tests indicate that matching the vehicle motion to that of a nutating satellite for nutation angles below 4° and rates below 4 rpm. Data are currently being collected for larger angles and rates.

Problems:

Testing in the manipulator and mobility unit simulations have been delayed because of procurement holds and facility changes.

Management Progress: None

Forecast:

1. During the next 6 months, the data from visual tests previously run will be analyzed and a report generated. Additional tests to be conducted and analyzed during the next period include range and range rate estimation tests and performance testing with a Fresnel stereoptic TV system.

2. Closed loop visual system data collection will be continued. A report documenting the experimental method and the dependent measures will be generated during the next period.

3. Data collection will be initiated in empirical tests of operator/system performance of both manipulator/controller systems and vehicle mobility systems. Test reports will be generated as tests are run and analyzed.

4. Analytical investigations of human factors design requirements will be performed to support design of the visual system engineering model. Essex will also design and fabricate human factors test equipment for the manipulator system tests.

Forecast: (continued)

5. Acceleration and deceleration threshold tests will be performed for the fore/aft, and pitch axes. Tests will be performed which involve other axes as requirements are identified through analytic efforts. Findings of these studies will be incorporated into methods for washout of motion during vehicle simulations.

References:

1. Kirkpatrick, M., Malone, T. B., and Shields, N. L. Earth Orbital Teleoperator Visual System Evaluation Program, Essex Corp., March, 1973.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
Marshall Space Flight Center	01 04 73 - 30 09 73	CURRENT NO.: 975 61 01 01	PRIOR NO.: None

4. TITLE: Mission Development Simulator, Experiment Definition and Stimulus Material Fabrication

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Charles W. Quantock	453-3424	Herman P. Gierow

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Mission Development Simulator, Experiment Definition and Stimulus Material Fabrication

OBJECTIVES:
(1) Prepare stimulus material for use in the Mission Development Simulator.
(2) Define experiments to exercise MDS with stimulus material, collect and analyze data.

APPROACH:
(1) Identify experiments (based primarily on Manned Earth Observatory study).
(2) Develop stimulus material specification.
(3) Acquire photo materials via U-2 photo missions.
(4) Fabricate slides for use in MDS.
(5) Develop experiment procedures.
(6) NASA personnel conduct experiment.
(7) Contractor assists NASA in evaluation of test results.

STATUS: Steps 1, 2, 3, and 5 eseentially complete. Awaiting delivery of film from ARC. Final definition of experiments will depend in part on what scenes are selected for MDS use.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Reports			

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MSFC	01 04 73 to 30 09 73	975-72-01	114-03-52

4. TITLE:

Spacecraft Surfaces

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMT W. T. Powers	453-5606	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Portable Multispectral Reflectometer (PMR)
In-house

OBJECTIVE(S): Spacecraft thermal control is entirely dependent upon radiative heat transfer. The condition of surface coatings of a craft affects the thermal efficiency of the system. No long term spectral reflectometer data has been gathered on coatings while still in space. The PMR is intended to provide a means of acquiring laboratory accuracy multi-spectral reflectance readings on a surface whenever such a reading is desired, while being a completely portable, self-contained instrument.

APPROACH: The PMR is to be used to measure surfaces before and during a mission as a means of determining the condition of the thermal control coatings while in use in space. The instrument is an Integrating Sphere Reflectometer with a digital signal processor and memory unit. Reflectance is taken in each of 8 spectral bands.

STATUS: Technical Progress - The development model is nearing completion. Only the top (handle, plate, and sides) remaines to be completed and that assembly is being manufactured now. Only final assembly and a complete checkout remains.

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STATUS (CONCLUDED): Forecast - The unit is to be completed, with testing and all documentation complete, by December 31, 1973. At this time no problems likely to stall progress are visible.
Conclusions - The project will be suspended in January 1974 leaving a development model and all necessary documentation for construction of more units. Most parts for about 4 more units are on hand, though no plans exist for more units. If it is considered desireable or important to construct more units for any purpose, such may be done with minimal start-up time once priorities have been established for manufacturing operations. With parts on hand, about 3 or 4 weeks are needed to assemble, set up, calibrate, and test a unit.
Remarks - The only difficulties with future units would be coating the spheres. Such capability would have to be regained if several units were required.

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MSFC	01 04 73 to 30 09 73	975-72-39	975-72-03

4. TITLE:

OPTICAL CONTAMINATION

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Hoyt M. Weathers	205 453-3040	Hoyt M. Weathers (Hoyt M. Weathers)

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Definition of the separate sensors which comprise the Integrated Real Time Contamination Monitor (IRTCM) System.

Contract No.	Contractor
NAS8-28270	The Boeing Company
NAS8-28987	General Dynamics-Convair Division
NAS8-28879	Faraday Laboratories, Inc.
NAS8-29197	PBR Electronics

OBJECTIVE: To define flight instruments and sensor systems which will be used on the Shuttle and Shuttle payloads to detect the presence and characteristics of an induced environment. This definition phase includes experimental work with pre-prototype equipment in order to develop confidence in the concepts selected to monitor contamination for the protection of the payloads.

APPROACH: Sensors are required which will determine the optical effect of contamination, the amount, its identity, and other factors such as particle sizes, distribution, and velocities. These sensors include Quartz Crystal Microbalances (QCM), Mass Spectrometer, Optical Effects Module, Particle Spectrometer, and Active Cleaning Technique. Other sensor/monitor systems may be added if the payloads require special contamination monitoring equipment.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA TR R-404	The Techniques of Holographic Particle Sizing	Robert L. Kurtz	March 1973
NASA SP-299	Holography and Optical Filtering	J. Williams	June 1973

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STATUS: Functional laboratory models have been developed of four of the five sensor/monitor concepts. The fifth, the Active Cleaning Technique equipment, will be available in mid-FY74. The Optical Effects Module and the QCMs are being evaluated in the laboratory and will also be used late in CY73 to instrument simulation tests of the Shuttle Solid Rocket Booster (SRB) separation motor exhaust contamination effects. The Particle Spectrometer has been used in tests at JSC of the Shuttle Thermal Protection System and will also be used in the Shuttle SRB separation motor simulation tests. The above laboratory and operational tests are being used to identify improvements needed in the sensor/monitor systems.

MANAGEMENT PROGRESS: The activities above are being funded from FY-72 funds reprogrammed for FY-74 and are extensions of the approved FY-73 RTOP.

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Marshall Space Flight Center	01-04-73 - 30-09-73	CURRENT NO.: 975-84-02	PRIOR NO.: 975-84-02

4. TITLE:

Atmospheric and Space Plasma Physics Sortie Payload

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. T. Roberts, PD-MP-S	453-3433	Herman P. Gierow, Director PD-MP-DIR

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Plasma Physics and Environmental Perturbation Laboratory Experiment Definition Study

OBJECTIVE: Emphasis - To develop a PPEPL concept with the widespread and continuous participation of the scientific community.

APPROACH:

- o Mailing of initial letter and questionnaire
- o Extensive follow-up and iterations with potential investigators
- o Science Advisory Board established to review study progress (four reviews given)
- o Three science working groups led by Science Advisory Board members
- o Formal talks on PPEPL at scientific meetings and university seminars

STATUS:

- o Final presentation given at MSFC on October 3, 1973.
- o Final report due November 15, 1973.

7. REPORT NO.: TITLE: AUTHOR(s): DATE TRANSMITTED

Briefing to MSFC on the Atmospheric and Space Physics Laboratory, October 3, 1973.

"Controlled Experiments from the Space Shuttle" Fredrick L. Scarf, IAGA Scientific Assembly, September 1973.

"The Design and Development of a Space Laboratory to Conduct Magnetospheric and Plasma Research" Allan Rosen, 7th ESLAB Symposium, June 1973.

"Experiment Definition Study for PPEPL" Fredrick L. Scarf, Annual AGU Meeting, April 1973.

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	975-90-95	

4. TITLE:
Immiscible Materials and Alloys - In-House and Contract Research MS/MS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. F. Nowakowski S&E-QUAL-QT	205-453-3987	Spencer E. Smith S&E-QUAL-Q

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Gravitational effects on process-induced dislocations in silicon.

Objective: To develop and formulate an experiment to be performed in outer space to determine the gravitational effects on process-induced dislocations in silicon semiconductor material.

Approach: These activities will be directed toward five major tasks.

I Determine the exact thermal conditions present when dislocations are created.
II Develop an analog simulation of the thermal cycle under zero gravity.
III Study the geometric effects of gravity when processing wafers.
IV Develop experiment to be performed in space.
V Characterize defects using X-ray topology, chemical etch, and other techniques.

Status:

Technical Progress - Pre-charged quartz ampules have been selected as the wafer sample holders and an electric furnace has been selected for processing. In preliminary experiments to study the effects of gravity, the investigator has discovered that creation of dislocations during thermal cycling is more probable with the polished side of the wafer down. Also there appears to be a different type defect produced in the polished side when it is up.

Management Progress - Minor material procurement problems have been solved and the program appears to be on schedule.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Monthly Progress Reports for July, Aug, Sept, 1973	Texas A&M	Aug-Oct 1973

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Conclusions: It is too early in the program to develop conclusions.

Problems: None

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MSFC	01 04 73 - 30 09 73	976-30-02	976-30-02

4. TITLE:
Thermal Control

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Structural Analysis of Non-Metallic Thermal Protection Systems
H-84825A Naval Ship Research and Development Center

OBJECTIVE(S):
1. To develop a finite element of 3-dimensional structural and thermal analysis of non-metallic thermal protection systems.
2. To correlate structural and thermal solutions based on this element to exact solutions and existing test results.
3. To incorporate this finite element into an existing matrix abstraction package such as NASTRAN.

APPROACH: Generate an isoparametric element that will have eight nodes and six sides. The element will be capable of structural and thermal analysis of a single structural model. Correlate structural and thermal analyses based on this finite element to exact solutions and existing test results. Upon completion of the development of this finite element, it shall be incorporated into NASTRAN.

STATUS: Technical Progress--The modification described above has been incorporated into the MSFC version of NASTRAN level 15. The revised program has been successfully demonstrated on the MSFC computer. The users manuals have been submitted to the printer and will probably be available by mid-November. The draft of the programmer manual is approximately half completed. It is anticipated that the programmer manual will be completed by the first of December.
Management Progress, Problems, Conclusions, and Forecast--None

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED

FIRST BENEFITTING PROJECT: Space Shuttle

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MSFC	01 04 73 - 30 09 73	976-30-04-01	976-30-04-01

4. TITLE:

Space Shuttle Auxiliary Propulsion System (APS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. Miller	205-453-3816	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Turbopumps for Cryogenic Upper Stage Engines, NAS8-27794, Rocketdyne

OBJECTIVE: Design, fabricate, test, and deliver two liquid hydrogen and two liquid oxygen pump assemblies of an advanced design. These pumps provide broad range, small turbopump system technology applicable to high energy, cryogenic, upper stage engines.

APPROACH: The program task will be accomplished in four phases. Phase I is the general screening analysis to select pump, inducer and turbine type. The combined characteristics of the components will be analyzed in detail.

Phase II consists of making component layout, detail, and assembly drawings.

Phase III consists of procurement, fabrication, and assembly of the hardware.

Phase IV consists of testing the liquid oxygen pump followed by the liquid hydrogen pump. IR&D tests by the contractor on the gas generator, pump bearings and seals, and turbine are also included in this phase.

STATUS: Technical Progress: The program is complete with the exception of issuing the final report. The No. 1 liquid oxygen pump successfully completed 66 tests and 7528 seconds of run time. The No. 2 liquid oxygen pump completed 12 tests for 1050 seconds of operation. The No. 1 liquid hydrogen pump completed 57 tests for 5091 seconds of operation, and the No. 2 liquid hydrogen pump was acceptance tested 13 times for 1260 seconds.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
1.	Program Plan	T. Zachary & J. Laufer	14 July 1971
2.	Milestone Report Phase I	" "	28 Aug 1971
3.	Milestone Report Phase II	" "	19 Nov 1971
4.	Test Plan & Facilities Review	" "	Jan 1972
5.	Test Plan & Facilities Review Amendment 1	" "	Aug 1972
6.	Final Report	T. Zachary	Oct 1973

FIRST BENEFITTING PROJECT: Full Capability Tug

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STATUS (CONCLUDED):

Management Progress: The program was completed within the budget. A no-cost extension has been added with a new contract completion date of September 30, 1973.

Conclusions: Building of long life, small size pumps is feasible and practical; mechanical reliability is very good. The general technology was demonstrated.

Problems: The liquid hydrogen pumps experienced two problems.

(1) The hydrodynamic efficiency was low compared with predicted values. Specifically, head rise was about 15% low at the design point.

(2) The turbine manifold cracked causing the manifold to deform and rub the turbine blades. This damaged both the wheel and the manifold causing a fire and the termination of one test.

Cause of Problems: The low pump head rise was caused by high diffuser losses which resulted from larger than estimated boundary layer thickness.

The manifold crack was due to a poor quality circumferential weld which was not found during inspection.

Problem Solution: Boundary layers should be calculated rather than estimated. Better quality should be exercised in weld inspection.

Forecast: The final report will be issued and distributed in October 1973.

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4. TITLE:
Materials

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Nichols, R. L.	205-453-2005	W. Angele

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Evaluation of Boron-Aluminum Composites for Space Shuttle Components
NAS8-27735 McDonnell Douglas Astronautics Co.-East, Saint Louis, Missouri

OBJECTIVE: The objective of this program is the development of sufficient technology to permit application of boron-aluminum to Space Shuttle components with high confidence.

APPROACH: This program is being conducted in the following separate phases, several concurrently: (I) Material Evaluation, (II) Design Studies, (III) Process Technology Development, (IV) Fabrication and Assembly, (V) Test and Evaluation, and (VI) Analysis of Structural Test of the Boron-Aluminum Panel. In addition to the acquisition of a significant quantity of mechanical property and process technology data, the realization of this objective will be further demonstrated by the fabrication and test of a 1.22m (48 inch) x 1.83m (72 inch) boron-aluminum compression panel capable of distributing a point load of 1555 kN (350,000 lbs) into a uniform running load within a peaking factor of 1.3 at a temperature of 589°K (600°F).

STATUS: Technical Progress:

Phase I - Material Evaluation - On the basis of a review of material from both Harvey Aluminum and Amercom, Inc., Amercom was selected as a boron-aluminum monolayer and bilayer material supplier and approximately 250 kg (550 lbs) was purchased. Approximately 12% of all material supplied was rejected with the most serious defect being poor diffusion bonds in bilayer material. Over 1000 coupon tension tests were performed to verify monolayer and bilayer strength - of which only 1.2% fell below minimum

7. REPORT NO.: | TITLE: | AUTHOR(s): | DATE TRANSMITTED

Twenty-one Monthly Progress Reports were received and were dated from 10 August 1971 to 10 April 1973.

First Quarterly Report, MDC E0491, "Design, Process Development, Manufacture, Test and Evaluation of Boron-Aluminum for Space Shuttle Components", R. A. Garrett, 10 Nov 1971.

Second Quarterly Report, MDC E0555, "Design, Process Development, Manufacture, Test and Evaluation of Boron-Aluminum for Space Shuttle Components", R. A. Garrett, 10 Mar 1972.

Third Quarterly Report, MDC E0650, "Design, Process Development, Manufacture, Test and Evaluation of Boron-Aluminum for Space Shuttle Components", R. A. Garrett, 10 Aug 1972.

Fourth Quarterly Report, MDC E0783, "Design, Process Development, Manufacture, Test and Evaluation of Boron-Aluminum for Space Shuttle Components", R. A. Garrett, 10 Mar 1973.

FIRST BENEFITTING PROJECT: Space Shuttle

TASK: Evaluation of Boron-Aluminum Composites for Space Shuttle Components

STATUS: Technical Progress: (Continued)

specification filament strength requirements (400 ksi, minimum). The material supplied by Amercom for this program was judged to be of significantly better quality than previously available material. All work required in Phase I has been completed.

Phase II - Design Studies - Components and assemblies representative of full scale hardware were designed and analyzed and included a 1.22m x 1.83m (48 inch x 72 inch) compression panel, a thrust structure beam of truss design, a thrust structure beam of shear web design, representative joint designs and panel components and element designs. Three of these structures designed under Phase II were also fabricated for structural testing. Of the remaining designs, the truss beam and the shear web beam thrust structure configurations were carried far enough to determine an overall structural arrangement, size all elements and calculate structural weights for comparison purposes. For the loading cases considered, the shear web beam design was 37.5 kg (82.8 lbs) or about 8% lighter than the truss beam design. For all design studies, specific analysis techniques tailored for metal matrix composites were developed, based in part on techniques already developed for resin matrix composites and in part for conventional metal structures. These techniques were fully verified by successful testing of the Stringer Test Assembly and the Component Test Assembly conducted at room temperature and 589°K. This effort has been completed.

Phase III - Process Technology Development - This work was concerned with improving the procedures and techniques used to fabricate boron-aluminum structures from monolayer foils. The primary emphasis was placed on the cleaning, coating and bonding thermal cycles associated with the eutectic bonding process and on improving lay-up procedures to reduce fabrication costs. As a result of these studies, the quality and reliability of eutectic bonded parts were improved significantly at the same time that processing costs were reduced. This work was completed with the preparation of process specifications which governed the successful fabrication of test components and the full size compression panel.

Phase IV - This effort included the manufacture of selected joint configurations, the component test specimen, the stringer element test specimen and the complete 1.22m (48 inch) x 1.83m (72 inch) compression panel. These units were successfully fabricated and delivered to the responsible test agencies. Notable in the fabrication achievements were the development of a mechanical forming technique which enabled producing the variable cross section stringers comprised of between 52 to 5 plies with "hard to form" titanium interleaves and the fabrication of the large 1.22m by 1.83m (4 x 6 ft) variable thickness complex skin of 62 to 10 plies, also with titanium interleaves. The successful fabrication of these test articles has demonstrated the present day capability to produce complex boron-aluminum composite assemblies of consistent sound quality.

Phase V - Work performed under the Test and Evaluation Phase included performance of joint tests, the component tests and the stringer element test by MDAC-E. Further, a Test Plan was prepared by MDAC-E for the compression panel test by MSFC followed by a summary report by MDAC-E of all program testing. Under Phase V testing, two significant milestones in panel design verification were achieved: the successful testing to ultimate design load (or equivalent) of the 1.83m (72 inch) Stringer Test Assembly at room temperature and the 0.61m (24 inch) x 1.22m (48 inch) Component Panel Test Assembly at 589°K (600°F). In the test of the Stringer Test Assembly, a maximum load of 100,000 pounds was applied to the test assembly at room temperature; this is equivalent to the

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TASK: Evaluation of Boron-Aluminum Composites for Space Shuttle Components

STATUS: Technical Progress: (Continued)

Stringer Design Ultimate Load (DUL) of 50,000 pounds at 589°K (600°F). In the Component Panel test at 589°K, a maximum load of 400,000 pounds (more than 1.15 times DUL) was achieved at 589°K; subsequent panel inspection revealed only minor structural damage. The results of these tests, coupled with the evaluation of associated test strain and deflection data, fully verified the full size Compression Panel design.

Phase VI - After the completion of the above five phases, a twelve month extension was given to the contractor. This time will allow the contractor to perform analysis of structural test of the boron-aluminum panel.

Management Progress: The contract was extended to June 30, 1974 at no additional cost.

Conclusions: Sufficient technology and test data have been developed to permit application of boron-aluminum to Space Shuttle components with high confidence. Mechanical property data and raw material quality have now stabilized to the point where rational and attractive design allowable data have been developed. The processing required for boron-aluminum fabrication has been clearly transformed from a laboratory operation status to a production shop status with appropriate process specifications developed to provide part quality assurance. The design and fabrication technology have also been significantly advanced. Complex tapered and contoured structures utilizing sophisticated re-inforcement techniques have been successfully designed, fabricated and tested to excess of design ultimate loads at temperatures up to 589°K to provide confirmation of the developed technology. In summary, the boron-aluminum material system has been developed to the point where its use can provide significant weight savings, system performance improvements and increased payload capabilities for the Space Shuttle or other vehicle systems.

Problems: None

Forecast: Contractual work is scheduled to be completed on June 30, 1974.

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4. TITLE:
Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. B. Herring	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Determination of Force Spectra for Complex Cylinders
NAS8-25811 Wyle Laboratories

OBJECTIVE(S): (1) To develop engineering guidelines for computing localized force-spectra environments for vehicle components. (2) Provide consulting efforts to support the development of in-house MSFC force spectra programs.

APPROACH: Engineering guidelines should be formulated to allow quick estimates of the predicted environments. Design equations should be converted into appropriate charts or nomograms whenever conditions permit. Sample problems to compute force spectra will be included in the design guideline report. The force spectra prediction equation will be programmed for MSFC computers.

STATUS: Technical Progress--Contractor developed and tested with successful results a method of specifying a 1-dimensional input force spectrum for aerospace vehicle components that is equivalent to an aerospace vehicle vibration environment. The method utilizes mechanical impedance concepts whereby the impedance of the component is combined with the impedance of the primary structure and the component test specification is modified by the impedance combination. This method is more realistic in specifying criteria which, for the most part, reduces overtesting. The primary drawback is the instrumentation devices required to read out force parameters in component vibration tests.
Management Progress, Conclusions, and Problems--None
Forecast--Contractor has successfully completed the effort, and this will be the last report on this task.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
71-1	Evaluation of Blocked Pressure Spectra on Stiffened Cylindrical Shells	V. Conticelli	Sept. 71
71-16	Prediction of Force Spectra by Mechanical Impedance and Acoustic Mobility Measurement Techniques	G. C. Kao	Oct. 71
72-9	Evaluation of Force-Control, Response Control Vibroacoustic Simulation Testing Techniques	G. C. Kao	Oct. 72
73-9	Prediction of Vibroacoustic Loading Criteria for Space Vehicle Components	G. Kao, C. Chang & J. Cockburn	Sept. 73

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:
Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. R. Admire	453-4348	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Evaluation of Modal Analysis Techniques
NAS8-26750 Martin Marietta Corporation

OBJECTIVE(S): The emphasis on correct analytical prediction of structural loads has been steadily increasing. As a consequence, dynamic models have been improved which results in large models. The heart of most dynamic response problems is the eigenvalue problem providing the modal characteristics of the structure. Thus, as the dynamic models are improved the eigenvalue problem becomes larger and the time consumed to extract the eigenvalues becomes a major economic factor. Consequently, different and more efficient methods of modal analysis must be developed.

APPROACH: A method of modal analysis has been proposed which shows potential savings in computer time. This method is an iterative application of the Rayleigh-Ritz principle. The method will be thoroughly evaluated to determine its value for modal analysis of aerospace type structures.

STATUS: Technical Progress--Four modal analysis computer programs based on the iterative Rayleigh-Ritz method have been implemented on the MSFC computer system. The program based on sparse matrix operations was compared with NASTRAN. The results of this comparison showed NASTRAN to be computationally faster for problems of less than 225 degrees of freedom and the iterative Rayleigh-Ritz method to be faster for larger problems.
Management Progress--A no-cost extension of the study was requested and granted. The purpose of the extension was to provide time needed for refinement and simplification

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of the input data for the computer programs. The study was extended to Dec. 15, 1973.
Conclusions--None
Problems--None
Forecast--None

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Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. B. Herring	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Statistical Determination of Space Shuttle Component Dynamic Magnification Factors
NAS8-28650 The Boeing Company

OBJECTIVE(S): To provide a guide for engineers in the design of components (including bracketry) used in severe vibration environments, based on experience accumulated during the Saturn qualification and reliability vibration testing programs.

APPROACH: (1) Statistically evaluate the amplification factors of the various components tested during the Saturn reliability and qualification vibration testing programs and compare with similar results derived from Saturn flight vibration data and assembly acoustic tests. (2) Categorize the components by their physical characteristics and determine the influence of these characteristics on the component amplification factor. (3) Prepare nomograms for designer use based on the amplification factors obtained and the characteristics which affect these values.

STATUS: Technical Progress--The final report was submitted May 31, 1973, and was evaluated as satisfactory. In the final report, the contractor developed a method for obtaining vibration design loads for components and brackets. The method utilized measured Saturn flight and test data from various component/bracket configurations operated on with statistics. A mean load or level was graphed for selected component bracket categories. The graphs also showed the scatter about the mean or how much confidence one could put in the design level chosen. Small amounts of measured component data restricted the number of component categories which reduces the usability range of the report.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
D5-17250	Statistical Determination of Space Shuttle Component Dynamic Magnification Factors	F. Lehner	May 31, 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS: Continued
Management Progress--None
Conclusions--None
Problems--None
Forecast--This will be the last report submitted on this task.

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Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. R. Admire	453-4348	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Reduction of Truncation Errors in Modal Analysis
NAS8-28167 General Electric Company

OBJECTIVE(S): Complex representations of structural assemblies are required for the accurate prediction of dynamic behavior. Many methods of modal analysis used to determine the characteristics of these structures are based on truncation of substructure modes. Therefore, it is the objective of this study to reduce the effect of the truncation on the accuracy of the modes.

APPROACH: Several modal analysis methods will be applied to structural models, and the effect of truncation will be evaluated. Next, transformation methods will be introduced in the modal analysis methods, and a study will be performed to determine if the effect of trunction on the accuracy of the modes can be reduced.

STATUS: Technical Progress & Conclusions--This task has been successfully completed. The results of the study indicate that the dynamic transformation method is an effective means to reduce the truncation errors associated with modal synthesis methods of vibration analysis. The final report contains numerical results to support the conclusion. A computer program called "DAMUS" was developed based on the stiffness coupling method and contains the dynamic transformation method to reduce the truncation errors. This program is suitable to analyze large complex structural assemblies. The program has been implemented on the MSFC computer system. A description of the program is presented in the final report.
Problems & Management Progress--None
Forecast--This will be the last report submitted on this task.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
GE No. 73SD4251	Reduction of Truncation Errors In Modal Analysis	E. J. Kuhar & C. V. Stahle	June 29, 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:

Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. F. Glaser	453-4381	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Performance of Statistical Energy Analysis
NAS8-28435 McDonnell Douglas

OBJECTIVE(S): Acoustic and aerodynamic excitation induce high frequency response in vehicular structure typical of the shuttle. This energy is then transmitted to secondary bracketry, internal components, and subsystems. The objective of this program is to develop an energy flow method for prediction of the high-frequency environment of internal components and secondary structure of the Space Shuttle.

APPROACH: Using the statistical energy analysis (SEA) approach, develop general forms of SEA-equations suitable for computerization. Conduct an idealized laboratory test program to determine the system-dependent parameters such as modal densities, coupling, and damping loss factors.

STATUS: Technical Progress--During this reporting period consisted of organization and preparation of the final report.
Management Progress--Contract has been completed.
Conclusions--SEA methods are evaluated by comparing analytical predictions to test results. In this way good insight in the SEA methods has been given.
Problems--None
Forecast--This will be the last report submitted on this task.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MDC G4741	Final Report "Performance of Statistical Energy	R. F. Davis & D. E. Hines	June 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:

Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. McComas	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Shuttle POGO Program
NAS8-28567 The Boeing Company, Huntsville

OBJECTIVE(S): To develop a digital computer program capable of evaluating the longitudinal stability (POGO) for Shuttle vehicles.

APPROACH: The program will be developed to use a minimum of 50 structural modes selected for POGO potential. Selection criteria should be based on modal gain. Accurate feedline models should be generated with horizontal sections, bellows, and elbows. The stability routine should contain option for open-loop or closed-loop analysis and should contain a control loop and POGO suppression devices which include active as well as passive devices.

STATUS: Technical Progress--The total scope of work proposed for this program has been successfully completed. A digital computer program has been delivered and a demonstration problem successfully run.
Management Progress--The documented program was delivered and reviewed by the principal investigator, Mr. W. Lawler.
Conclusions--This contract has been successfully completed.
Problems--None
Forecast--None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
D5-17271	Shuttle POGO Stability Analysis Program, Vol. I Theory Manual, Vol. II Users Manual	T. H. Springfield, W. Lawler, and L. G. Palermo	Sept. 17, 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:

Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. McComas	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Flexible Body/Water Interaction During Water Impact
NAS8-28522 Universal Analytics, Inc.

OBJECTIVE(S): To develop hydroelastic dynamic analysis methods applicable to the Space Shuttle Booster Solid Rocket Motors during water impact and develop a computer program to predict pressure loads and internal loads.

APPROACH: Recommend and develop analytical methods for predicting the rigid and flexible body dynamic response of solid rocket motor resulting from water impact. Then, using the results obtained from the initial study, formulate the equations to represent a rigid SRM vehicle entering the water in a tail-first mode and a broadside mode and to determine the resulting pressure and response. Incorporate the equations into NASTRAN.

STATUS: Technical Progress--The analysis techniques and equations have been developed during the reporting period. The feasibility of the analyses for practical use has been determined. Preliminary pressure values obtained in the nozzle impact formulations are much smaller than test results. Extensions to the model to include other effects are being evaluated.
Management Progress--The contract has been extended to develop computer programs and analyze specific structure.
Conclusions--The analytical methods developed during the first part of this study must be examined by comparison of analytical and experimental results.
Problems & Forecast--None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Universal Analytics, Inc. Unnumbered	Development of Methods for the Dynamic Analysis of Flexible Body/Water Interaction During Initial Impact	A. P. Capelli	Jan. 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:
Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. F. Glaser	453-4381	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Investigation of Vibrational Energy Transfer in Connected Structures
NAS8-28171 Northrop Corporation, Aircraft Division

OBJECTIVE(S): To investigate the coupling mechanism in typical space vehicle structures and to determine the degree of modal diffusion and energy transmission through the structural interface to establish guidelines that can be used by practicing engineers for statistical energy calculations.

APPROACH: (1) Using test models, determine the degree of modal diffusion and energy transmission between substructures. (2) Apply equations of wave motion to confirm the energy transfer mechanism of task (1). (3) Explore the frequency and wave length limitations of the statistical energy analysis method (SEA) - develop new formulations to broaden the applicable range of SEA. (4) Develop guidelines and recommend preliminary test procedures for practical use.

STATUS: Technical Progress during this reporting period consists of measurements of the response level of the half cylinder and the base plate when the system is excited with 1/3-octave excitation; Determination of the loss factors; Check of the validity of the SEA method; Analytical work on the expressions of energy transfer has been completed.
Management Progress--A no-cost extension was given to June 30. Contract has been completed
Conclusions--The basic foundation and assumptions of the SEA method have been examined by tests and verified. A new SEA formulation based on the strong coupling condition is presented. Its validity needs further confirmation.
Problems--None
Forecast--This will be the last report on this task.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NOR 73-105	Final Report Investigation of Vibrational Energy Transfer in Connected Structures	Chintsun Hwang W. S. Pi	July 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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4. TITLE:

Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-DDS Homer C. Pack, Jr.	205-453-2526	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Structural Modes Accuracy Analysis

Cont. No. NAS8-27331, J. H. Wiggins Company, 1650 So. Pacific Coast Highway, Redondo Beach, CA 90277

OBJECTIVE: Accurate dynamics data are needed for control system design and vehicle stability analyses of the Space Shuttle. Tolerances for these data are presently determined by engineering judgment. The development of a method of improving structural mathematical models based on dynamic testing of structures or major components would make possible more accurate dynamics data with meaningful tolerances. Consequently, a more refined system could be designed and realistic stability margins defined.

APPROACH: The approaches in the literature have either attempted to construct a simple low order structural model using only the measured modal characteristics of the structure or have sought to verify or modify the parameters of a pre-established analytical model using available experiment data. A procedure for the estimation of structural stiffness and mass matrices is possible when the number of structural degrees of freedom exactly corresponds to the number of modal properties measured. A structural model so formed from test data is said to be complete and is mathematically unique. This is seldom possible since a one-to-one relationship between structural degrees of freedom and measured modal characteristics is difficult to achieve.

The following features are incorporated in the method developed in this study:

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Interim Report	Structural Modes Optimization Using Statistical Evaluation	Jon Collins Gary Hart R. T. Gabler Bruce Kennedy	Feb. 1972
TR 73-1087-2	Model Optimization Using Statistical Estimation	Jon Collins Gary Hart Timothy Hasselman Bruce Kennedy	May 1973

FIRST BENEFITTING PROJECT:

Space Shuttle

o The procedure begins with an initial or prior estimate of the finite element model and one's confidence in the various estimates of stiffness and mass.

o The method accepts incomplete data from test, i.e., data are not required from every mode and node-point. In fact, the method will operate with only a single data point, although the results will not be as valid as those where more data are used.

o The result is a revision of the finite element model with stiffness and mass parameters yielding frequency and mode characteristics in agreement with the data.

o The method can be applied to data from sequential tests where the loaded mass varies from test to test. The result is a single stiffness matrix applicable to all of the tests.

STATUS: Technical Progress: The MOUSE (Model Optimization Using Statistical Estimation) program, which was developed incorporating the features mentioned, has been delivered and demonstrated using our computer (Univac 1108). The demonstration problem was developed from data obtained from the dynamic test of the Saturn V vehicle. Data for four loading conditions were available, and the results from runs made so far are encouraging. The stiffness and mass data were modified to give good correlation with test for the three lowest bending modes. Higher modes seem to give more trouble, probably because of contributions of components of the vehicle that cannot be modeled as a beam as was assumed.

Formulation of a method to improve mathematical models, based on test data from component structure tests, has been completed. The method is documented in the May report. However, no work has yet been done toward implementing the method for other projects at MSFC. The computer program will be released for general use through COSMIC.

Management Progress: The MOUSE final report has been reviewed and accepted.

Problem: The study has not been funded for 1974.

Conclusions: A system identification procedure has been developed which can be used to estimate the mass and stiffness parameters of a finite element model, based on experimental data. The method acknowledges both experimental and modeling uncertainty in optimizing the model to fit the data with respect to a minimum variance criterion.

Forecast: Future activity is contingent upon program funding.

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4. TITLE:

Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Frank M. Bugg, S&E-AERO-DDS	205/453-2526	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Experimental Investigation of Shuttle Propellant Dynamics

Cont. No. NAS8-28086, Southwest Research Institute, San Antonio, TX

OBJECTIVE: To provide comprehensive experimental propellant dynamics data for liquid oscillating in a particular non-axisymmetric container at high bond number. This data will be used to verify and supplement results computed under 908-52-40-17, "Propellant Dynamics in a Shuttle-type Launch Vehicle."

APPROACH: Construct a non-axisymmetric tank model. Measure the liquid oscillation frequency, the forces, and moments exerted by the liquid, the liquid amplitude at the tank wall, and photograph each mode shape. Make these measurements for the first three natural modes of oscillation produced by excitation in three directions.

STATUS: Technical Progress: The tests have been completed and documented. Some of the more important accomplishments were: identification of slosh mode shapes and photographic recording of these, measurement of frequencies for each mode through a broad range of tank orientation and excitation direction, measurement of slosh damping magnitude and trends. The test tank was delivered to MSFC at contract completion and is, therefore, available if further tests are needed.

Management Progress: The contract final report was reviewed and approved.
Problems: None
Forecast: This task has been completed and this is the final progress report.
Conclusions: None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
02-3363	Experimental Investigation of Liquid Propellant Dynamics in a Double Cylindrical Tank	Guido E. Ransleben, Jr.	N/A

FIRST BENEFITING PROJECT: Space Shuttle

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4. TITLE:

Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Larry A. Kiefling, -DDS	205/453-2527	J. A. Lovingood, S&E-AERO-D

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Propellant Feedline Dynamics

Contract No. NAS8-25919, Southwest Research Institute, San Antonio, TX

OBJECTIVE: The coupling of engine dynamics with the structure via the dynamics of the propellant feed system has been characteristic of the Pogo problem. Since nearly all large launch vehicles have experienced Pogo oscillations, it seems that similar problems will be associated with the Shuttle vehicle. In fact, the problem may be complicated because of the large c.g. offset during flight. This is one of the few problems not effectively solved during the Saturn V program.

APPROACH: Develop an analytical method including a computer program for the study of the vibrations of typical liquid rocket propellants in typical engine feedlines; then conduct a test program to verify the validity of the analytical method and perform the experiments.

STATUS: Technical Progress: An analytical model and corresponding computer program to allow for the study of disturbances of liquid propellants in typical engine feedline systems have been developed. Also, an experimental test program has been conducted to verify many of the assumptions and models used in the computer simulation. Tests have been conducted to determine the validity of the analytical techniques used to model the effects of:

(a) steady, turbulent mean flow

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
02-2889 (Final)	Analysis of Propellant Feedline Dynamics	J. L. Holster W. J. Astleford C. R. Gerlach	July 17, 1973

FIRST BENEFITING PROJECT: Space Shuttle

STATUS (CONTINUED):

(b) linear and nonlinear resistance elements

(c) blocked lines

(d) elastic walls

(e) dissolved gases

(f) complex side branches

(g) local compliances

(h) bends, and

(i) structural-hydraulic coupling with mounting stiffness.

Management Progress: Work on this contract has been completed.

Conclusions: The following conclusions can be drawn from the experience gained from both the analytical and experimental phases of this program:

(1) Analytical investigation has shown that the predominant effect of turbulence is to increase the damping at low frequencies.

(2) The terminal pressure amplitudes at resonance are affected more by the value of the line terminal impedance (resistance) than any other single factor.

(3) The use of a linearized model for nonlinear type resistance elements provides satisfactory results for cases where the mean flow rate, Q, is considerably greater than the dynamic flow perturbation amplitude, Q_d.

(4) It has been concluded that the effect of the wall compliance (or elasticity) can be correctly modeled by the classic Korteweg equation.

(5) For the homogeneous distribution of very small gas bubbles entrained in the liquid propellant, the net effect over the frequency range of interest is to lower the phase velocity of the mixture. Experimental data indicate that there is also greater damping with increasing mass ratio than predicted by theory.

(6) Small diameter gas bubbles entrained in the liquid reduce the phase velocity in the mixture by the amount predicted by an isothermal model for the gas speed of sound rather than the adiabatic model.

(7) The model for a complex side branch such as an accumulator, predicts response amplitudes somewhat greater than those obtained experimentally. The experimental resonant frequencies were shifted in accordance with theory, but agreement with theory becomes poorer as the terminal gas volume is increased.

(8) The analytical model used for a local compliance (large local gas volume)

STATUS (CONCLUDED)

agrees very well with the data from the experimental tests conducted. The experimental data also indicate that for cases where the gas bubble resonant frequency is far above that encountered through excitation, a model which neglects the bubble dynamics would be satisfactory.

(9) A line with bends or elbows behaves exactly like a straight line of equal total length when the method of excitation does not involve structural acceleration of the line.

(10) The line-structure coupling equations which were developed were not adequate.

Problems:

(1) Further studies are needed to be able to correctly predict feedline damping.

(2) The modeling of the supporting structure for some of the experimental cases was not adequate.

(3) A method for the analysis of coupled structure-feedline systems is needed. The form of the equations needs careful attention if efficient computation is to be achieved.

Forecast: None

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4. TITLE:

Dynamics & Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-DDD Stephen W. Winder	205-453-2521	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Aero Elastic Effects on Shuttle Vehicle Dynamics
NAS8-26363, General Dynamics Convair, San Diego, CA

OBJECTIVE(S): The Space Shuttle is a new concept in space vehicle design which requires that the vehicle be reused. This reuse leads to potential fatigue problems requiring more detailed dynamics analysis. Aeroelastic effects on vehicle structure can lead to extended periods of high-frequency oscillations, large dispersions in aerodynamic center of pressure, and crew discomforts, all of which must be properly evaluated in order not to overdesign the structure, thus penalizing payload and system flexibility. Spurious signals from aeroelastic effects can also introduce control system problems due to local dynamic effects at the control sensors. Develop technology for evaluating the aeroelastic effects, lift growth, gust penetration, buffeting, static aeroelasticity, and flutter on the various Space Shuttle configurations.

APPROACH: In a previous contract (NAS8-26363), technology studies were started to study the interaction of the Space Shuttle vehicle's control system, structure, and sloshing modes when subjected to random and deterministic disturbances. The study produced a program that provides a detailed analysis of the loads and moments incurred on the vehicle. The program as it is now used requires detailed structural and aerodynamic modeling, and as such, is not very useful in the preliminary design stage where the details are not known. However, the loads information produced by this program

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None	Space Shuttle Response to Atmospheric Turbulence, AIAA Dynamics Specialists Conference, Williamsburg, Virginia, March 19-20, 1973	R. G. Huntington	
None	"Aeroelastic Effects on Space Shuttle Dynamics", Final Report, NAS8-26363, June 1973	R. G. Huntington & H. Riead	

FIRST BENEFITTING PROJECT: Space Shuttle

APPROACH (CONCLUDED): are needed in the preliminary design stage. Hence, a way is needed to simplify or modify the existing program to allow estimates to be made before the detailed structure is finalized. Also, one would require knowledge of the approximate accuracy of the simplified answers. Thus, the new tasks are:

Task 1: Provide reasons and a methodology for any and all simplifying assumptions that are used. All potential trouble spots should be noted.

Task 2: Simplify the existing analysis program or adapt other programs to yield the same aeroelastic information in contract NAS8-26363 (static aeroelastic deflections and loads, gust responses, etc). The programs should be simplified to provide for a minimum of modeling and ease of data handling. Also, the program should be easy enough to run so that a quick turnaround may be expected.

Task 3: Solve a sample problem where both the simplified and detailed results are available to help validate all assumptions made. The problem will be furnished by MSFC after discussions with the contractor. For planning purposes, the contractor shall consider the tandem vehicle configuration depicted in figure 1 for the sample problem. The aerodynamic and mass characteristics will be prescribed at a later date.

STATUS: Technical Progress: This contract has been completed. The last part of the contract consisted of running a sample problem of a representative Shuttle configuration. The purpose of this example was twofold: First, and primarily, it served to compare the simplified aerodynamic assumptions with the more detailed results and secondly, to observe the general nature of the control/aerodynamics/and structural interaction for a shuttle vehicle.

Management Progress: A final oral presentation by GDC was made on July 2, 1973 at MSFC to summarize their work. Also, the final written report has been received.

Conclusions: The simplification in going from interference to lumped aerodynamic data has been found to give adequate results for preliminary design aeroelastic analyses.

A comparision of the detailed (frequency domain) turbulence response analysis with the simplified (time domain) method indicates that the simplified approach gives good results.

Applying these simplified tools to the current space shuttle configuration has revealed that the gust loads are approximately 50-percent of the maximum static aeroelastic loads. This is a larger percentage than for conventional launch vehicles where typically, the gust loads are 20-percent of the static values at maximum $\bar{q}$.

Conclusions (Concluded): The autopilot became unstable when the ten elastic modes were included. This is not surprising since the gains were established from a rigid body analysis. When only the first elastic mode was included, the system was stable.

It was also found that at the nose of the orbiter, the design gust produced a peak acceleration of 1.8g. This compares to 1.6g reported for the earlier fully reusable space shuttle configuration.

Problems: None

Forecasts: None

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4. TITLE:

Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Larry A. Kiefling S&E-AERO-DDS	205/453-2527	J. A. Lovingood, S&E-AERO-D

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Dynamics of a Flexible Bulkhead and Contained Fluid

Contract No. NAS8-27012, Lockheed, Huntsville, AL

OBJECTIVE: To develop a computer program which will give the natural modes and frequencies for liquid oscillation at high bond number in flexible tanks of general shape. The completed program will be used for analysis of liquid-structure dynamics interaction problems including Pogo-type oscillations.

APPROACH: A computer program has been developed which uses a finite element representation of the liquid and tank. These elements are compatible with an existing structural network analysis program which is efficient for solving large eigenproblems of structural dynamics.

STATUS: Technical Progress: A computer program has been developed which uses a finite volume element representation of liquid in a container. The natural modes of oscillation can be computed for small amplitude periodic motion of liquid in a tank of any shape. A special version of the program can compute vibration modes of a flexible cylindrical tank containing liquid. Check cases for sloshing in a cylindrical tank and in a rectangular tank gave frequencies which were 1.4% and .6%, respectively, different from closed form solutions. The computer program was delivered to MSFC at contract completion and is now operational on the MSFC UNIVAC 1108 computer.

Management Progress: The final report was evaluated and approved.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-HREC D225823	Study of Propellant Dynamics in a Shuttle-type Launch Vehicle	C. E. Jones G. C. Feng	N/A
LMSC-HREC TR D306476	Dynamics of a Flexible Bulkhead and Contained Fluid	C. E. Jones G. C. Feng	July 17, 1973

FIRST BENEFITING PROJECT: Space Shuttle

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Problems: None

Conclusions: The analysis method developed has met expectations and will be suitable for analysis of fluids in the Space Shuttle.

Forecast: The task has been completed and this is the final progress report.

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4. TITLE:

Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU William W. Clever II	205-453-0179	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Unsteady Aerodynamic Analysis of Space Shuttle Vehicles, NAS8-28130, Lockheed Missiles and Space Co. Inc., Sunnyvale, California.

OBJECTIVE: The objective of this effort was to investigate the unsteady aerodynamic phenomena that will effect the dynamic aeroelastic stability characteristics of the Space Shuttle vehicle during boost, cruise, and reentry operations. The aeroelastic effects induced by unsteady separated flows, oscillating shockwaves, vortices, gust penetrations, and other unsteady flow phenomena were investigated.

APPROACH: The approach was broken into four parts:

(1) Provide estimates of the separated flow regions and shock wave interactions on the Space Shuttle system from analytical studies, or from existing experimental data.

(2) Determine the lag times involved with forces transmitted from one part of the vehicle to another by separated flows or oscillating shock waves analytically or from experimental data.

(3) Consolidate this information to provide input data for the quasi-steady aeroelastic analysis of the Space Shuttle vehicle.

(4) Extend the quasi-steady aerodynamic technique, developed by Lockheed, Sunnyvale, for application to the Space Shuttle configuration.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-D352320	Unsteady Aerodynamic Analysis of Space Shuttle Vehicles Part I: Summary Report Part II: Steady & Unsteady Aerodynamics of Sharp-Edged Delta Wings Part III: Booster Interference Effects Part IV: Effect of Control Deflections on Orbiter Unsteady Aerodynamics	Lars E. Ericsson J. Peter Reding	Aug. 1973
J. of Spacecraft & Rockets Vol. 10, No. 7, pp. 421-428	Effects of Delta Wing Separation on Shuttle Dynamics	J. P. Reding & L. E. Ericsson	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

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REPORT NO.: (CONCLUDED)	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Interim Status Report	Technical Progress June Through December 1972	J. Peter Reding	N/A
Informal Report	Recommendations for a Wind Tunnel Test to Investigate the Unsteady Aerodynamics of the Space Shuttle Orbiter	J. Peter Reding	N/A
Trip Report	Report on Visits to European Research Institutes and Industries During May & June 1972	L. E. Ericsson	N/A
19 Informal Monthly Progress Reports		L.E. Ericsson	

STATUS:

Technical Progress: The results of this study show that slender wing theory can be modified to give the potential flow static and dynamic characteristics over a large Mach number range from M=0 to M 1. A semi-empirical analytic approximation is derived for the loads induced by the leading edge vortex; and it is shown that the developed analytic technique yields good predictions of the experimentally determined steady and unsteady delta-wing aerodynamics, including the effects of leading edge roundness. At supersonic speeds, attached leading edge flow is established and shock-induced flow separation effects become of concern. Analysis of experimental results for a variety of boost configurations has led to a definition of the main features of the flow interference effects between orbiter and booster. The effects of control deflections on the unsteady aerodynamics of the delta-wing orbiter have also been evaluated using available experimental data. The results indicate that the effects of delta platform lifting surfaces can be included in a straightforward manner when determining elastic launch vehicle dynamic characteristics.

Management Progress: The period of performance of this contract was extended by two months (through August 31, 1973) to enable the contractor to perform a brief study of the unsteady aerodynamics associated with the orbiter pitch-over maneuver during reentry and the SRB plume during launch for the latest Shuttle configuration.

Conclusions:

- A modification of Jones' slender wing theory can be applied to the delta wing to give steady and unsteady potential flow characteristics. The agreement with experimental data for small angles of attack is good up to aspect ratios approaching 1.5.
- The effects of leading edge vortices on steady and unsteady aerodynamics are determined analytically using static experimental data to define the longitudinal distribution of vortex-induced loads. Agreement with the limited amount of available

Conclusions: (Concluded)

experimental data is good for both sharp and rounded leading edges.

- The solid rocket exhaust plumes induce flow separation on the orbiter and booster. This plume induced flow separation coupled with the booster forebody flow field through vortices from separated flow regions generated on the body provide a mechanism which can possibly cause aeroelastic instability of one or more of the low frequency deformation modes.

- The flow separation induced by the orbiter bow shock can also cause aerodynamic undamping of the elastic booster. The possible coupling between booster and leeside orbiter flow fields at angle of attack contribute additional possible sources of aerodynamic undamping that need further investigation.

- Elevon control deflections have large effects on the orbiter flow field, causing nonlinear, often discontinuous changes in the aerodynamic characteristics due to shock-induced flow separation, sudden leading edge stall, vortex burst, and separation from the OMS pods. The angle-of-attack Mach number boundaries for these undesirable effects have been determined using a combined theoretical-experimental approach.

Forecast: This contractual effort has been completed.

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4. TITLE:

Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Luke A. Schutzenhofer	205-453-0178	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study of the Fluctuating Pressure Field Associated with the Plume Induced Flow Separation (PIFS) Phenomenon that Occurs on Launch Vehicles at High Altitude
NAS8-28180
University of Alabama, P.O. Box 2846, University, Alabama 35486

OBJECTIVE(S): This study is an experimental investigation and is being conducted to determine the spatial and spectral decomposition of the unsteady pressure field associated with the plume induced flow separation phenomenon. From these experiments, data will be developed which will lead to an understanding of scaling laws and to an understanding of the predominant mechanism responsible for the flow fluctuations. The only data available are the "limited" amount acquired from a Saturn flight. Thus, the results of the present investigations will provide badly needed design data.

APPROACH: A unique experimental technique for achieving plume-induced separated flow has been developed at the University of Alabama in Tuscaloosa. This method utilizes a floor-mounted axisymmetric wind tunnel model with controllable thrust fluctuations which excite the separated region in addition to the natural unsteadiness in the approach flow. With this apparatus a systematic series of experiments will be conducted with fluctuating pressure transducers mounted in the model with the data being recorded on magnetic tape. From these recorded data, pressure-cross-power spectral densities will be computed and these data will be nondimensionalized with the various aerodynamic parameters in order to determine scaling laws and forcing mechanisms along with providing design data.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final report is in progress.			

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS: Technical Progress: Wind tunnel testing has been conducted using chamber pressure fluctuations of various frequencies. During these tests measurements were made of pressure fluctuations in the region of the separation shock wave and in the separated flow region. Also, high speed schlieren movies were taken under these conditions to determine shock wave excursions and angle changes. All these data have been reduced using statistical procedures and will be presented in the final report. To nondimensionalize the aforementioned data, a boundary layer probe was designed, constructed, and calibrated; subsequently, the boundary layer thicknesses were measured.

Management Progress: A no-cost extention was implemented which extended this effort from May 22, 1973 to August 30, 1973.

Conclusions: Preliminary evaluation of the fluctuating pressure data in the vicinity of the separation shock wave shows a strong influence of the plume forcing on the pressure fluctuation in the vicinity of the separation shock wave with a lesser influence in the separated region. The optical flow visualization data indicate the excursions of the separation shock wave have a probability density distribution that is nearly Gaussian.

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4. TITLE:

Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AUU William W. Clever II	205-453-0179	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Nonlinear Panel Flutter: A Comparison Between Experiment and Theory
NAS8-28577
Princeton University, James Forrestal Campus, Princeton, New Jersey 08540

OBJECTIVE(S): The objective of this effort is to correlate the results of a recently developed theory, which includes nonlinear structural effects and has the capability of determining pertinent parameters well beyond the flutter on-set boundary, with the results of an experimental investigation which has provided a carefully controlled study of these parameters during high amplitude panel flutter. Improved experimental techniques and theoretical refinements resulting from this effort will enable the analysis of the Space Shuttle panels to be made with greater accuracy and confidence than heretofore possible.

APPROACH: The technical approach will consist of the following tasks:

1. The theoretical method will be adapted to the specific panel used in the experimental program (Ref. NASA CR-1837).

2. Use the method to calculate the panel flutter characteristics (i.e., deflection amplitude, stress amplitude, flutter frequency, etc.) and compare the results with those of the experimental investigation.

3. Critically assess the strengths and weaknesses of both the theoretical method and the experimental techniques and recommend improvements in both.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
AMS-11-16	A Numerical Study of the Large Amplitude Flutter of a Low Aspect Ratio Panel at Low Supersonic Speed	C. S. Ventres C. K. Kang	June 30, 1973
7 Bimonthly Progress Reports		C. S. Ventres	N/A

FIRST BENEFITTING PROJECT: Space Shuttle, however the results of this effort are general enough to be applied to any supersonic or hypersonic vehicle.

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APPROACH (CONCLUDED):

4. Outline additional experimental programs to parametrically investigate the factors found from this study to be most critical for closer scrutiny.

STATUS:

Technical Progress: Flutter boundaries, as well as flutter limit cycle amplitudes, frequencies and stresses, were computed for a panel of length-width ratio 4.48 exposed to applied in-plane and transverse loads. The Mach number range was 1.1 to 1.4. The method used involved direct numerical integration of modal equations of motion derived from the nonlinear plate equations of Von Karman, coupled with linearized potential flow aerodynamic theory. Because of the range of Mach numbers involved, the popular quasi-steady or piston theory expression for the aerodynamic pressure on the panel was not applicable. The results obtained were compared to experimental data reported in NASA CR-1837. This effort constitutes the first attempt at predicting theoretically the severity of flutter of a low aspect ratio panel in the critical low supersonic Mach number range.

Management Progress: This effort has been concluded.

Conclusions: Comparison with experimental data indicate reasonably good correlation for Mach number and in-plane loading, except near the buckling load. The influence of static pressure differential depends on the in-plane boundary conditions assumed. Assuming zero edge restraint (in-plane) provided the best correlation with experiment, although not enough calculations were made to firmly establish this point.

The flutter mode shapes calculated were in good qualitative agreement with experiment. The flutter frequency, however, proved to be sensitive to the amount of structural damping assumed. With no damping, the coupled flutter frequency was several times higher than the experimental value. Because flutter frequency is an important factor in determining panel fatigue life, future experimental programs should include a determination of panel damping. In addition, the theoretical model employed should be improved to include the damping effect of the boundary layer.

Attempts to compute panel deflection and stresses during flutter met with limited success for buckled panels. The maximum deflections and stresses can be calculated with greater accuracy, however, than deflections and stresses at a specific point.

A wind tunnel test program using a carefully constructed high aspect ratio panel would be very helpful. An extensive set of data should also be collected with little or no in-plane loading present. Such data would help in assessing current theoretical methods without the perplexing, but not fundamental, difficulties associated with low aspect ratio and panel buckling.

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4. TITLE:

Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU George C. Duve	205-453-0172	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Modification of Ground Wind Data Reduction Device for Space Shuttle Ground Wind Load Studies

NAS8-28611

Baganoff Associates, 6809 West Florissant, St. Louis, Missouri 63136

OBJECTIVE(S): The objective of this technical effort is to design and develop test equipment and techniques for use on upcoming ground wind load wind tunnel tests on Space Shuttle vehicle models. The multimodal responses of the multibody parallel arranged Space Shuttle configurations necessitate development of new test equipment and techniques not previously required for the symmetrical Saturn vehicles.

APPROACH: Feasibility studies will be performed to determine the required modifications to an existing ground winds data reduction device to extend its capability to record and analyze multimodal response data. Bandpass filters will be designed and fabricated for the system to allow separation of the different multimodal responses. A means of selecting any response(s) to be analyzed in real time during wind tunnel tests will be provided.

STATUS:

Technical Progress: The final report under this contract was received in April 1973. The report consisted of the design modifications and operation and maintenance information on the modified data reduction equipment.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Baganoff Associates Report No. 609	Space Shuttle Wind Tunnel Tests Utilizing the Ground Winds Data Reduction Device	Fredrick Baganoff	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

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Management Progress: This contract was completed in May 1973.

Conclusions: The total data acquisition/reduction device performed successfully during the Space Shuttle ground winds wind tunnel test program. The system was used in recording all test data and the modified data reduction device provided the necessary real-time information for guiding the wind tunnel test program. With additional modifications to the data system, it will be an indispensable device for conducting upcoming aeroelastic ground wind load tests which are considerably more complex.

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4. TITLE:

Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Jess H. Jones	205-453-0176	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Shuttle Launch Deflector Design and Noise Suppression Study
NAS8-28566; Chrysler Corporation, Huntsville, Alabama

OBJECTIVE: High intensity acoustic environments associated with space vehicle launches have long been recognized as a problem. These environments affect the land use around the launch pad, the vehicle structure, and the launch support equipment. To counteract the increase in sound pressure levels with each new generation of boosters it is imperative that improved techniques be developed to suppress these high noise levels. Noise suppressors have been proven effective against ground-runup-noise in jet engine noise abatement programs. Therefore, it is essential that noise suppression techniques be developed to reduce the intense rocket noise environment developed by the Space Shuttle during launch holddown and static testing. The objective of this effort is to perform an analytical/experimental study of possible noise suppression techniques for the Space Shuttle propulsion system.

This effort has been expanded to obtain basic design information that is to be used in the development of the Space Shuttle launch facility deflector design. The Space Shuttle propulsion system presents a unique problem in terms of launch facility design requirements. The three separate exhaust ducting arrangements are of special concern to launch facility design personnel. The two solid motor exhausts are in opposite directions and the Hi Pc exhaust is normal to it. Of particular concern, is the insurance that modification to the existing Launch Complex 39 facility can be made so that the exhaust products can be adequately discharged from the launch facility.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
HSM-R13-73	Analytical/Experimental Study of Noise Suppression During Holddown of the Space Shuttle	J. Seracki	October 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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OBJECTIVE (CONCLUDED): It is mandatory that each exhaust duct be designed so that it does not restrict the exhaust flow which will in turn result in pressure buildup within the duct and at the base of the Space Shuttle and possible degradation in the performance of the Space Shuttle propulsion system. Adequate design of the exhaust deflector duct system can only be accomplished by testing.

APPROACH: The current design of the Space Shuttle launch facility with three separate exhaust deflector ducts has necessitated the need for a joint MSFC/KSC Cold Flow Launch Deflector Design and Noise Suppression Test. This joint program will provide basic information with respect to the orbiter and SRB's exhaust flow design requirements and relative effects of potential beneficial noise suppression which can be achieved by covering the exhaust ducts. Specifically, this study will consist of the following:

a. Develop, design and fabricate a cold flow model and implement a cold flow test program (to be conducted at MSFC) to establish basic design information for the Space Shuttle launch facility deflectors.

b. Design, develop and implement a noise suppression program, using a covered duct technique, with optimum launch deflector configurations to provide an assessment of the potential advantage of this approach.

c. Perform an analytical analysis of the diffraction effects caused by the launch facility and SSV configuration so that corrections can be applied to the existing Space Shuttle environmental estimates for the on-pad conditions.

STATUS: Technical Progress: Theoretical analysis of the formulations for diffraction and scattering of the Space Shuttle acoustic field due to the launch facility and vehicle is in progress. Refinements to the formulations have been made with emphasis on computing the resultant diffracted spectrum assuming a known free field spectrum. A summary of these program developments and some numerical results obtained using these programs has been documented and will be released as Vol. II of the indicated report. It has been found that the effect of scattering on the overall pressure level is insignificant with respect to the measurements at the Shuttle surface. The effect on the spectrum levels is significant however.

The design and fabrication of the cold flow test model have been completed. This design was based upon the current baseline configuration and consists of the Space Shuttle in the launch configuration with the mobile launcher and service tower. The scale is a 1/60th scale of the Shuttle configuration. The model is scheduled to be delivered on September 28, 1973, and testing is to begin the second week in October.

Preliminary cold flow tests have been conducted. Acoustic data reduction is complete and the analytical analysis of the data is in progress. This series of tests served as a facility checkout test program and the results will be used to design and implement the noise suppression portion of this test program. During the course of this test program, a "screeching effect" occurred at critical test conditions. This screeching had pronounced effects on the measured spectrum and in some conditions it had an effect on the overall sound pressure level. The cause of this screeching phenomenon is presently under investigation.

Forecast: Results of this study will be used to provide design information for the modification of the Saturn V Launch Complex 39 facility for use in the Space Shuttle program.

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4. TITLE:
Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Jess H. Jones	205-453-0176	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Scaling Characteristics for Defining Design Environments Due to Transient Ground Wind Loads and Nearfield Nonlinear Acoustic Fields
NAS8-28249; University of Alabama, Huntsville, Alabama

OBJECTIVE(s): This contract effort is directed in two phases. Phase A is an experimental investigation of the propagation characteristics of one-dimensional pressure waves. The main emphasis being to understand the nonlinear and the thermoviscous wave interaction mechanisms that are exhibited in wave propagation. These data are pertinent to understanding the noise propagation characteristics of rocket exhausts. Phase B is also an experimental investigation. In this study instantaneous force measurements will be taken on a right circular cylinder in a flow where the free stream velocity varies with time. These data will provide design information for bluff bodies submerged in unsteady flows, e.g., the transient atmospheric winds.

APPROACH: In the wave propagation study, temporal and spatial velocity profiles are being acquired in a 3-inch-diameter, open-end pipe. These velocity profiles result from a wave produced by the propagation of nonlinear pressure waves generated by a modified shock tube driver. These data will be acquired at stations along a 190-foot pipe. An attempt will also be made to acquire temperature and pressure data. In the Phase B studies, the instantaneous cylinder force components will be acquired in the Unsteady Hydrodynamic Flow Facility at the University of Alabama. In this facility controllable transient flows can be achieved. These transient flows are similar to transient atmospheric winds.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Attenuation Characteristics of Nonlinear Pressure Waves Propagating in Pipe (1973 International Symposium on Wave Propagation of Finite Amplitude, Denmark, August 1973)	C. C. Shih	N/A
	Nonlinear Pressure Wave Propagation (Proceedings of Interagency Symposium of University Research in Transportation Noise, Stanford, CA, March 1973)	C. C. Shih	N/A

Final report is in progress.

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS: Technical Progress: In the Phase A effort, experiments have been conducted for the finite amplitude wave propagation in 190-foot pipes. In these experiments two pipe diameters were used, i.e., 1-inch and 3-inch-diameter. The data from these experiments indicate a modified version of Burger's equation could be a good approximation when modeling the "thermoviscous" diffusion process. When Burger's equation is modified to provide a resistance mechanism similar to that given by Daray's formula, friction factors can be determined such that the theoretical results compare favorably with the experimental observations. This implies that entropy changes do not appear to be significant in the range where these experiments were conducted.

In the Phase B effort, lift and drag coefficients were determined as a function of instantaneous Reynolds number for an accelerating flow of 1 g. The results indicate that the drag coefficient versus Reynolds number is very similar to the steady flow drag versus Reynolds number. The lift coefficient versus Reynolds number is very oscillatory. All these data were obtained below the critical Reynolds number.

Management Progress: In this reporting period, the Phase B experimental apparatus had to be refurbished and subsequently calibrated. The calibration was accomplished using hot film probes and accelerometers. The results indicate that the flow is very close to 1 g. Plans were being made to study blockage and surface roughness; however, this contract effort expired at the end of August 1973.

Conclusions: The Phase A effort results indicate that the modified Burger's equation seems to predict the "thermoviscous" wave decay for finite amplitude wave propagation. However, empirically determined friction factors would have to be developed. In the Phase B effort, the drag and lift coefficients have been determined as a function of Reynolds number for 1 g flow.

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4. TITLE:

Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Jess H. Jones	205-453-0176	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Wave Propagation in Thermoviscous Media
NAS8-26084; Washington University, St. Louis, Missouri

OBJECTIVE: This study effort is directed towards the development of analytical and/or empirical technique for estimating the nonlinear noise field adjacent to jet and rocket exhaust flows.

APPROACH: This effort is a continuation of a theoretical study which was initiated with OART funding. At the present stage of investigation, a solution has been obtained which describes the wave propagation characteristics in thermoviscous media that is valid for one-dimensional and axisymmetric conditions. Specifically, this study will (1) examine in detail the one-dimensional solution, (2) obtain an exact mathematical characterization of the three-dimensional model equations, (3) obtain explicit analytical solutions for the three-dimensional equations for specific regions of interest, (4) develop numerical methods for the computer-aided solution of other three-dimensional problems, and (5) establish the manner and mechanism of energy dissipation.

STATUS: Technical Progress: It is customary to derive a general equation for nonlinear acoustics involving the fluctuations of density and pressure about their equilibrium value. However, by using density and pressure as dependent variables, a general equation can be derived which seems to offer some advantages. This has been done and a resultant three-dimensional equation governing thermoviscous wave propagation has been obtained. This equation is in differential form and an exact solution

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Interim report is due in October 1973.

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS (CONTINUED):
Technical Progress (Concluded): for the two-dimensional form has been obtained. The full three-dimensional equation does not appear to be integrable analytically, however, this is still under investigation. Further, this three-dimensional equation can be shown to reduce to Burger's and Kuznetsov's equation and for the case of confined beams to the equations of Zabolotskaya and Khokhlov.

A number of techniques for obtaining approximations are under investigation. The techniques that appear most promising are piston radiation, perturbation solution of Goldberg and parabolic inequalities approaches. The results of the study to date are being documented as an interim report. This report is scheduled to be released in October.

Management Progress: This study is presently being extended.

Forecast: As a result of this study, fundamental advances in the understanding of the three-dimensional propagation characteristics of a nonlinear wave in a viscous medium will be made.

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4. TITLE:
Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Robert W. Walker	205-453-0172	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Shuttle Ground Wind Loads Analyses
NAS8-26838; McDonnell Douglas Astronautics Company East, St. Louis, Missouri 63166

OBJECTIVE(S): The primary objectives of the technology development effort are to review the current methods, models, and techniques used to assess vehicle sensitivity to ground wind excitation and determine their applicability to multibody planform configurations of the contending Space Shuttle configurations. Further, the current methods, models, and techniques are to be modified and expanded such that the sensitivity to ground wind excitation of asymmetric aeroelastic models with the additional problems of torsional and/or coupled cantilevered modes can be adequately assessed. This effort will culminate an orderly, well-planned program to assess the ground wind sensitivity of the Space Shuttle system and its impact on the operational aspects of the system.

APPROACH: The technical approach is to be broken primarily into three phases: (1) Review and evaluate the current test methods, aeroelastic models, data acquisition, reduction, and extrapolation techniques used to determine the wind-induced loads on space vehicles and modify and expand them to account for the more aeroelastically complex Shuttle configurations (i.e., multibody, asymmetric aeroelastic effects such as torsional and/or coupled mode excitation). (2) Define, plan, coordinate, and conduct a series of parametric ground winds model tests for the contending Space Shuttle configuration. Develop a central rigid core model with variable base boundary conditions to encompass all possible dynamic characteristic parameter variations of the contending

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
McDonnell Aircraft Company, SA-81	Stress Analysis - 3-Percent Scale Space Shuttle Ground Wind Loads Model	W. Cerski	N/A
McDonnell Douglas Astronautics Co. East, MDC E0758	Design and Fabrication of a Dynamically Scaled Space Shuttle Ground Wind Loads Model	T. B. Sellers and J. A. Zara	June 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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APPROACH (CONCLUDED): Shuttle configurations. Additionally, this rigid model will have the flexibility for mounting all external aerodynamic planforms for the contending Shuttle configurations.

STATUS: Technical Progress: Review and publication of the final technical report was completed.

Management Progress: This contractual effort was completed in June 1973.

Conclusions: The final technical report along with the stress analysis report of the 3-percent model design completely covered all aspects of this contractual effort. A very good dynamically variable parallel-burn, multibody Space Shuttle ground wind loads model was provided under this contractual effort. This model was dynamically variable in three total systems and three orbiter modes. Wind tunnel tests were conducted on this model to measure the ground wind load responses in each of the six dynamic modes.

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Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Robert W. Walker	205-453-0173	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Shuttle Ground Wind Loads Analyses
NAS8-26901
Rockwell International Corporation, Downey, California

OBJECTIVE(S): The primary objectives of the technology development effort are to review the current methods, models and techniques used to assess vehicle sensitivity to ground wind excitation and determine their applicability to multibody planform configurations of the contending Space Shuttle configurations. Further, the current methods, models and techniques are to be modified and expanded such that the sensitivity to ground wind excitation of asymmetric aeroelastic models with the additional problems of torsional and/or coupled cantilevered modes can be adequately assessed. This effort will culminate an orderly, well-planned program to assess the ground wind sensitivity of the Space Shuttle system and its impact on the operational aspects of the system.

APPROACH: The technical approach is to be broken primarily into three phases:

(1) Review and evaluate the current test methods, aeroelastic models, data acquisition, reduction and extrapolation techniques used to determine the wind-induced loads on space vehicles and modify and expand them to account for the more aeroelastically complex Shuttle configurations (i.e., multibody, asymmetric aeroelastic effects such as torsional and/or coupled mode excitation).

(2) Define, plan, coordinate and conduct a series of parametric ground winds model tests for the contending Space Shuttle configuration. Develop a central rigid core

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
Rockwell International Report No. SD-73-SH-0170, dated June 29, 1973	Design of Dynamic Model for Investigating Ground Wind Effects on Space Shuttle Vehicle	N/A	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

APPROACH (CONCLUDED): model with variable base boundary conditions to encompass all possible dynamic characteristic parameter variations of the contending Shuttle configurations. Additionally, this rigid model will have the flexibility for mounting all external aerodynamic planforms for the contending Shuttle configurations.

(3) Define, plan, coordinate and conduct a series of parametric ground wind tests on an aeroelastic model of the final Space Shuttle configuration. Establish realistic ground winds restrictions and criteria.

STATUS:

Technical Progress: Final design of a four-percent Space Shuttle ground wind loads dynamic model has been completed. The model design was primarily based upon the August 1972 RI baseline Shuttle vehicle with design updates to reflect significant changes of the March 1973 baseline configuration. The approach taken in the model design was to provide rigid body structures with mass distributions representative of the empty weight condition and to add ballast weights to simulate the fueled weight condition. Design analyses of the model are published in RI's final report SD 73-SH-0170.

Management Progress: This contractual effort was completed in June 1973.

Conclusions: The model design provided adequate representation of the lowest fundamental system modes in the pitch and yaw of the Shuttle vehicle. However, adequate simulation of the lower orbiter modes was not accomplished. More elaborate methods of design of the orbiter flexures/ties will be required in the design of the final Space Shuttle ground wind loads model.

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Space Shuttle Dynamics and Aeroelasticity

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AU Paul W. Howard	205-453-0172	W. K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Modification of Damper Systems for Space Shuttle Ground Wind Loads Studies NAS8-28613, Applied Dynamics Research Corporation, Huntsville, Alabama 35801

OBJECTIVE(S): The primary objective is to develop model damper systems for use during upcoming Space Shuttle parametric ground wind loads test programs. Additionally, these dampers will be used during pre-test dynamic checkout tests. The complex multibody configuration of contending Space Shuttle parallel-arranged vehicles represents a significant departure from the axially symmetric Saturn series, and will create additional aeroelastic modes of excitation such as cantilevered, torsional, and coupled modes of the booster, orbiter, tankage, etc. The damper systems will be used to help identify and provide damping to the fundamental modes of vibration and therefore will assist in establishing adequate Space Shuttle ground wind loads design criteria.

APPROACH: Existing damper systems will be modified for use in upcoming parametric ground wind loads tests on parallel solid Space Shuttle dynamic models. An instrumentation system will be designed and assembled that will facilitate dynamic checkout tests of the model and will be used in the actual wind tunnel testing as an integral part of the total damper/model instrumentation system. All spare parts necessary for reliable operation of the damper system will be obtained. In addition, the damper system will be operated during model vibration checkout tests and during wind tunnel testing. Also, data pertinent to the performance of the system will be obtained during these initial tests.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
A.D.R.C. Report No. T 1045F	Space Shuttle Damper System for Ground Wind Load Tests	G. D. Robinson J. R. Holt C. S. Chang	N/A

FIRST BENEFITTING PROJECT: Space Shuttle

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STATUS:

Technical Progress: The final technical report was published in April 1973. Two damper systems previously used in other ground winds test programs were modified for use in the Space Shuttle model to act as primary and back-up dampers. This report describes the modifications made to the damper systems, along with associated control systems and instrumentation.

Management Progress: The contract was completed in April 1973.

Conclusions: The objectives of this contract were accomplished with the highest degree of success. Existing damper systems were modified (both physically and electronically) for use in the Space Shuttle ground winds dynamic model. The damper systems have the unique capability of acting both as a shaker and as an internal damper. The system was used as a shaker during dynamic check-out/calibration tests at MSFC and at LaRC; it was used as a damper during actual ground wind testing to achieve various levels of simulated structural damping and to protect the test model from structural failure.

The entire damper system included a control console for both dynamic calibration and wind tunnel testing. This damper system will be used during upcoming aeroelastic ground wind load studies on the final Shuttle configuration.

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4. TITLE:

Shuttle Development

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AT Terry F. Greenwood	205-453-1157	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study on Solid Rocket Motor Plume Flow Field and Radiation Analysis
NAS8-28609, Lockheed Missiles and Space Co., Inc.
Huntsville Research and Engineering Center
P. O. Box 1103, West Station
Huntsville, Alabama 35807

OBJECTIVE(S): To incorporate into existing gaseous plume and plume impingement computer programs the capability to calculate solid rocket motor two-phase plume flow fields and plume impingement effects; and to use these analyses to improve and update existing solid motor radiation calculations.

APPROACH: It is proposed to improve and update existing plume flow field and plume impingement analytical models to account for the effects of solid particles in the flow field. Using this better description of the two-phase flow field, the prediction of solid motor radiation can be improved. Extensive use will be made of existing solid motor radiation data from ground and flight tests of Minuteman, Titan IIIC, Polaris, etc., to develop and improve the radiation analysis. The updated plume impingement analysis will include particle heating, gaseous convective heating, impingement pressure, and particle impingement pressure.

STATUS: - Technical Progress - The coupled two-phase solid motor plume flow field analysis has been programed and the program is being checked out. An uncoupled two-phase flow plume analysis has been incorporated into the plume impingement program so that preliminary design numbers could be generated. Work is continuing on making

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the coupled analysis compatible with this program. Polaris, Posidon, Titan IIIC solid motor radiation data have been obtained and is being carefully reviewed. Improvements in the existing solid motor radiation analysis are being made based on this data. Indepth analyses of both the full scale SSME boundary layer and the 4% base heating model SSME engine are underway using MABEL and BLIMP. Some modifications of these programs are required in order to run them for these cases.

Managment Progress - Contract NAS8-28609 has been extended until February 1974.

Conclusions - Preliminary examination of the coupled, two-phase plume analysis indicates that it will be useful in generating the Shuttle design environments.

Problems - None

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4. TITLE:

Shuttle Development

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-AT David C. Seymour	205-453-1157	Werner K. Dahm

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: SSME Orbiter Radiation Analysis
NAS8-29270, Remtech, Inc.
2603 Artie Street
Huntsville, Alabama 35805

OBJECTIVE(S): To develop an analytical SSME plume radiation model that can be used to generate SSME plume radiation heating to the base of the Orbiter, ET, and SRB's.

APPROACH: During the development of the Saturn S-II stage, a computer program was developed to calculate the gaseous radiation from the five S-II stage J-2 engines. Since the engines used on the Space Shuttle orbiter utilize the same propellants, i.e., H_2/O_2, this computer program is applicable. It is proposed, therefore, to modify and update this program to include the geometry and plume flow fields of the Space Shuttle and to use this program to generate the SSME radiation contribution to the overall Shuttle base thermal environment.

STATUS: Technical Progress - Since the gaseous radiation computer program developed for the Saturn applies only to rocket engines parallel to each other, a program was developed to transform the plume flow field data for the engines from an uncanted position to a canted position. This program also allows adding together different parts of the flow field obtained from different sources. Several modifications which simplify and specialize the program for the orbiter configuration have reduced the computer time of the radiation program by nearly an

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order of magnitude. Preliminary orbiter radiation heating predictions to the external tank and orbiter heat shield have been obtained for sea level conditions and more extensive predictions are planned. High altitude radiation is predominantly from the shock layers formed by the plume interaction of the three engines and an approximation of this three-dimensional flow field is being developed by using S-II flight radiation data.

Management Progress - Contract NAS8-29270 started on January 1, 1973.

Conclusions - None

Problems - None

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4. TITLE:
Eastern Test Range Ocean Wave Statistics for Space Shuttle Booster Design & Recovery Operations

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. C. Brown, S&E-AERO-YT	205 453-3141	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Contract No. NAS8-29578, New York University
Contract No. NAS8-29616, The City University of New York, New York

OBJECTIVE: To develop a body of sea state statistics for use in the design and recovery operation of the Space Shuttle Solid Rocket Booster (SRB). From present indications it appears that the parameters having the greatest effect upon the SRB water entry and recovery operations are the wind speed, wave height, and wave slope. Distributions of these sea state descriptors at any given instant are applicable to SRB water entry, but for all other operations (afloat, secure, towback recovery) where some considerable time interval is involved exposure period statistics must be developed.

APPROACH: From a detailed wind analysis of the Atlantic Ocean generate 3-dimensional sea surface spectral data. Each spectrum, computed for several grid points in the SRB water entry and recovery area, will provide sea surface information on all pertinent frequency bands and the direction from which they propogate. From these sea state spectra develop point statistics, exposure period statistics, and persistency statistics for all phases of the SRB water recovery operations.

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Eight monthly progress reports have been received.

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STATUS: Technical Progress: Checkout of a new wave forecasting model has been completed. This model will produce wave spectra of 15 frequency bands and 12 directional bands.

Management Progress: Contract NAS8-29578 with the New York University was completed. Contract NAS8-29616 with the City University of New York was begun.

Conclusions: The wave forecast model will produce the information required for better SRB recovery definition.

Problems: Difficulty in obtaining sufficient manpower and computer time to generate the sea state statistics from the wave forecasting model has been experienced.

Forecast: Continue to develop additional years of ocean wind fields to improve and expand the basic data sample. Develop 3-dimensional ocean wave spectra for the Vandenberg AFB SRB recovery area.

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4. TITLE:

Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Methods for Elevated Temperature Designs
NAS8-28170 Lockheed Missiles & Space Company

OBJECTIVE(S): To define a procedure for structural design at elevated temperatures. Desired goal is to have the same confidence in structural integrity at elevated temperature as the factor of safety gives on mechanical loads at room temperature.

APPROACH: Examine the various philosophies used in combining mechanical loads and thermal loads. Select from these philisophies a structural design criterion which is best suited for the Space Shuttle. Where required, analytical studies should be made to aid in the selection.

STATUS: Technical Progress--The work outlined under Approach has now been completed, and the final report described below is available for distribution.
Management Progress--Since this contract is complete, this progress report terminates reporting.
Conclusions--The recommended approach to elevated temperature design consists of applying a factor of safety to the mechanical loads, a life factor to service life, and a factor to the design heating rates or temperatures. The rationale for applying the factors is explained in the final report.
Problems--None
Forecast--None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-HREC TR D306579	Methods for Structural Design at Elevated Temperatures	A. M. Ellison W. E. Jones, Jr. K. R. Leimbach	April 1973

FIRST BENEFITTING PROJECT: SPACE SHUTTLE

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4. TITLE:
Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Incremental Proof Test Feasibility
NAS8-28514 North American Rockwell

OBJECTIVE(S): To study the feasibility of performing low level proof tests at regular intervals over the life of the shuttle instead of one high level proof test prior to the first flight.

APPROACH: To perform analytical studies to determine the advantages and disadvantages of the incremental approach of proof testing when compared to one high level proof test. Structural weight, cost of damage due to premature failure, etc., shall be considered in this effort.

STATUS: Technical Progress--The large solid rocket booster (SRB) case has been the primary object of investigation during the reporting period. The emphasis was placed on crack growth in the SRB case. In all cases, the calculated life terminated in crack instability rather than break-through (leakage).
Management Progress--None

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Conclusions--Based on a scatter factor of four, the following conclusions regarding the influence of proof testing can be drawn.

1. If a proof test to 0.9 F_{ty} is performed before each operational cycle, the risk of service failure is very small.

2. If a proof test to the stress level required to guarantee four more service cycles (1 cycle times the scatter factor) is performed before each operational cycle, the risk of service failure is slightly greater but the possibility of case survival through a lifetime of twenty proofs and twenty operational cycles is greatly improved. Note that this proof level is smaller than 0.9 F_{ty}.

3. Leakage type failures are improbable.

4. Long shallow slaws give the most conservative predictions but are most easily detected by nondestructive test and inspection techniques.

Problems--None

Forecast--None

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4. TITLE:

Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of a Method for Elastic Plastic Analysis of Branched Shells NAS8-28569 Grumman Aerospace Company

OBJECTIVE(S): The objective of this program is to develop theory for plastic analysis of axisymmetric thin shells. This development shall be incorporated into an existing computer program for predicting elastic stresses in shells of revolution subjected to symmetric and unsymmetric loading. In addition to the above extensions, processes that are presently being done by the program user will be automated, and plot routines will be incorporated to facilitate the program user.

APPROACH: A thorough literature search shall be conducted, the theory shall be formulated, and a computer program shall be developed for calculating stresses and displacements in axisymmetric shells that experience plastic deformations.

STATUS: Technical Progress--The programming effort is essentially complete. Test cases comparing analytical solution with experimental results are in good agreement. The demonstration of the program on the MSFC computer is scheduled for Oct. 15, 1973. It is anticipated that the documentation of the program will be completed for final delivery by November 15, 1973.
Management Progress--None
Conclusions--None
Problems--None
Forecast--None

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Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. E. Key	453-4349	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Criteria for Structural Test
NAS8-29070 The Boeing Company

OBJECTIVE(S): The objective of this program is to define criteria, methods, techniques of design, analysis, and test of structural assemblies, components, or materials which would permit the use of a single structural assembly test item for cyclic life and strength design verification.

APPROACH: Review completed structural test programs and correlate the success of the final product to the testing program.

STATUS: Technical Progress--The work outlined under Approach has been completed, and the final report described below is available for distribution.
Management Progress--Since this contract is complete, this progress report terminates reporting.
Conclusions--The primary conclusion of this effort is that using a single test article for static, dynamic, and fatigue testing is technically feasible. But there are penalties to this approach which involve longer schedules, possibly more development tests, and the risk of failing the only specimen. A cost savings could be realized under the single test specimen approach.
Problems--None
Forecast--None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
D5-17269	Criteria for Structural Test	W. H. Armstrong A. R. Farsoun	Aug. 73

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4. TITLE:

Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. B. Herring	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Assessment of Loads Resulting from Parachute Deceleration Systems
NAS8-29144 Goodyear Corporation

OBJECTIVE(S): (1) Complete a parametric evaluation of the use of parachutes to decelerate cylindrical bodies weighing from 150,000 to 300,000 pounds from Mach 1.4 to a terminal velocity of 50 to 150 FPS.
(2) Develop a digital computer program to calculate the dynamic response and loads on the vehicle due to parachute deployment.

APPROACH: Parametric evaluations shall be performed on the effects of significant parachute parameters on vehicle loads and parachute weight. Significant parameters to be evaluated are number of parachutes, size, weight, deployment sequence, number of reefs, and terminal velocity. The computer program documentation will include a methodology explanation, a users manual, a program listing, and a card deck or program tape executable on the Univac 1108 machine.

STATUS: Technical Progress--The contract was completed May 2, 1973. Contractor personnel established a parachute loads program and ran sample problems on the MSFC 1108 computer. The program calculates deployment loads for the parachute and SRM, both possessing 3 degrees of freedom (2 translation & 1 rotation). Contractor also developed an engineering design manual that allows an engineer to design and/or evaluate parachute parameters such as diameter type (ring, sail, slot) and number of suspension lines for a particular SRM. It also covers recovery system weights for a special SRM, drag coefficients, and trajectories for specific SRM configurations.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
GER-15853	Users Manual - Computer Program for the Load and Trajectory Analysis of Two 3 Degrees-of-Freedom Bodies	George Doyle & J. W. Burbick	Feb. 5, 1973
GER-15887	Engineering Design Manual of Parachute Decelerator Characteristics for Space Shuttle Solid Rocket Booster Recovery	David L. Mansfield	May 1, 1973

FIRST BENEFITTING PROJECT: Space Shuttle Solid Rocket Motor

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STATUS: Continued
Management Progress--None
Conclusions--None
Problems--None
Forecast--This will be the last report submitted on this specific task. A new effort is being finalized to modify the loads program to allow 6 degrees of freedom on the SRM and parachute.

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Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. McComas	453-4386	H. R. Coldwater

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Combined Loading Criteria Influence on Structural Performance
NAS8-26916 General Dynamics Corporation Convair Aerospace Division

OBJECTIVE(S): The development of methods for rationally combining deterministic and probabilistic loading in order to provide realistic design criteria and factors of safety, and to enable the analyst to make calculations of fatigue life and determine structural probabilities of success.

APPROACH: Phase 1 - Investigate and define the relative sensitivity of structural weight to loading parameters. Provide recommendations on those loading parameters which must be accurately defined and those which can be estimated with little effect on structural weight.
Phase 2 - For the significant loading parameters, define the sensitivity of structural weight to levels of loading parameter variability and varying levels of probability.
Phase 3 - Define the loading parameter variability and probability as a function of program schedule from conceptual definition to final design.
Phase 4 - Define and document rational methods for combining time dependent and probabilistic loading parameters to provide realistic design criteria and factors of safety with determinable probabilities of load exceedance.

STATUS: Technical Progress--The scope of work of this contract has been successfully completed, and the oral presentation has been given to all interested MSFC personnel and was well accepted.
Management Progress--The contracted effort has been completed.
Conclusions & Problems--None
Forecast--Last report.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
GDCA-HAB73-016	Combined Loading Criteria Influence on Structural Performance - As Applied to the SRM Configuration	B. J. Kuchta and P. J. Townsend	April 30, 1973

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Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Kenneth E. McCoy	205 453-3824	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Thermal Engineering for Structural Mission Simulation Testing: NAS8-25569, LMSC

OBJECTIVE: Perform Shuttle TPS analyses in support of the testing program to verify Shuttle TPS designs. In addition, specify test articles, test environments, methods of simulation and instrumentation plans.

APPROACH: Develop a computer model of candidate Shuttle TPS designs and test fixtures. Also develop computer models of large structural prototype sections and their test fixtures. From results of various environments and conditions imposed on these computer models, recommendations will be made as to tests to perform, instrumentation requirements, and methods of simulation.

STATUS:

Technical Progress: In the current reporting period the principal activity has been in analyzing and correlating data from thermal tests of foam and ablator TPS systems for the External Tank (ET). These ET TPS tests include both Hot Gas Facility (HGF) tests and radiant tests. An analytical thermal model has been developed to predict surface recession and internal foam temperatures in the HGF tests. Also, an analysis was performed on the similarities and differences between the conditions of the HGF tests and those to which the ET TPS will be exposed to in flight.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-HREC-D30662	"Thermal Support for Space Shuttle Second Interim Final Report"	W.G. Dean	June 1973

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Management Progress: This task is an addition to contract NAS8-25569 (Lockheed Missiles and Space Company). Contract modification was signed September 11, 1973 extending the period of performance to December 11, 1973.

Conclusions: The thermal model developed gives a fair correlation with experimental data over a narrow range of conditions. However, to make the model useful in predicting flight performance, it is being revised as more data becomes available. Although the heating rate is adequately simulated in the HGF, the aerodynamic shear, free stream enthalpy, static pressure and free stream oxygen content are different and additional tests are recommended to determine the exact nature of their effect.

Problems: None

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Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. R. Fisher	205-453-3825	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Thrustor Penetration Heating; Contract NAS8-27683, GDC/San Diego, CA

OBJECTIVES: Establish ascent and reentry heating environment of the ACS thrustor penetrations and select the best candidate to provide a long life, reusable, low cost TPS for the thrustor nozzle and local vehicle Thermal Protection System (TPS).

APPROACH: Phase I: Design and fabricate vehicle and thrustor models. Determine windtunnel pertinent test requirements to be simulated. Conduct windtunnel test program with and without thrustor firing. Phase II: Predict heating and temperatures for Shuttle vehicle based on windtunnel test data. Design and optimize TPS for thrustor and surroundings, and verify by testing.

STATUS:

Technical Progress: A windtunnel test program was established to obtain heat transfer and pressure data associated with separated hypersonic flow caused by either a deep cavity or by lateral jet interaction. The test program was performed in Tunnel B at AEDC during May 1972. Thrustor firing simulated by ejecting conditioned helium and air. Results of these tests have been used to establish heat transfer amplification factors for determining heat rates in the vicinity of ACS thrustors located in the forward nose region of a shuttle orbiter. Thermal analyses have shown that a non-firing ACS thrustor on the lower nose surface can be protected by submerging the metallic (Hastalloy X assumed) nozzle and utilizing a TPS nozzle insert. Maximum heating rates, however, are realized for a firing thrustor during reentry on the surface upstream of

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
584-TP-487,	Preliminary Pretest Report for Space Shuttle Attitude Control System (ACS) Thrustor Penetration Heating Tests at AEDC VKF Tunnel B	O. Brevig	November 1971
632-TP-19,	Pretest Report for Space Shuttle Attitude Control System (ACS) Thrustor Penetration Heat Tests at AEDC VKF Tunnel B	O. Brevig	March 1972
632-TP-34,	Third Quarterly Report, "Space Shuttle Attitude Control System (ACS) Thrustor Penetration Heating	O. Brevig	April 12, 1972
632-2-TP-46,	Fourth Quarterly Report, Space Shuttle Attitude Control System (ACS) Thrustor Penetration Heating	O. Brevig	July 12, 1972
AIAA Paper No. 72-93,	Aerothermodynamics of the Space Shuttle Reaction Control System	O. Brevig W. Strike R. Fisher	Jan. 10, 1973

FIRST BENEFITTING PROJECT: Space Shuttle

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the nozzle. Carbon/carbon, low density ablator, RSI and coated columbium with beryllium heat sink were considered as candidate TPS materials. The results showed that only carbon/carbon and the low density ablator offer feasible solutions to the thermal protection problem. Thermal models using the carbon/carbon material for scarfed and unscarfed nozzle configurations were tested in the MSFC Hot Gas Facility during April 1973. The heating environments measured inside the nozzle of the TPS models agreed well with earlier data obtained during the tests at AEDC. A final report summarizing the analytical effort and test effort has been published.

Management Progress: NAS8-27683 was let to GDC on June 30, 1971 for $67.7K. Forty hours of windtunnel test time in Tunnel B at AEDC has been contracted by MSFC and will be made available to GDC for conducting required ACS penetration environmental tests. (GDC study program was based on using AMES test facility. However, due to AMES windtunnel being down and uncertainty when tests could be conducted at AMES it was decided to furnish GDC windtunnel time at AEDC.) A no cost extension of NAS8-27683 to 30 June 1973 was approved 30 December 1972 to enable inclusion of TPS tests at MSFC. The MSFC tests were conducted during April 1973 and the contract was satisfactorily completed July 10, 1973.

Conclusions: (1) The two-dimensional cavity analysis of Burgraf indicates that the normalized cavity reattachment heating is a function of the ratio of cavity diameter to cavity depth and produces heat transfer distributions that agree well with the AEDC data. However, the three-dimensional cavity heat transfer rates were 1.5 and 3.0 times the Burgraf theoretical values for model angle of attacks of 0° and 30° respectively. (2) Based on the AEDC test data the effect of air bleed into the bottom of the cavity was to reduce the heating on the recompression wall of the cavity and increase the heating on the surface downstream from the cavity. Model boundary layers aft of the cavity were laminar except for the 30° angle of attack case which was turbulent. The cavity bleed gas caused the reattaching flow to be fully turbulent. For the cases of fully turbulent flow ahead of the cavity ($\alpha = 30^{\circ}$) the effect of cavity bleed was to reduce reattachment heating slightly. (3) For the jet interference case (yaw thrustors), the heat transfer amplification factors obtained from the AEDC test program were 10 to 40 times the undisturbed reference heating rates. Heating rates of this magnitude can cause surface temperatures near 4000°F just ahead of firing thrustors located on the side of an orbiter nose during reentry.

Problems: None
Forecast: None
Remarks: None

7. Report No.	Title:	Author(s):	Date
	Twelve Monthly Progress Reports	O. Brevig	Aug. 1971-Nov. 1972
GDCA-DD B73-002,	Space Shuttle Attitude Control System (ACS) Thrustor Penetration Heating (Final Report)	O. Brevig	March 1973

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Structures

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
F. Huneidi	205-453-3820	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Shuttle Heat Pipe Leading Edge: Contract NAS8-28656; MDAC

OBJECTIVES: Design and fabricate two heat pipe cooled leading edge test segments.

APPROACH: (a) Develop test model specifications and heat pipe design including model configuration, dimensions, materials and optimum heat pipe fluid. Also predict operation characteristics from L.O. to touchdown and during testing, influence of environments and trajectory parameters, and temperature history during flight. (b) Conduct laboratory tests to determine compatibility of heat pipe materials with selected fluid, and heat transfer as a function of temperature and gravity force. (c) Fabricate two leading edge heat pipe test models including forming, mounting and instrumenting. (d) Establish test procedures and submit test plans for testing at MSFC facility.

STATUS:

Technical Progress: Analysis and design effort completed. Development testing completed. Manufacture of test module and facility adapter completed. Brazing operations were successful. Two models were delivered on April 15, 1973. Test program outline and final report were issued.

Management Progress: The above contract NAS8-28656 was awarded to MDAC on June 1972 for a period of 6 months. A no cost extension was granted through

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
7 Monthly Progress Reports	V. A. Niblock R. V. Masek	June 1972 Jan. 1973
1 Final Report, "Design, Fabrication, Testing, and Delivery of Shuttle Heat Pipe Leading Edge Test Modules"	MDAC-East, Report MDC E0775	April 20, 1973
AIAA Paper No. 73-738, "Four Space Shuttle Leading Edge Concepts"	G. A. Niblock J. C. Reeder F. Huneidi	July 16, 1973

FIRST BENEFITTING PROJECT: Hypersonic Vehicles

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April 20, 1973. The contract was funded from FY'72 Space Shuttle source 976-30-61, for $59.6K. Contract was terminated during the month of April 1973.

Conclusions: This program, consisted of the construction of two test modules for a feasibility demonstration of a concept for reusable Space Shuttle wing leading edge surfaces. In this leading edge concept, high temperature heat pipes were incorporated into the structure to cool the stagnation region, allowing the use of super-alloys in place of refractory metal, ablator protected, or carbon-carbon structures.

The program included the analysis and design of the heat pipes, their integration into the test module structure, heat pipe development testing, construction of the test modules and a facility adapter, and formulation of recommended testing conditions. The heat pipe analysis and testing was conducted at the Donald W. Douglas Laboratories (DWDL) in Richland, Washington. Structural analysis and design, fabrication of sheet metal and machined parts, and final assembly were accomplished by MDAC-E in St. Louis, Missouri.

The results of the heat pipe and leading edge module thermal analyses indicate the test modules will meet their design goal; reducing the leading edge temperature at the stagnation line from 1315°C (2400°F) to less than 1010°C (1850°F). The development tests demonstrated that the module assembly could be brazed with active heat pipes, as was borne out by the subsequent successful brazing of both modules with active heat pipes loaded with sodium. Construction of the two modules in this fashion conclusively demonstrated the manufacturing feasibility of the concept.

A test plan was formulated to be used in subsequent performance testing which will be conducted by the NASA, MSFC.

Leading edge concepts trade studies show that the heat pipe leading edge is heavier than other leading edge concepts when redundancy of heat pipes is considered. Cost of the heat pipe leading edge is higher than carbon/carbon system, but less than ablative systems. Since the carbon/carbon is not flight proven, the heat pipe may be considered as back up. Further development and studies of the heat pipe leading edge will result in a lighter weight system than presently constructed models.

Problems: None

Forecast: None

Remarks: None

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	976-30-61	976-30-61

4. TITLE:

Structural

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL: MHR
S&E-AERO-DDD Gaines L. Watts	205 - 453-2521	J. A. Lovingood

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Parachute Dynamics & Stability Analysis

Cont. No. NAS8-28607, Honeywell Inc., Systems and Research Division, Minneapolis, MN 55413

OBJECTIVE: To provide a data base for the optimization of design of a parachute system for recovery of large vehicles.

APPROACH: To formulate the equations of motion for a Parachute/Vehicle combination (Phase I) then to linearize these equations (Phase II) and use standard linear techniques to analyze parameter sensitivity (Phase III).

STATUS: Technical Progress: Formulation of the equations of motion is complete except for small refinements. An elastic canopy analysis is being used to find the parachute shape and weight. Assumptions are being evaluated and refined. Several checkout runs have been made with the parachute dynamics program.

Management Progress: The contractor gave a 6 month oral progress report to bring NASA up to date on the contract work. At this time, instructions were given the contractor on model refinement and the direction of future work.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
N/A	Sixth Monthly Progress Report	Dr. S. K. Ibrahim & Dr. R. E. Rose	N/A

FIRST BENEFITTING PROJECT:
Shuttle

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

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Conclusions: None

Problems: None

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	976-30-61	908-54-08

4. TITLE:

Structural

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Robert S. Ryan, S&E-AERO-D	205/453-2481	J. A. Lovingood, S&E-AERO-D

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Control Trajectory and Loads Optimization

Contract No. NAS8-28299, Honeywell, Inc., Systems and Research Division, 2345 Walnut Street, St. Paul, MN

OBJECTIVE: Develop and integrate a computer program that **simultaneously optimizes** vehicle design considering trajectory, control, and structures.

APPROACH: Phase I: Optimization technique -- Develop an interdiscipline optimization routine; develop basic program using RAGMOP* trajectory and boost six-flight control decks. Tie together these programs in an acceptable manner and make provisions for additional modules, such as structural loads and weight.
Phase II: Structural model -- Develop a structural loads and weight module. Incorporate into program of Phase I.
Phase III: Documentation -- Document and provide computer program.

STATUS: Technical Progress: The RAGMOP trajectory program was used to generate a zero angle of attach trajectory for the 150K lightweight orbiter, mated vehicle configuration 00006IC. The gross vehicle mass and aero properties were generated from the distributive mass and aero properties using the data reduction routines developed earlier in the program.

The loads analysis routines were integrated with RAGMOP and the attach force computations were checked at several points along the trajectory. Sectional loads computations

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FIRST BENEFITING PROJECT: Space Shuttle

*RAGMOP is an acronym for: Rocket Ascent G-Limited Moment-Balanced Optimization Program

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 976-30-61

STATUS (CONCLUDED)

are currently being checked out.

The most recent effort centered on the integration of the flight control program with the RAGMOP program. The nominal trajectory was flown with tight attitude and load relief options from liftoff to staging to check for consistency.

Management Progress: Most of the program development is complete with the exception of the equivalent shell thickness and wing weight computations. The trajectory and flight control integration is complete except for the flight performance reserve computation.

Conclusions: None

Problems: None

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN		PAGE 1 OF 3	
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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 - 30 09 73	982-52-03	None

4. TITLE:

Shuttle Main Propulsion Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. A. Gross	205-453-3816	J. A. Lombardo

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: POGO Dynamic Flowmeter Evaluation
In-House S&E-ASTN-PPM

OBJECTIVES: Evaluate and calibrate flowmeters believed to have potential for dynamic flow measurement in SSME testing under simulated operating conditions.

APPROACH: Available flowmeters believed to have potential for dynamic flow measurement in SSME POGO testing will be procured and evaluated in a cryogenic flow facility at MSFC. The 8-inch flowmeters will be evaluated over a frequency range of 2 - 40 hz with dynamic velocity variations the same as expected in SSME POGO testing. The standards for evaluation will be 2" meters previously calibrated by NBS. The expected results from the program will be recommendations to the SSME contractor for flowmeters to be used in engine POGO testing.

STATUS: Technical Progress: Construction of the flowmeter evaluation facility is complete. The facility consists of approximately 30 ft of 8-inch-diameter line containing two 8-inch and one 2-inch Ramapo flowmeters. Also attached to the 8-inch line at a 90^{o} angle is a 2-inch pulser line containing a 2-inch Ramapo flowmeter and a 2-inch hydraulic actuated servo valve.

Three flow tests have been run to date in an attempt to calibrate the 8-inch meters using the calibrated 2-inch meters. Data are currently being analyzed. The facility is also being insulated to prevent boiling of the liquid nitrogen. This appears to be a deterring factor in the calibration.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

No reports have been issued to date.

FIRST BENEFITTING PROJECT: SSME

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 982-52-03 PAGE 2 OF 3

STATUS (CONCLUDED):

Management Progress: All hardware has been received and installed. Propellant requirements are within the budgeted amounts.

Conclusions: None.

Problems: (1) One-month schedule slip.

(2) The natural frequency of the 8-inch flowmeters appears to be in the range of dynamic flow being investigated. This may preclude the use of these particular meters in this application.

Cause of Problems: (1) Difficulty in calibrating flow meters at NBS.

(2) The natural frequency of the 8-inch flowmeters appears to be lower than expected.

Solution of Problems: (1) Recalibrate flowmeters with a new orifice and line configuration.

(2) Conduct a thorough analysis of the 8-inch flowmeters to determine their natural frequency. Conduct tests to confirm analysis.

Forecast: The major activity during the next six months will be facility checkout, flowmeter testing, and data evaluation.

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01 04 73 - 30 09 73	CURRENT NO.: 982-52-61	PRIOR NO.: 976-30-61

4. TITLE:

Space Shuttle Engine and Vehicle TPS Review

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. E. Price	205-453-3825	H. G. Paul

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Vehicle Engine and Heat Shield Review; NAS8-27802, BECO

OBJECTIVE: (1) Determine the degree of agreement between flight and scale model results and analytical prediction techniques. (2) Identify and implement improvements in the analytical methodology. (3) Identify and evaluate probable errors associated with the flight instrumentation and propose a solution which will correct the errors.

APPROACH: Work scope has four tasks: Task 1 - Adopt the solid rocket plume data previously collected to the present Shuttle SRM configuration through math modeling for capability of assessing the impact of solid rocket plume emission at altitude. The methodology should include incorporation of plume-to-vehicle radiation view factor determination on a rapid turn-around computer run basis. Task 2 - Incorporate in the current operational computer program for flow reversal base heating the effects of cryogenic engine internal boundary layer condensation phenomena which is possible at the reduced power level operation of the Space Shuttle Main Engine (SSME). Task 3 - Evaluate the base region instrumentation requirements of the SRM and ET as dictated by the past and currently available instrumentation design criteria. Task 4 - Prepare a final technical report that describes in detail the results, conclusions, and recommendations of the "Space Vehicle Engine and Heat Shield Review".

STATUS:

Technical Progress: Initiated 14 September due to funding delay. Task 1 near completion.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
July 1971 - June 1972 (933-40-50)	Monthly -	July, August, Oct, Nov, Jan, Feb, April, May	
	Quarterly -	Sept, Dec, March	
	Interim -	June	
July 1972 - March 1972 (976-30-61)	Monthly -	July, August, Oct, Nov, Jan, Feb, April, May	
	Quarterly -	Sept, Dec, March, June	
July 1972 - March 1973 (976-30-61 and 933-40-50)		Monthly - July, Aug, Oct, Nov, Jan, Feb Quarterly - Sept, Dec, March	
March 1973 - July 1973 -		Postponement of Continuing Effort	
July 1973 - Sept 17, 1973 -		Funding Delay	
Sept 17, 1973 - Dec 14, 1973 (RTOP, 982-52-61)		Final Period of Performance Concluded with Final Report	

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 982-52-61

STATUS: (Continued)

Management Progress: Initial contract signed June 28, 1971. Fifth cost extension covers period from June 30, 1973 to 1 October 1973. Funding delay til 17 September caused schedule shift of period of performance to 17 September through 14 December at no cost to Government. Funding of 1 July 1971 through 30 June 1973 activities under 933-40-50 and 976-30-61 respectively.

Conclusions:

Flight Test Data - Measuring instruments influences the measured parameters rather than being driven by them. Plume radiation characteristics cannot be extrapolated from one vehicle configuration to others as has been previous practice.

Scale Model Test Data - are widely scattered and subject to questionable interpretation and always over predict the base thermal environment for booster stage. Scaling factors remain undefined. Scale model data useful primarily for trend definition but not as a design tool in their present approach.

Engine Cryopropellant Effects influence the overall base thermal environment and have generally been ignored in analyses and model testing.

Base Region Flight Instrumentation not measuring the parameters they were intended to measure and requirement for new instrumentation is evident.

Base Region TPS Materials can significantly influence base region thermal environment if they are highly hygroscopic.

Analytical Models generally force too conservative a design and indicate that the existing empirical correlation for base region heat transfer/flow phenomena are not adequate except in parametric application.

Solid Rocket Motor plume radiation prediction techniques are not adequately developed and require development prior to appplications to Space Shuttle/SRB.

Milestones:

Review of all SATURN I, IB, & V booster vehicle base region flight and base region thermal environment design criteria has been completed and critiqued and impacted on SS design analyses.

Computer programs from previous vehicle programs throughout the Aerospace industry have been reviewed and compacted into a rapid turn around design tool in manual and simplified programming form; convection and radiation heating environment definition capability included in component form.

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RESEARCH AND TECHNOLOGY OPERATING PLAN
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STATUS: (Continued)

Problems: Analytical techniques for instrumentation correction not proven and require further analysis beyond scope of work of present extension.

Forecast: By 15 December - Complete final report of 29 month study inclusive of final extension period.

Remarks: Results of the study will be implemented directly into consideration of of Shuttle TPS and base region heat shield instrumentation design.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	983-15-21	976-30-13

4. TITLE:

Instrumentation for Space Shuttle

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMP H. Harman	453-5620	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: 035, Low Differential Pressures in High Line Pressures
NAS8-27227, Celesco, Inc. Chatsworth, CA
NAS8-27446, Toroid Corporation, Huntsville, AL

OBJECTIVE(S): To develop a lightweight (12 oz.) dual isolated (wet-wet type) differential pressure transducer having full scale ranges of 0-10 psid and 0-100 psid for line pressures up to 8000 psi.

APPROACH: Two parallel approaches have been chosen for this development; i.e., development of a torus type pressure sensitive element which will generate a force capable of being sensed with conventional strain gage elements and boron doped silicon strain gages bonded inside an integral diaphragm beam.

STATUS: Technical Progress - Celesco will make minor changes in the method of mounting strain gages to the integral beam. Gages will first be applied to a small beam and the small beam will be inserted into the integral beam-diaphragm. This approach eliminates the problem of matching the strain gage to the integral beam-diaphragm material.
Management Progress - Toroid Corporation has delivered final report and hardware. Additional funds were granted Celesco, Inc. in order that the contract might be completed. Celesco, Inc. has given additional time to complete contract.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final Report NAS8-27446		Toroid Corporation	

FIRST BENEFITTING PROJECT: Space Shuttle

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
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CURRENT NO./CODE: 983-15-21

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STATUS (CONCLUDED): Management Progress (cont'd) - Hardware delivery will be by January 1, 1974.
Conclusions - Research and development performed indicates that all guideline specifications may not be met.
Problems - Toroid was not able to achieve the required working pressure of 8000 psi.
Forecast - Basic problems associated with low range differential pressure transducer will not be completely solved requiring follow-on contracts in order to meet guideline specifications. This task is no longer an SRT task and is being funded under the engine program. This will be the final report.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01 04 73 to 30 09 73	983-15-21	976-30-13

4. TITLE:

Instrumentation for Space Shuttle

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IMP H. Harman	453-5620	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: 035 Flange Mounted Preburner Pressure Transducer
Flange Mounted Cryogenic Pressure Transducer
NAS8-27442, Conrac, Inc., Durrant, CA
NAS8-27444, Consolidated Controls Corporation, Bethel, CT
NAS8-27445, Statham Instruments, Oxnard, CA
NAS8-27443, MB Electronics, Gilmore Industries, Cleveland, OH

OBJECTIVE(S): To develop a flange mounted pressure transducer capable of meeting the frequency response and accuracy needed for the Space Shuttle Engine Controller. Reliability and elimination of potential leak problems will be a prime consideration in the development.

APPROACH: A development has been initiated for pressure transducers capable of meeting the environmental restraints of the Shuttle engine preburner and cryogenic pressure measurement. The transducer will be low level strain gage type capable of interfacing with the engine controller. The most logical transduction technique, at this time, appears to be strain gage. The contracts awarded represent four different strain gage approaches: conventional, bonded, deposited film, and piezo resistive.

STATUS: Technical Progress - Composite requirements for flange mounted preburner and cryogenic pressure transducers have been developed based on information

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Final Report NAS8-27743		Gilmore Industries	
Final Report NAS8-277445		Statham Instruments	

FIRST BENEFITTING PROJECT: Space Shuttle

PROGRESS REPORT
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STATUS (CONCLUDED): Technical Progress - available from the three engine Phase B contractors and MSFC engine working groups. Preliminary design reviews were performed and approved September 9, 1971.
Phase II of the Scope of Work on all contracts has been completed and contractors advised to proceed to Phase III.
Management Progress - As of October 1, 1973, Statham Instruments, Inc. and Gilmore Industries, Inc. have delivered hardware and final reports.
Consolidated Controls and Conrac, Inc. have been granted additional time to complete hardware and final reports. Hardware will be delivered by Jan. 1, 1974.
Conclusions - Some additional time may be required to complete prototype transducers.
Forecast - The current effort will result in prototype transducers which will allow an evaluation to be conducted for the purpose of defining final unit development.
This task is no longer an SRT task and is being funded under the engine program.
This will be the final report.

OFFICE OF TRACKING AND DATA ACQUISITION

PROGRESS REPORT
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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 30 09 73	150-22-01	150-22-01

4. TITLE:

AM Baseband Telemetry for Vibration and Acoustic Data

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IT F. H. Emens	453-4624	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Investigate ways of adding Wideband Capabilities to a GFP demultiplexer
NAS 8-29039 Martin Marietta Corp. Denver, Colo.

Design, Development, Fabrication and delivery of a Linear Modulator Breadboard System.
NAS 8-25987 Martin Marietta Corp. Denver, Colo.

OBJECTIVE: The objective of this program is to complete the development of a ground demultiplexer compatible with newly adopted Inter Range Instrumentation Group (IRIG) Standards (106-71 Jan. 1971 Revision) for AM baseband frequency - Division Multiplexer Telemetry Systems.

APPROACH: The airborne multiplexer and the Ground Demultiplexer originally contained provision for data bandwidths of 2 KHz maximum. The necessary electronics to increase the data bandwidth capability to a maximum of 16 KHz are to be designed and incorporated into both units. Then the two will be tested as a system.

STATUS: Technical Progress - All system modifications have been completed and the contractor has completed all system tests. Both units were tested individually and as a system. The system was able to process data signals up to 16 KHz. Although the system had a slightly higher noise level for quadrature double sideband signals than the design goal it was apparent that this could have been eliminated if more effort

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Progress Report	J. E. Goodwin	Monthly for each contract
MCR-73-92	Adding wideband capability to an AM Baseband Demultiplexer Final Report	J. E. Goodwin	May 1, 1973

FIRST BENEFITTING PROJECT: Shuttle

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RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

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could have been spent but this was not possible within the scope of the work.
Conclusion - Based upon test results conducted by the contractor it is apparent that a Wideband single sideband, double sideband, and quadrature double sideband system that conforms to IRIG standards (see above) is well within the present state-of-the-art.
Problems - Manpower limitations have prevented the extensive testing for compliance to all IRIG standards. However all tests conducted at MSFC indicated that the overall results of this effort were highly successful.
Forecast - No further effort presently planned in this area. It is assumed that this report closes out reporting on this line of Research and Technology investigations.

PROGRESS REPORT
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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 150-22-04	PRIOR NO.:

4. TITLE:

Unmanned Spacecraft Communications Systems

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. O. Lowrey	205-453-1578	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Task: Parametric Analyses for TDRSS Relay Compatibility

Objective: To investigate the feasibility of utilizing the TDRSS system as a relay medium for tracking and data communications for unmanned user spacecraft. The unmanned TUG spacecraft and High Energy Astronomical Observatory will be modeled as potential users of TDRSS. The HEAO offers the potential of a fully automated spacecraft requiring high data rates in real time. Design goals will be determined for both TUG and HEAO communications and tracking systems operating through a TDRSS. The feasibility of using the HEAO as a test user spacecraft through TDRSS will be determined. The applicability of the study results to other TDRSS user spacecraft will be evaluated.

Approach: The task will accomplish the desired objective through both analytical and experimental studies with emphasis on the utilization of in-house personnel and facilities. The effort will be concentrated primarily in the areas of antenna pointing and tracking, polarization diversity, multipaths, modulation concepts, and a theoretical system paper design. Close liaison and coordination will be maintained with the GSFC personnel responsible for the current TDRSS program. A large amount of laboratory experimentation and antenna range testing will be utilized to test the validity of theoretical and analytical results at frequencies compatible with the TDRSS systems.

Status: Technical Progress --- A 14 GH_2 degenerate parametric converter and amplifier was fabricated and tested. Modifications in design and operating technique were made and fabrication of the

(Continued)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
	Procedure for Factoring the Effects of Spread Spectrum Techniques Into Power Budget Calculations for TDRSS — User Links	Weathers, Glenn	May 25, 1973
	Monthly Progress Reports		

FIRST BENEFITTING PROJECT: TUG/SORTIE/HEAO

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 150-22-04 PAGE 2 OF 2

Status: (Continued)

improved circuit was made on polyolifin substrate.

The converter and mixer circuits were set up and the circuits were successfully gold plated. Varactor diodes were received which will permit further performance evaluation.

Another circuit was fabricated on duroid substrate. Schottky barrier beam lead diodes have been bonded to the microstrip. The circuit has not been tested. Necessary noise sources have been received to permit noise figure measurement of the devices.

Orbital parameter and spread spectrum analyses have continued during this period. Trade studies have been concluded due to cancellation of a task agreement to perform work on this effort.

Management Progress --- None

Conclusions --- Due to lack of Task Agreement and RTOP authority, work on this effort is being terminated under RTOP 150-22-04. This will be the final report under the RTOP title and code.

Problems --- None

Cause of Problems --- None

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		CURRENT NO.:	PRIOR NO.:
Marshall Space Flight Center	01-04-73 to 30 09 73	310-20-05	150-22

4. TITLE:

Fifty Megabit/Second Data Transmission Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-ASTR-IT F. H. Emens	453-4624	O. T. Duggan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE: The objective of this RTOP is to identify the problems involved in implementing and operating a 50 megabit/second digital data transmission system for typical earth orbital applications and to determine and verify solutions to these problems. Specific objectives include identifying the requirements of planned missions, evaluating the present state of data transmission capabilities, identifying areas requiring further development of technology, and pursuing the development of technology required.

APPROACH: The elements of a 50 megabits/second data transmission system will be assembled as a test bed for experimental investigation. Close coordination of the effort under this RTOP will be maintained with the concept verification testing (CVT) program to minimize costs and maximize benefits to be achieved. Efforts accomplished under this RTOP will include both analytical and experimental studies as appropriate for accomplishment of the objectives. The data requirement of proposed experiments which appear likely to place maximum loads on transmission facilities will be examined to determine a realistic data model for the experimental system. This examination will include considerations of data compression, sampling efficiency, and other factors that may influence the actual data to be transmitted. Digital modulation waveforms, data formats, coding and similar design alternatives will be studied and evaluated to derive the nearest optimum system design approaches. Several signal reception techniques will be evaluated which show promise in improving the performance of communication links under marginal conditions. Techniques now under development for determining the end-to-end performance of data systems will be further advanced and used to evaluate the merit of various alternatives in system design by determining their effect on overall system performance.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None this period			

FIRST BENEFITING PROJECT: Sortie Lab

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 310-20-05
	PAGE 2 OF 2

STATUS: No funds have been allocated for this task since FY 72 and in-house manpower authorizations have been reduced to a minimum since 04 73. For these reasons much of the proposed activity either will not be carried out or will be modified to more directly support the Sortie Lab and CVT programs and performed as program support. Two contracts remain in force for which modifications were funded in FY 72 under 150-22-03, "Mission Spacecraft Compatibility with TDRSS", which was the precursor to this RTOP. The period of performance for both contracts has been extended and work stretched out because of the need to defer costing from FY 73.

Contract NAS8-20765 with Auburn University will expire in March 1974. A draft report has been received on a detailed study comparing the use of general purpose computer and special purpose devices for performing several adaptive data compression algorithms. The conclusion is that special purpose hardware is the most cost effective unless surplus capacity is available in a general purpose computer whose size and speed are justified by some other peak computation requirement. Publication of the report will occur in October or November 1973. The remainder of the contract period will be spent in testing and analyzing the performance of a system for suppressing "FM clicks" and a report published.

Contract NAS8-20172 with University of Alabama will expire in June 1974. Work is resuming on two tasks which have been deferred for several months. The contractor has developed techniques for designing digital filters for pulse shaping and equalization (The Use of Linear Programming Techniques to Design Optimal Digital Filters for Pulse Shaping and Channel Equalization - University of Alabama Technical Report number 142-102-April 1972) and will investigate the possibility of extending the techniques to adaptive equalizers. Time and resources permitting, the contractor will investigate the possibility of removing some of the present design limitations to include an energy optimization algorithm, complex valued coefficients for the frequency sampling filter, and application to other forms of recursive digital filters which do not have finite duration impulse responses.

A paper has been prepared covering in house work on the realization of PSK demodulators of the IQ (or Costas) type operating at S-Band frequencies. This paper "A Binary PSK Demodulator Operating at S-Band" (thesis by Edmund H. Gleason) will be completed within the next three months.

It is not anticipated that any further work other than nominal interaction with the two abovementioned contracts will be performed under this unfunded RTOP. The report mentioned will be available through the appropriate data dissemination channels. It is assumed that this report closes out reporting on this line of Research and Technology investigations.

OFFICE OF APPLICATIONS

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01-04-73 - 30-09-73	CURRENT NO.: 161-80-01*	PRIOR NO.:

4. TITLE:

Solar Energy for Residential Heating and Cooling

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Georg von Tiesenhausen	453-2789	Herman P. Gierow

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Solar Residential Heating and Cooling Engineering Demonstration.

OBJECTIVE: To demonstrate a complete solar thermal conversion system, energy storage system, solar powered air conditioning system, hot water system, and automatic control system for residential application. To provide data base for further developments.

APPROACH: After a complete systems and thermal analysis manufacture and assembly of solar collector modules using MSFC developed selective absorber coating process and Tedlar/Wire bonded transparent cover. Build 1500 ft^2 of collector area located on a roof structure. Three house trailers to provide the thermal load. Modification of 3-ton ARKLA absorbtion cycle air conditioner for cooling. Provision of energy storage system for a three day demand (10^6 BTU). Provide for fully automatic operation of total system. Scheduled demonstration in June 1974.

STATUS: Project is on schedule. Component testing revealed no technical difficulties at this time. Procurements and obligations proceed as planned.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC D 306275	The Development of A Residential Heating and Cooling System Using NASA Derived Technology	O'Neill McDanal Sims	Nov. 72

* Follow-on effort to 908-51-02.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
		CURRENT NO.:	PRIOR NO.:
MSFC	01-04-73 to 30-09-73	175-21-71	160-44-58

4. TITLE:

Climatological-Statistical Atmospheric and Cloud Cover Models

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YT Dale L. Johnson	205-453-3141	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Four-Dimensional Atmospheric Model (World-Wide)Study
NAS8-28720, Environmental Research & Technology, Inc.
429 Marrett Rd., Lexington, MA 02173.
McDonnell Douglas Contract 29663, McDonnell Douglas Corp., Huntington Beach, CA 92647

OBJECTIVE: To compile monthly mean and daily standard deviation values of atmospheric pressure, density, temperature, and moisture from 0 to 25 km altitude on a global basis; to develop techniques and procedures to permit use of these data in computer mission simulations, and to develop techniques to combine the cloud and 4-D attenuation models, with a view toward developing simulation programs to predict not only cloud cover but also signal attenuation. This will aid in determining the atmospheric attenuation affects on electromagnetic sensors used in earth oriented space missions. The atmospheric parameters can produce severe distortion of earth resources signatures obtained from various sensors. In addition to being necessary to instrument design studies, these data will be used in computer simulation studies of earth resources experiments and will form the basis for calculating the electromagnetic program through the atmosphere.

APPROACH: Task 4: Continue to improve and expand the 4-D model by extending the data base to approximately 50 km altitude and by incorporating wind statistics. Develop techniques and procedures to permit use of these data in computer mission simulations. Examine the feasibility of combining the 4-D output with the cloud model to produce atmospheric attenuation results applicable to a wide variety of sensors.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-61362	"Development of Four-Dimensional Atmospheric Models (World Wide)"	D.B. Spiegler & J.R. Greaves	Aug. 1971
NASA CR-2082	"Four-Dimensional World-Wide Atmospheric Models (Surface to 25 Km Altitude)"	D.B. Spiegler & M.G. Fowler	July 1972
NASA CR-129007	"Use of 4-D Atmospheric Models in the Simulation of Radiometric Measurements"	D.T. Chang & M.G. Fowler	July 1973

FIRST BENEFITTING PROJECT: Sortie Lab

PROGRESS REPORT
RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 175-21-71

STATUS: Technical Progress: The first 3 tasks of the 4-D project, under NASA contracts NAS8-25618, NAS8-26928 and NAS8-28720 have been completed and are documented as NASA CR-61362, NASA CR-2082 and NASA CR-129007 respectively. These 3 tasks included the assembling and computerizing of the atmospheric data base and construction of the global 4-D model by homogeneous regions. Improvement and expansion of the model followed, involving atmospheric profile extraction ability for any arbitrary latitude/longitude point on the globe. Comparing the effects of the 4-D model with standard models in the calculation of expected radiometric values began. Task 4 has not been started.

Management Progress: Completion date for contract effort NAS8-28720 was June 18, 1973.

Conclusions: The 4-D model has developed as planned. Comparison of this model, with other standard atmospheric models has been started.

Problems: None.

Forecast: A body of world-wide atmospheric statistics and an operational computer program for extraction of these data are presently available. These 4-D atmospheric statistics can be used in space vehicle trajectory and heating studies, as well as in earth resources (sensor design, attenuation, etc.) problems. Expanding the model in altitude, adding wind statistics, and combining with the cloud model would be the next logical step of development.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	175-21-71	160-44-58

4. TITLE:

Climatological-Statistical Atmospheric and Cloud Cover Models

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
P.A.L. Paul A. Larsen, S&E-AERO-YE	205/453-2897	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Atmospheric Effects on Remote Sensing of Non-Uniform Temperature Sources
Contract No. NAS8-28722 University of South Alabama
Mobile, Ala. 36688

OBJECTIVE: Conduct an analytical investigation of the effects of the atmosphere on the transfer and sensing of electromagnetic energy, considering a non-uniform earth surface temperature.

APPROACH: Basic problem formulation is to be valid for all wavelengths. Parameters to be included in the analysis, insofar as possible, will be wavelength, temperature, pressure, gas concentrations vs altitude, and presence of dust, smoke, and clouds.

STATUS: Technical Progress--Solutions of the plane-parallel, scattering atmosphere model, with a point-source of energy on the lower bounding surface, indicate that a sensor operation in or above the earth's atmosphere will detect energy originating from a target on the ground, even though the target is not in the sensor field of view.

Conclusions: Results to date have been largely analytical, thereby providing a good base upon which to expand the subsequent parts of the investigation.

Problems: None.

Forecast: Project will be extended and efforts will be directed toward trying to incorporate the effects of emission and absorption by the atmosphere.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-129004	Atmospheric Effects on Remote Sensing of Non-Uniform Temperature Sources	W. A. McNeill, J. M. Elliott, & B. P. Dixon	May 22, 1973

FIRST BENEFITTING PROJECT: Spacelab (Earth Observational Payloads)

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 175-21-71	PRIOR NO.: 160-44-58

4. TITLE:

Climatological-Statistical Atmospheric and Cloud Cover Models

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YT S. Clark Brown	205 453-3141	W. W. Vaughan, S&E-AERO-Y

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: World-Wide Cloud Cover Model
Contract No NAS8-28721, Environmental Research & Technology, Inc.

OBJECTIVE: To develop a statistical cloud model incorporating data on cloud amount, type, thickness, and composition. Because clouds will adversely affect many earth oriented space missions, the cloud model will find application in mission simulations to determine the feasibility of and support requirements for proposed earth resources experiments. The model must be designed for computer simulations. Flexible enough to apply to a variety of missions, it must predict not only cloud amounts but also cloud characteristics.

APPROACH: Continue to improve and expand the cloud model by adding cloud type information to the cloud amount data. Develop a means of adjusting the current simulation output as a function of the raito of the cloud size to the sensor resolution size. Develop cloud type frequency distributions for each homogeneous cloud region. Develop a statistical model to correlate cloud type, thickness, water content, and water drop size. Investigate the problems of adjusting cloud cover statistics derived from satellite photographs to correspond more to statistics derived from ground observations.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
15 Monthly Progress Reports giving informal details of current activities and future plans. Draft of interim report covering 12 months effort was submitted in August 1973.			

FIRST BENEFITTING PROJECT: Sortie Lab

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CURRENT NO./CODE: 175-21-71

STATUS: Technical Progress: Evaluation of the homogeneous cloud regions resulted in the creation of a new region in S. W. United States and revised statistics for several other regions. Cloud liquid water content measurements taken from aircraft and concurrent meteorological satellite flights have resulted in over 1,000 cases suitable for analysis of cloud microstructure.

Conclusions: The results indicate definite similarities between stations in the same homogeneous cloud region and systematic differences between summer and winter. Some cloud regions required data and boundary changes.

Problems: None.

Forecast: A body of world-wide cloud cover statistics and operational computer programs to analyze these data are presently available. The improved cloud cover statistics, the streamlined utilization techniques, and the inclusion of a cloud type model will enhance the utility of the cloud data in mission analysis of earth viewing space missions. The close cooperation of this work with NASA Hq., GSFC, and other MSFC units will insure widest application of the end product.

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MSFC	01-04-73 to 30-09-73	CURRENT NO.: 175-61-71	PRIOR NO.: 160-44-69

4. TITLE:

Interrelationships Between Atmospheric Motions of Different Scales

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Robert E. Turner RT S&E-AERO-YE	(205)-453-3109	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Interrelationships Between Atmospheric Motions of Different Scales
Contract No. NAS8-26751, Texas A&M University, College Station, Texas.

OBJECTIVE(S): The objectives of this effort are (1) to analyze the AVE-I data (Atmospheric Variability Experiment I) and present in a tabular form, (2) to investigate the relationship that exists between mesoscale meteorological phenomena and large-scale averages of the same phenomena, (3) to determine the value of an AVE II experiment, and (4) to determine the use of an AVE II experiment in the SMS project evaluation.

APPROACH: To enhance the applicability of mesoscale analyses, the AVE I data will be documented for use by other research groups. Selected cases of AVE I will be studied to investigate the relationships between mesoscale and larger-scale averages meteorological related phenomena. This relationship will involve parameters such as cloud cover, thunderstorms, precipitation, maximum surface temperature and minimum surface temperature, and the gradients of pressure and temperature. The information obtained above will be used to determine an AVE II experiment for comparative measurements and analysis of satellite and ground-based atmospheric measurements to establish applicability of satellite data from such satellite projects as SMS, Nimbus, NOAA-2, for sensing and predictions.

STATUS: (Continued on following page)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA TMX-	Data for First NASA Atmospheric Variability Experiment (AVE I); Data Tabulation	Scoggins, J.R. Smith, O. E.	
NASA TMX-	Data for First NASA Atmospheric Variability Experiment (AVE I): Graphical Presentation of Data	Scoggins, J.R. Smith, O.E.	

FIRST BENEFITTING PROJECT: SMS

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RESEARCH AND TECHNOLOGY OPERATING PLAN
(Continuation Sheet)

CURRENT NO./CODE: 175-61-71

STATUS: (Cont'd)

Technical Progress: The AVE I data analysis was completed this period and published as a NASA Report.

Management Progress: A meeting was held at MSFC in June to select an Operating Plan for AVE II. The meeting coordinator presented four workable plans for conducting AVE II with the determining factor being cost and the extent of cooperation NOAA will participate in the experiment.

Conclusions: The AVE II project will be conducted with MSFC being the focal point of the coordination effort between NOAA and NASA. The experiment is scheduled for March-April 1974.

Problems: None

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
Marshall Space Flight Center .	01 04 73 - 30 09 73	CURRENT NO.: 177-32-71	PRIOR NO.: 160-75-99

4. TITLE:

Remote Sensing Data Management and Interpretation Techniques for Earth Resources Survey

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Messer, C. W.	(205) 453-1619	

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Most of the basic data covering the Jetplex test site which are necessary to support this effort has been obtained. This data consists of ERTS imagery, multispectral aerial photography - high altitude (60,000 ft) as well as low altitude (12,000 ft) and some ground truth surveys. The algorithms to process this data have already been developed and are being applied to the classification analysis phase. Criteria are being developed both to match algorithms to specific sub-functions and to establish the performance measures to be used for comparing such techniques as the composite sequential and K-Means Clustering Technique with more standard approaches using non-parametric supervised methods.

Although curtailment in funding has essentially eliminated hardware purchases and supporting contracts to develop components for the parallel optical processing system, a small level of effort is being maintained and centers around design trade-off studies and software interfacing.

Near term activities call for the completion of the classification computer runs and development of the evaluation criteria. Later effort will be pointed towards the actual performance comparison of all the techniques including less automated methods.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR-2213	Digital Processing of Radiographic Images	A.D. Bond and H. K. Ramapriyan	April 1973
CSC Rpt. 736014-1	Experiments in Computer Analysis of Multiband Aerial Photography	A.D. Bond and H. J. Atkinson	December 1972

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Marshall Space Flight Center	01 04 73 - 30 09 73	CURRENT NO.: 177-51-71	PRIOR NO.: 160-75-15

4. TITLE:
Remote Sensing of Vegetation and Wildland Resource Stresses

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Derington, J. C.	205-453-2143	

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Based on a previous demonstration project on the remote sensing of nematode and pH stress in tomatoes, a proposal was received and a contract let with the Auburn University Cooperative Extension Service for a 2 year study of the detection of soil acidity and nematode stress in cotton, peanuts, and tomatoes through the use of multispectral aerial photography. Seven small test sites in Alabama were identified by the Extension Service. Four-band multispectral photographic data was acquired by the MSFC leased aircraft in Sept. 73. Detailed ground truth data was acquired by Extension Service personnel. This data will be studied preparatory to defining the test program for next spring.

A data gathering flight over the University of Geogia test sites was planned for late summer in a continuation of crop stress studies begun last year, but unfavorable weather prevented the flight until after harvesting had begun. Further action on this project will be deferred until next year.

Study of the peach tree decline in Georgia by remote sensing continued, with data collection flights taking place in May and Oct., 1973. False color infrared photography was acquired over sites selected by researchers at the U.S.D.A. Research Station at Byron, Georgia. This data is being analyzed and correlated with ground truth data by the Station personnel. In addition,the data is being used by Georgia researchers in a study of the capability of automatic interpretation techniques for the pre- and post-visual detection of peach tree decline. A JSC aircraft flight to acquire low altitude, 24 channel multispectral scanner digital data in support of this effort has been requested.

A limited amount of multispectral and false-color IR photography has been acquired in support of a project to demonstrate classification of forest cover types. This data is being analyzed and compared to available RB-57 and U-2 aircraft data by investigators at MSFC and Alabama A&M University.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

MSFC - Form 350 (March 1973)

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Marshall Space Flight Center	Apr.1,1973-Sept. 30, 1973	CURRENT NO.: 177-52-71	PRIOR NO.: 160-75-07

4. TITLE:
Land-Use Mapping for Resource Management

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. T. Paludan	205-453-2142	

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

A. User Liaison. The needs of the Alabama Development Office (Office of the Governor) were defined, and an Alabama Land Use Classification System published. Land-use information derived from ERTS-1 imagery was produced for over 1/3 of the state and coded into one-kilometer square cells in the UTM projection. Further experimental maps were published by TVA, using NASA-advised classification and NASA data. The Tennessee State Planning Office also began land-use mapping, using NASA techniques and data. Land-use studies were initiated with the Tennessee-Tombigbee Waterway Development Authority. Liaison continued with the Commission on World Land Use Survey of the International Geographical Union.

B. Automated Classification. Unsupervised automated classification produced printout maps which formed the basis for selection of training sets. It is expected that this will lead to more efficient supervised classification, and permit imposition of the selected standard land-use classification system. This has been tested at the Jetplex Test Site in North Alabama. Further tests are planned for the Atlanta region, using ERTS-1 data.

C. Automated Retrieval. A teletype terminal has been installed at the Alabama Development Office in the state capitol. This permits tabulation of land-use information upon request. Near-term plans call for addition of a graphic display to permit map-type projection.

D. Other. Activity of NASA Summer Fellow Robert Honea included modeling of the land-use decision process--an investigation of why a particular use was selected for a particular site. A study for MSFC by the University of Denver included assessment of urban land use. These studies are covered in reports outlined in Section 7.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
(No Number)	"Land Use Development Processes: A Conjectural Model Employing Sequent Aerial Photography"	Robert B. Honea	August 10, 1973
ALA-ADO-X996-1020-02	Planner's Mapping and Classification Guide (Revised June 1973)	Alabama Development Office	September 1973
S&E-AERO-YF-1-73	"Automated Computer Program Description for Analysis of Earth Observation Data"	Robert R. Jayroe	June 21, 1973
TR-73-1	An Evaluation of the Usefulness of Remote Sensing Techniques in Making Environmental Quality Determinations	Howard, Herold, Driscoll, and LaPerriere	August 1973

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E. Problems. The USGS/NASA Proposed Standard Land-Use Classification System will soon under-go needed revisions. This will necessitate some minor revisions in our automated classification activity. A shortage of travel funds has hampered some user liaison activities.

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		CURRENT NO.:	PRIOR NO.:
Marshall Space Flight Center	April 1, 1973 - Sept. 30, 1973	177-53-71	160-75-10

4. TITLE:

Remote Sensing for Geological Resources Survey

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Bensko, J.	453-0187	

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Preliminary field work was carried out during August. Two contracts to the University of Alabama at Tuscaloosa were initiated on July 1st. High altitude photography and ERTS photography were examined over one test site. Low altitude photography over two other sites is expected during October.

Objectives of one of the university-MSFC studies is to determine the feasibility of utilizing satellites for the detection of geologic hazards. A second project is to relate satellite remote sensing of land and water pollution from several types of strip mining and to study the immediate and long term effects of surface mining activity.

ERTS photographs were studied to select a site where large scale non-contour stripping is current whereas other sites were chosen on the basis of ground studies.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

Annual reports due July 1974.

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 - 30 09 73	177-54-71	160-75-86

4. TITLE:

Investigations of the Hydrologic Cycle and Large Scale Hydrologic Systems

RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Herman G. Hamby	453-0889	

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

The major effort during this period was the planning of an integrated program leading toward early demonstration systems. These early systems have as their primary criteria the application of remote sensing instrumentation and techniques.

The following efforts are underway or in the early contractual phase:

- Watershed Modeling from Remotely Sensed Data: The work completed during this interval includes:
  (1) The complete compilation of data tapes for 35 TVA Watersheds.
  (2) The calibration of a selected set of these Watersheds.
  (3) The performance of a preliminary sensitivity analsysis.
  (4) The beginning effort to correlate optimum model parameters as discernable using remote sensing for observable characterisitcs of a sub-set of these TVA Watersheds.

- Three-Dimensional River and Estuary Modeling: This effort has just started and has as its primary objective the incorporation of three-dimensional flow field modeling developed by MSFC for rocket plume monitoring into models under development by user agencies with whom the MSFC is jointly cooperating on hydrological cycle and water quality monitoring studies.

- Watershed Modeling by Finite Element Methods for Remote Sensing Applications: This effort is still in the definition stage and will be concerned with using a very powerful mathematical procedure for the detailed description of flows in bays and estuaries.

- The Application of Remote Sensing to the Development and Formulation of Hydrologic Planning Models: This is a proposal that we are presently evaluating for its worth as another utilization of remote sensed data which can assist planners on both a state and national level in the optimum disbursement of resource and material, particularly for new public works, roads, or new cities.

7. Report: IBM No. 73 W-00089

Title: Application of Remote Sensing to Hydrology (A technical progress report)

By: Jack Simmons, IBM Huntsville

Date Transmitted: March 1973

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	179-11	975-90-95-89

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Boese, A.	205-453-1661	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Levitation Processing of Tungsten (179-11-XX-XX)
Contract (To be established - DCN 1-3-65-38033)

OBJECTIVE: The primary objective of this program is the development of containerless process for the preparation of tungsten with improved service characteristics.

APPROACH: A contract will be established to accomplish necessary work to meet the required objectives of this program. This work will include contractual effort to: (1) Investigate improvement of service properties of tungsten. (2) Establish the limitations of ground based levitation heating and melting of tungsten. (3) Supply the necessary knowledge for conceptual development of a space processing experiment to produce tungsten with improved service qualities.

STATUS: Technical Progress: The procurement action was written and forwarded to the Procurement Office.

Management Progress: Funding has been approved for this procurement action.

Conclusions: None

Problems: None

Forecast: Contractual work is scheduled to be completed within twelve months after award of contract.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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MSFC	01 04 73 to 30 09 73	179-11	975-90-95-81

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yates, I. C., Jr.	205-453-1664	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Solidification of Metals Exhibiting Immiscibility in the Solid State(179-11-13-01) NAS8-29725 Washington State University, Pullman, Washington 99163

OBJECTIVE: The objectives of this study are to: (1) conduct solidification studies with the gold-silicon system to determine the effects of varying cooling rates on crystallographic structures and microstructure. (2) perform analyses and develop experiments for the MSFC 300' drop tower and the KC-135 research to show the effects of processing in a low gravity environment. (3) analyze and interpret the results of experiments performed under low gravity conditions and compare them with the results of experiments performed under the influence of earth's gravitational field.

APPROACH: The contractor shall conduct laboratory studies to determine the effects of varying solidification rates on the crystallographic structures and microstructures in gold-silicon alloys; perform analytical and experimental studies to define specimen sizes, containers where applicable, heating, and cooling rates; prepare specimens of gold-silicon alloys of different compositions for processing by MSFC in the drop tower and in the KC-135 research aircraft; and analyze and interpret the processed specimens by using optical microscopy and replica electron microscopy, x-ray diffraction and other techniques.

STATUS: Technical Progress: Contractor is performing work in accordance with their scope of work.

Management Progress: Contract NAS8-29725 was awarded on April 17, 1973 for a twelve month period of performance.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Fifth Monthly Progress Report	"The Solidification Under Zero Gravity Conditions of Binary Alloys Exhibiting Solid State Immiscibility"	R. J. Horylev, A. A. Johnson, R. M. Horton, and S. P. Gupta	September 1, 1973.

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TASK: Solidification of Metals Exhibiting Immiscibility in the Solid State

STATUS: (Continued)

Conclusions: None

Problems: None

Forecast: Contractual work is scheduled to be completed by April 17, 1974.

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		CURRENT NO.:	PRIOR NO.:
MSFC	01 04 73 to 30 09 73	179-11	975-90-95-47

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yates, I. C., Jr.	205-453-1664	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Process Development for Immiscible Materials and Alloys (179-11-14-01)
NAS8-28267 TRW Systems Group, TRW Inc., Redondo Beach, CA 90278

OBJECTIVE: The primary objective of this effort is to develop techniques for processing immiscible systems in space and to define process and equipment requirements for space experiments.

APPROACH: This effort will be performed in two phases: Phase I will include studies to define parameters for processing immiscible materials in a low gravity environment; evaluate mixing techniques and devices to obtain complete dispersion of immiscible materials; evaluate techniques and devices to melt the immiscible materials, bring them up to temperature, and to control cooling so as to maintain a homogeneous density distribution upon solidification; and design and build experiments to verify processes on a sub-scale and test system components or models in short duration, low gravity tests. Phase II will continue the above work and will include studies to select immiscible systems suitable for experimental investigations in low gravity research facilities; perform analyses and evaluate processing techniques; and design and develop short duration low gravity experiments to evaluate processing techniques and material properties.

STATUS: Technical Progress: Cooling experiments were conducted on instrumented Bi-Ga cartridges. Based on the results, six experimental heater packages/cartridges with reduced orifices were prepared and shipped to MSFC. An acoustic mixer has been fabricated and successfully tested. Fabrication was initiated on an electromagnetic mixer. Other work continued as planned.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Interim Report	14725-6010-RU-00, "Study on Processing Immiscible Materials in Zero Gravity"	J. L. Reger	May 1973. (For the period 27 April 1972 to 30 April 1973)
Monthly Progress Report No. 11	14725-6013-RU-00, "Study on Processing Immiscible Materials in Zero Gravity"	J. L. Reger	18 September 1973.

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TASK: Process Development for Immiscible Materials and Alloys

STATUS: (Continued)

Management Progress: After completing twelve months of work, Contract NAS8-28267 was amended on 30 April 1973 by expanding the Scope of Work (Phase II added), extending the period of performance to 30 June 1974, and increasing the contract amount.

Conclusions: Several tentative conclusions were noted by the contractor and included the statements that stable dispersions of zinc in lead were successfully produced by direct thermal processing in the MSFC drop tower; the variation of the cooling rates of the Pb-Zn specimens did not appear to have as large an effect as the Bi-Ga system, although no data was obtained on Specimen 12 for complete correlation; all of the specimens containing the additive (patented chemical compounds) tended toward a more uniform structure than the "pure" alloy compositions; remelt seemed to improve the homogeneity of the dispersion; free convection cooling was somewhat faster than anticipated; the NASA supplied sample appeared to be within the 60/40 w/o Cu/Pb compositional range in comparison with the TRW processed specimens; and it would appear that as the amount of lead in the specimen is increased, the amount of additive should be proportionately larger.

Problems: Considerable difficulty was encountered by the contractor in obtaining standard lighting for all specimens due to the polished condition of the copper.

Forecast: Contractual work should be completed on 30 June 1974.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01 04 73 to 30 09 73	179-11	975-90-95-84

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yates, I. C., Jr.	205-453-1664	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Immiscible Materials Selection (179-11-14-03)
NAS8-29748 Battelle Memorial Institute, Columbus Laboratories, Columbus, OH 43201

OBJECTIVE: The primary objective of this effort is to investigate immiscible materials systems and their potential applications.

APPROACH: The contractor shall conduct studies to develop theoretical relationships and experimental techniques for determining behavior of immiscible systems in a low gravity environment; perform experimental studies including tests in the MSFC drop tower to check out the theories and provide data on effects of low-g on processing immiscible materials; evaluate techniques for synthesizing mixtures of immiscible systems for characterization and assessment of technological potential; and select candidate immiscible systems having the highest potential for each product area.

STATUS: Technical Progress: Contractor is performing work in accordance with the contractual scope of work.

Management Progress: Contract NAS8-29748 was awarded on 28 June 1973 for a fourteen month period of performance.

Conclusions: None - New Contract

Problems: None

Forecast: Contractual work is scheduled to be completed by 28 August 1974.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Third Monthly Progress Report	"Investigation of Immiscible Systems and Potential Applications"	A. J. Markworth and S. H. Gelles	September 10, 1973.

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN		PAGE 1 OF 2	
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MSFC	01 04 73 to 30 09 73	179-11	975-90-95-52

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Berge, L. H.	205-453-1661	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Metal Drop Solidification in Zero-G (179-11-15-02)
NAS8-28604 Grumman Aerospace Corporation, Bethpage, L.I., NY 11714

OBJECTIVE: The primary objective of this task is to demonstrate that unique alloys with superior qualities can be obtain by achieving large undercooling through nucleation control during solidification.

APPROACH: This effort is being performed in two phases: Phase I (Basic Contract) produced drop tower hardware and evaluated specimens solidified during free fall in a drop tower. Phase II (Modification 4 to Contract) will modify the hardware to improve the control and measurement of parameters affecting undercooling through nucleation control. The Phase II effort will include (1) redesign and modification of experiment hardware, (2) selection of materials to demonstrate supercooling and surface evaporation in drop tower tests and (3) drop tower tests and specimen evaluation.

STATUS: Technical Progress: Direct resistance melting of wire specimens has proven to be an effective method to prepare molten metal specimens for limited time zero-g processing. Lack of process control of super heat, cooling rate and accurate temperature measurement reduced supporting process data. Modification 4 to the contract will improve hardware to include lower vacuum, larger specimen size and uniform heating. However, the shadow grains found on several specimens are indicative of the hexagonal grains sought in the Statement of Work.

Management Progress: Contract NAS8-28604 was awarded on June 14, 1972. Modification 4 was awarded on August 2, 1973 for eight more months of performance.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Report No. 11 (NAS8-28604)	"Research of Metal Solidification in Zero-G State"	William M. Aubin	May 1973.

Final Report (Interim Report-NAS8-28604), RE-463, "Research of Metal Solidification in Zero-G State", William M. Aubin, Dave Larson, Jr., & Gary I. Geschwind, September 1973.

Monthly Progress Report No. 1 (NAS8-28604 Mod. 4), "Drop Packages for Metal Solidification in Zero-G State", David J. Larson, Jr., September 1973.

Paper to be presented in November 1973 at the NASA/AIAA 7th Space Simulation Conference in Los Angeles, "Sphere Forming in Zero Gravity", W. Aubin, D. Larson, Jr., G. Busch and G. Geschwind.

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(Continuation Sheet)

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TASK: Metal Drop Solidification in Zero-G

STATUS: (Continued)

Conclusions: A vacuum of 1×10^{-4} torr in the chamber is necessary to assure sphere formation associated with evaporative cooling. A duplex structure in which a thin shell of material solidifies first, followed by an apparent simultaneous nucleation of the rest of the volume leaving a uniform distribution of small voids was observed. Samples with the highest degree of sphericity invariably exhibited an equiaxed surface grain morphology. These grains were not always representative of the interior grain structure. That is, they were not always carried through into the interior, and sometimes the interior grain structure could be seen in addition to the equiaxed surface morphology.

Problems: The contractor reported that the melting process has introduced more forces one the specimen than was originally anticipated. The forces seem to be primarily due to an elongation in the wire specimen just prior to unduloid formation. Since they have no way of controlling specimen motion after the droplets are formed, it becomes very important that the droplets are released with little or no accelerating forces. Careful study of the wire melting process in the laboratory should lead to ways of minimizing these forces.

Forecast: Contractual work is scheduled to be completed by April 2, 1974.

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RESEARCH AND TECHNOLOGY OPERATING PLAN

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MSFC	01 04 73 to 30 09 73	179-11	975-90-95-83

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yates, I. C., Jr.	205-453-1664	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Process Development for Fine-Grain Castings in Space (179-11-15-03)
NAS8-29626 Battelle Columbus Laboratories, Columbus, Ohio 43201

OBJECTIVE: The objective of this program is to develop processes for producing fine-grain castings in the weightless environment of space. The objectives of this initial effort are to (1) develop a data base for evaluating use of power metallurgical techniques and processes to produce fine grain castings or dispersion strengthened materials in space and (2) develop requirements and concepts for space processing of beryllium.

APPROACH: This effort will be performed in two phases: Phase I - Aluminum-aluminum oxide powders will be used as a model system. Laboratory experiments will be performed to select powder sizes and compositions, to determine the heating and cooling conditions for powder compact melting and solidification, and to define furnace characteristics and experimental parameters for the experiments in short duration low gravity test facilities. The first phase will also be concerned with developing the analytical tools for characterizing the structure of the melted powder compacts and the distribution of oxide so that quantitative comparisons may be made between compacts melted in 1 g and low-g environments. Phase II - Experiments will be developed for processing in low gravity test facilities or in research rockets. Sealed capsules containing powder compacts of suitable composition, density, and powder size will be fabricated and supplied to MSFC for low g and 1 g processing. A study will be conducted to compare the grain structure and oxide distribution of the low g and 1 g processed samples.

STATUS: Technical Progress: Contractor is performing work in accordance with their scope of work.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Second Monthly Progress Report, "Process Development for Producing Fine Grain Castings in Space",	S. H. Gelles,	September 10, 1973.	

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 179-11 PAGE 2 OF 2

TASK: Process Development for Fine-Grain Castings in Space

STATUS: (Continued)

Management Progress: Contract NAS8-29626 was awarded on June 29, 1973 to the Battelle Columbus Laboratories for a twelve month period of performance.

Conclusions: None - New Contract

Problems: None

Forecast: Contractual work is scheduled to be completed by June 29, 1974.

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MSFC	01 04 73 to 30 09 73	179-11	975-90-95-33

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yates, I. C., Jr.	205-453-1664	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Development of Techniques for Processing Metal-Metal Oxide Systems (179-11-31-01)
NAS8-29145 Arthur D. Little, Inc., Cambridge, MA 02130

OBJECTIVE: The major objective of this effort is to perform theoretical and experimental investigations to determine effects of processing and materials properties such as wetting and density differences on distribution of particles in systems processed in a weightless environment and to develop techniques for processing metal-metal oxide systems in space.

APPROACH: This effort will be performed in three phases: Phase I - To select model materials and conduct laboratory experiments to determine the effects of material properties such as wettability and density difference and processing techniques on the grain structure and oxide distribution of a metal-metal oxide system. To propose an experiment for studying the effects of processing such systems in a low gravity environment. Phase II - To design ampoules required for the proposed experiment; to provide the metal-metal oxide samples for processing in MSFC low gravity facilities; and to evaluate the results by comparison of the samples processed in low gravity with identical samples processed under 1-g conditions. Phase III - To define follow-on experiments for future opportunities in sounding rockets, a Skylab type facility, Shuttle sortie mission, etc.

STATUS: Technical Progress: Contractor is performing work in accordance with their scope of work. During the month of August, efforts to refine the procedures for obtaining wetting of Pyrex powders by the 50In-50Pb matrix alloy as a liquid was continued.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Tenth Monthly Progress Report, "Development of Techniques for Processing Metal-Metal Oxide Systems", P. C. Johnson, 14 September 1973.			

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 179-11 PAGE 2 OF 2

TASK: Development of Techniques for Processing Metal-Metal Oxide Systems

STATUS: (Continued)

Management Progress: Contract NAS8-29145 was awarded on October 24, 1972 for a fourteen month period of performance.

Conclusions: None

Problems: None

Forecast: Contractual work is scheduled to be completed by December 24, 1973.

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1. CENTER:	2. PERIOD COVERED:	3. CODE	
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MSFC	01 04 73 to 30 09 73	179-11	975-90-95-36

4. TITLE:

Metallurgical Processes (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yates, I. C., Jr.	205-453-1664	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Process Development for Composite Materials Manufacturing in Space (179-11-31-02) NAS8-29620 General Dynamics Corp., Convair Aerospace Div., San Diego, CA 92111

OBJECTIVE: The major objective of this task is to develop processing specifications for preparation of fiber/particle reinforced metal-matrix composites and controlled density metals in space.

APPROACH: This effort will be divided into three tasks: (1) Establish specific materials compositions, processing requirements, and processing techniques for preparation of aluminum-base fiber/particle reinforced composites and controlled density metals in space and produce prototype composites and controlled density metals by processing in zero-g test facilities. (2) Define expected properties that may be attained in space processed composites based on ground based and short duration zero-g experiments. (3) Define applications potential, users, and the technical and/or economic pay-off for specific products.

STATUS: Technical Progress: Contractor is performing work in accordance with the contractual scope of work. The successful development of a new technique for the joining of non-wetting reinforcement materials with liquid aluminum has been reported. In view of the promising results, additional dispersion (mixing) experiments were carried out with the following reinforcement materials: Bare Pyrolytic Graphite Fibers, Chopped Silicone Carbide Filaments and Chopped Alumina (Sapphire) Filaments. Considerable effort was spent on the improvement of the sample preparation facility, particularly the installation of a high-performance vacuum system.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Progress Report #4,	"Space Processing of Composite Materials",	W. H. Steurer and S. Kaye,	September 20, 1973.

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 179-11 PAGE 2 OF 2

TASK: Process Development for Composite Materials Manufacturing in Space

STATUS: (Continued)

Management Progress: Contract NAS8-29620 was awarded on 12 April 1973 for a twelve month period of performance.

Conclusions: None

Problems: None

Forecast: Contractual work is scheduled to be completed by 12 April 1974.

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 179-11-14-02	PRIOR NO.:

4. TITLE:

IMMISCIBLE MATERIALS - GROUND BASED STUDIES

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL
L. Lacy - S&E-SSL-NP	453-5135	R. Decher - S&E-SSL-N

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE(S): This research program will determine the feasibility of producing in space a new class of composite materials for electronic application. The materials are immiscible in the molten state (i.e., the components are mutually insoluable) and separate when mixed together in one-g due to different densities. This effort will consider different techniques for melting and mixing immiscible materials in space and determine the properties and applications of such materials.

APPROACH: The electronic properties of dispersed immiscibles prepared in the laboratory, in the MSFC Droptower and in Skylab are being studied. The physical properties of the materials and their potential applications are being investigated by using electrical, low temperature, magnetic and ultrasonic techniques. The characterization techniques used depend on the particular materials selected and may be used either singularly or in any combination.

STATUS: The initial phases of this work have concentrated on measuring the electrical and superconducting properties of Ga-Bi which was processed in the MSFC Droptower. The results of the initial phase will be presented at the AIAA 12th Aerospace Sciences Meeting on January 1974. The evaluation of the physical properties of AlCu which was processed on SL-3 will be continued, including evaluation of the flight samples. A new non-contacting technique for measuring the electrical resistivity of space processed samples has been developed. This non destructive technique can be used to accurately determine the chemical and metallurgical homogeneity of bulk rods (diameters of 3mm and larger). A science demonstration of the behavior and properties of a melting material in zero-gravity was performed on Skylab III. Another science demonstration concerning

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MISC-SSL-73-2	Immiscible Materials - Ground Based Studies. First Quarterly Progress Report	L.L.Lacy G. H. Otto	Aug 1973

STATUS: Continued

the behavior of immiscible liquids in zero-gravity is planned for Skylab IV.

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MSFC	01 04 73 to 30 09 73	179-11-21-00	

4. TITLE:

ZONE REFINING IN A ZERO-GRAVITY ENVIRONMENT

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. Davidson, S&E-SSL-TR	453-3090	WCS W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract No: Not selected
Contractor Not selected

OBJECTIVE(S): Determine the applicability of float zone solidification techniques in zero gravity for producing improved materials of industrial importance.

APPRAOCH: Study possibilities of increased zone diameter and floating liquid zones having lower surface tension to density ratios due to low-gravity environments. Analyze promising candidate materials with respect to maximum diameters possible, zone stability under rotation, and potential cost savings to the industrial community.

STATUS: In contract negotiations.

FORECAST: Contract by December, 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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MSFC	01 04 73 to 30 09 73	179-12-13-03	

4. TITLE:

CRYSTAL GROWTH BY THE VAPOR PHASE

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. Davidson, S&E-SSL-TR	453-3090	WCS W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract No.: NAS8-26146
Contractor: Rensselaer Polytechnic Institute

OBJECTIVE(S): To determine whether a significant improvement in crystal quality can be expected from vapor growth in a low-gravity environment.

APPROACH: Isolate effects of convective transport on crystal quality from effects of growth rate and static density variations. The degree of convective transport will be varied by adjusting experimental papameters (e.g., temperature, temperature gradient, and vapor pressure).

STATUS: Kinetic studies on the growth of GeSe single crystals are being carried out. The mechanism of sublimination of GeSe has been derived.

FORECAST: Vapor transport experiments on the GeSe and GeTe systems in inert atmospheres are planned in order to separate the effects of the physical and chemical processes on the transport mode and mechanism.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Quarterly progress reports covering the period June 1970 - present.		TITLE: Growth of Single Crystals by Vapor Transport in Zero-Gravity Environment	
Final Reports -		TITLE: Growth of Single Crystals by Vapor Transport in Zero-Gravity Environment	

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MSFC	01 04 73 to 30 09 73	179-12-13-06	

4. TITLE:

ANALYTICS OF CRYSTAL GROWTH

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
T. Bannister, S&E-SSL-TR	453-3090	WCS W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract: NAS8-29847, University of Southern California

OBJECTIVE(S): To analyze mathematically solution crystal growth and float zone crystal growth. Lab work will be performed on an as-required supporting basis.

APPROACH: (1) To develop a set of equations describing each growth system. (2) To solve the set of equations using analytical and computer techniques.

STATUS: (1) Equations are being set up and studied to obtain a soluable set without making unrealistic simplifying assumptions.

FORECAST: (1) Finalize equations. (2) Initiate analytical solutions. (3) Initiate lab work.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
One bimonthly report			

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 179-12-15-01	PRIOR NO.:

4. TITLE:

Space Processing Research on Crystal Growth

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. Davidson, S&E-SSL-TR	205 453-3090	W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract No.: NAS8-29542
Contractor: University of Alabama in Huntsville

Objective: Improve existing techniques and develop new techniques for the analysis of crystalline perfection in order to determine the effects of a low-gravity environment on the growth of crystals.

Approach: Study various techniques for determining crystalline perfection. Photovoltaic effects and photoluminescence will be considered. Noncontacting techniques for measuring high frequency resistivity and mobilities in semiconductors will be studied. An effort will be made to reduce the sample area in order to provide better spatial resolution.

Status: Resistivity and Hall effect measurements have been made on GaAs samples. High frequency resistivity measurements have also been made on GaAs.

Forecast: High frequency resistivity and photoluminescence studies will be continued.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Reports January 1972 - Present		Title: Electrical Characterization of GaAs Single Crystal in Direct Support of M555 Flight Experiment	
Final Report December 1972		Title: Investigation of Crystal Growth in Zero Gravity Environment and Investigation of Metallic Whiskers by: J. H. Davis H. U. Walters R. B. Lal J. G. Castle, Jr.	

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MSFC	01 04 73 to 30 90 73	179-12-15-02	

4. TITLE:

CRYSTAL GROWTH AND CHARACTERIZATION

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. Davidson, S&E-SSL-TR	453-3090	W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract No.: In-house
Contractor: In-house

OBJECTIVE(S): Conduct in-house studies supplementing contractual efforts in solidification and crystal growth.

APPROACH: Examine various crystal growth methods and characterization methods, including X-ray topography, dc resistivity, Hall mobilities, and photovoltaic scanning. Methods selected for study are those which have application to growth of crystals in low gravity and the evaluation of those crystals.

STATUS: Current studies emphasize photovoltaic scanning of semiconductor crystals with the goal of relating photovoltages to crystal quality. Work continues on growth of metal-doped organic single crystals. A vacuum coater has been modified and techniques developed to apply low resistance contact to GaAs. X-ray defect analysis techniques are being used and topographs of Ge single crystals have been made.

FORECAST: Continue study of photovoltaic characterization of semiconductor crystals. Further studies of epitaxial growth techniques for semiconductor crystals will be conducted. An X-ray transmission topography apparatus is being assembled and should be operational shortly.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
MSFC R&T Review	Crystal Growth Studies	C. F. Schafer	Feb 1973

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4. TITLE:

TASK: SOLUTION CRYSTAL GROWTH

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
T. Bannister, S&E-SSL-TR	453-3090	WCS W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

CONTRACT NAS8-28098, University of Alabama at Tuscaloosa

OBJECTIVE(S): (1) To determine the effects of gravity-induced convection on the quality of solution grown crystals, primarily Rochelle salt. (2) To determine the mechanism of metal ion doping in solution grown organic crystals. (3) To define flight experiment on solution crystal growth for rocket flights, Skylab, and Space Lab missions.

APPROACH: (1) To grow crystals from concentrated solutions at varying rates. (2) To characterize the crystals using ferroelectric hysteresis and etching of the crystals. (3) To photograph growth and convection.

STATUS: It has been shown that increased growth rates increase convection and correspondingly cause ferroelectric degradation of Rochelle salt crystals.

FORECAST: (1) To define the nature of metal ion doping. (2) To develop a technique for Skylab IV demonstration.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
UAT 28098-1	Investigation of Crystal Growth from Solutions	I. Miyagawa	Feb 1973

10 bimonthly progress reports

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MSFC	01 04 73 to 30 09 73	179-14	975-90-95-34

4. TITLE:

Glass and Ceramics (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Nichols, R. L.	205-453-2005	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Production of Unique New Glasses in Space - Analytical Studies (179-14-10-01)
NAS8-28991 Rockwell International, Space Division, Downey, CA 90241

OBJECTIVE: The primary objective of this effort is to obtain glass spheres 6 - 8mm in diameter from compositions which do not normally form glasses and to characterize their properties.

APPROACH: Utilizing data obtained from a prior contract, NAS8-28014, the contractor shall select six (6) oxide compositions which appear to be candidate materials for producing glasses during a simulated zero-gravity condition. He shall conduct the experiments required to produce these glasses and analyze the results for percentage of glass obtained. For those samples providing the greatest yield, he shall determine the optical properties obtained in the glass spheres. That compositions considered to give the greatest glass yield shall be selected for further study. Small, but controlled, quantities of an impurity which simulates contamination of the melt by a container material shall be added to the compositions and further tests conducted in a free-fall system to determine the effect of impurities on glass forming ability and glass properties. A study shall be conducted which results in a conceptual design of hardware, monitoring facilities, control mechanisms, and engineering data required for conducting an in-space experiment for producing glasses.

STATUS: Technical Progress: Contractor is performing work in accordance with the contractual scope of work. A wind tunnel air suspension device has been designed, fabricated, and installed at the laser site. Initial tests are being conducted to determine the optimum procedures for suspending the oxides for melting and cooling.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

(Prior Contract NAS8-28014 Final Report, SD72-SA-0083, "Study of the Production of Unique New Glasses", R. A. Happe, 13 June 1972)

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 179-14 PAGE 2 OF 2

TASK: Production of Unique New Glasses in Space - Analytical Studies

STATUS: (Continued)

Management Progress: Contract NAS8-28991 was awarded on 30 April 1973 for a twelve month period of performance.

Conclusions: None - New Contract

Problems: None

Forecast: Contractual work is scheduled to be completed by 30 April 1974.

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MSFC	01 04 73 to 30 09 73	179-14	975-90-95-82

4. TITLE:

Glass and Ceramics (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Nichols, R. L.	205-453-2005	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Theoretical Study of Producing Glasses in Space (179-14-10-02)
NAS8-29850 IIT Research Institute, Chicago, IL 60616

OBJECTIVE: The major objective of this effort is to investigate the theoretical aspects of producing glasses in space and to compare the relative importance of cooling rates and lack of heterogeneous nucleation.

APPROACH: Contractual effort will be utilized for this study. The phenomena which causes a melt to cool into an amorphous state rather than one of polycrystalline structure must be considered carefully during the selection of candidate material systems which are potential glass formers in zero-g. To eliminate excessive laboratory experimentation, a model of the glass forming system shall be developed and applied to processing of glass compositions in the space environment.

STATUS: Technical Progress: Contractor is performing work in accordance with contract.

Management Progress: NAS8-29850 was awarded on 1 July 1973 for twelve months of effort.

Conclusions: None - New Contract

Problems: None

Forecast: Contractual work is scheduled to be completed by 1 July 1974.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Second Monthly Status Report, "Theoretical Study of Producing Unique Glasses in Space", A. Z. Hed, September 10, 1973.			

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4. TITLE:

Glass and Ceramics (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Nichols, R. L.	205-453-2005	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Study of Diffusion Coefficient of Glasses Under Zero-G (179-14-20-02) In-House

OBJECTIVE: The primary objective of this in-house effort is to perform a phenomena investigation of diffusion coefficient in Glasses when processed in zero-g.

APPROACH: This program will consist of the investigation of diffusion rate phenomena in relation to viscosity in glass forming materials. A simple oxide system will be selected for this study. High fidelity viscosity measurements will be established for the system in One-G conditions, thereby relating viscosity to temperature. An in-space experiment for measuring diffusion coefficient in the absence of gravity will be developed. The experiment will consist of the measurement of diffusion coefficients in space and the establishment of a relationship between viscosity in zero-g with that on Earth.

STATUS: Technical Progress: In-house work continues in accordance with project plan.

Management Progress: Funds have been approved for this in-house work.

Conclusions: None - New Task

Problems: None

Forecast: In-house work is expected to continue through FY-75.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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4. TITLE:

Glass and Ceramics (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Nichols, R. L.	205-453-2005	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Processing of Glass-Ceramics in Space (179-14-20-03)
Contract (To be established - DCN 1-4-65-48002)

OBJECTIVES: The objectives of this effort are to study the effects of low gravity processing on Glass-Ceramic compositions with respect to microstructure and mechanical properties and processing techniques and to define process parameters for recrystallization of Glass-Ceramics in a low gravity environment.

APPROACH: The contractor shall conduct a specific program of Earth experiments which will lead to the development of glass-ceramics material having novel composition, microstructure, or properties by processing in space. The program should utilize the unique features of the zero-gravity environment in space which could provide containerless processing, uniform dispersion of phases, and high temperature crystallization without deformation.

STATUS: Technical Progress: A procurement action has been prepared and is ready to be forwarded to the Procurement Office.

Management Progress: Funding has been approved for this procurement action.

Conclusions: None

Problems: None

Forecast: Contract should require twelve months for completion.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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4. TITLE:

Glass and Ceramics (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Nichols, R. L.	205-453-2005	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Processing of Chalcogenide Glasses (179-14-20-04)
Contract (To be established)

OBJECTIVES: The objectives of this effort are to (1) develop experiments for producing chalcogenide glasses in low-g for laser transmission uses and (2) produce and characterize the chalcogenide glasses produced in low-g.

APPROACH: Contractual effort will be utilized for the performance of a specific program to determine processing techniques, designing low-g flight experiments, and conducting experiments and evaluating results.

STATUS: Technical Progress: A procurement action is being prepared.

Management Progress: This program is a new start. Funding has been approved for FY-74.

Conclusion: None

Problems: None

Forecast: Contract should require twelve months for completion.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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4. TITLE:

Physical Processes in Fluids (Materials and Process R&D - RTOP 179-10)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Adams, G. D.	205-453-5084	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Electrohydrodynamic Space Processes (179-15-10-01)
Contract (To be established - DCN 1-4-65-48000)

OBJECTIVE: The major objective of this effort is to develop methods of applying electrohydrodynamic (EHD) phenomena to processing materials in space.

APPROACH: A contract will be established to accomplish necessary work to meet the required objective of this program. This work will include contractual effort to: (1) Study the application of EHD phenomena to space processing. (2) Provide experimental proof of critical phenomena in terrestrial laboratory tests. (3) Establish a detail Experiment Plan for phenomena requiring zero-g environment in order to become effective for specific space processing phases.

STATUS: Technical Progress: The procurement action was processed and proposal has been received for evaluation.

Management Progress: Funding has been approved for FY-74.

Conclusions: None

Problems: None

Forecast: Contractual work is scheduled to be completed within twelve months after award of contract.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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4. TITLE:

CONVECTION ANALYSIS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
T. Bannister, S&E-SSL-TR	205 453-3090	W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract Number: NAS8-29610
Contractor: Lockheed Missile and Space Co.

OBJECTIVE(S): (1) To analyze the effects of low gravity on fluid behavior (heat and mass transfer) as applied to the space processing applications program. (2) To determine the effects of convection induced by surface tension, thermoacoustic expansion, g-jitter, etc., in low gravity. (3) To define flight experiments on convection and diffusion for rocket flights, Skylab, and Spacelab missions.

APPROACH: (1) To develop dimensional analysis techniques on certain fluid problems. (2) To model selected processes on a computer. (3) Initiation of convection criteria for low-g application.

STATUS: (1) Initiated a study on heat transfer due to vibrations. (2) Initiated a study to define criteria for thermoacoustic convection. (3) Initiated a sounding rocket experiment proposal.

FORECAST: (1) Will accomplish criteria for thermoacoustic convection. (2) Will continue sounding rocket work. (3) Will initiate definition of demonstrations for Skylab IV.

7. REPORT NO.: TITLE: AUTHOR(s): DATE TRANSMITTED

NOTE: This is a new contract resulting from the requirement to go RFP for continuation of the convection effort.

The following are reports generated previously which are related to this task:

LMSC-HREC TR D306402	Fluid and Particle Dynamic Effects in Low-g Composite Casting	P. G. Grodzka S. V. Bourgeois	Feb. 1973
LMSC-HREC TR S306350	Types of Natural Convection in Space Manufacturing Processes	P. G. Grodzka	Jan. 1973
LMSC-HREC D306140	A Numerical Solution for Thermoacoustic Convection of Fluids in Low Gravity	L. W. Spradley S. V. Bourgeois C. Fan P. G. Grodzka	Jan. 1973

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Report No.	Title:	Authors:	Date Transmitted
LMSC-HREC TR D306300	Convection Phenomena in Electrophoresis Separation	C. Fan	Dec. 1972
LMSC-HREC D306065	Convection in Space Processing (M512)	S. V. Bourgeois P. G. Grodzka	July 1972
LMSC-HREC D225365	A Study of Natural Convection in Low Gravity Solution Growth of Rochelle Salt Crystals	L. W. Spradley C. Fan	Oct. 1971
LMSC-HREC D225333	The Apollo 14 Heat Flow and Convection Demonstration Experiments - Final Results of Data Analysis	P. G. Grodzka C. Fan R. O. Heddon	Sept. 1971
LMSC-HREC D162926	Natural Convection in Space Manufacturing Processes	P. G. Grodzka C. Fan	July 1971
LMSC-HREC D225149	Mass Diffusion of Gallium Arsenide in a Gallium Solution	P. G. Grodzka C. Fan	June 1971
LMSC-HREC D148619-A	Zero-Gravity Solidification	P. G. Grodzka	Mar. 1970
UAT 28098-1	Investigation of Crystal Growth from Solutions	I. Miyagawa	Feb. 1973
	Heat Flow and Convection Demonstration Experiments Aboard Apollo 17 (Early Results)	T. C. Bannister	Feb. 1973
	Heat Flow and Convection Demonstration Experiments Aboard Apollo 14	T. C. Bannister	May 1972
	Heat Flow and Convection Demonstration (Apollo 14)	T. C. Bannister	July 1971
	Surface Tension Convection During Floating Zone Refining	P. G. Grodzka T. C. Bannister	May 1970
	A Proposed Crystal Growth Program for Space Processing Including Flight Experiments	T. C. Bannister G. M. Arnett	Jan. 1970

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4. TITLE:

SORET SEPARATION IN ZERO GRAVITY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
B. Facemire, S&E-SSL-TR	205 453-3090	WCS W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract Number: NAS8-29609
Contractor: Lockheed/Huntsville and In-House

OBJECTIVE(S): (1) Survey literature for important parameters in Soret separations (a paper will be published). (2) Determine whether Soret separation is influenced by the space environment. (3) Determine whether this process will be significantly improved in the space environment.

APPROACH: (1) Perform literature survey. (2) Since convective patterns play a role in these separations, determine optimum flow for good separations (experimentally and analytically). (3) Determine whether the optimum flow (as determined in (2) above) can be achieved in low-g in such a manner as to improve the process - either larger volumes of purified materials (presently only very small samples may be used - about 4cc - with a yield of about 1/4cc) or by decreasing the power requirements required, possibly both of these). (4) Determine materials which would be advantageously separated by the technique in low-g.

STATUS: (1) Contract with Lockheed was signed June 1, 1973, with subcontract to the University of Texas (to study cell rotation effects on Soret separation). Lockheed start date was delayed until July 1. (2) In-house equipment (and equipment to be GFE to Lockheed) ordered. The required water baths have arrived with delivery date of commercially available Soret equipment to be October 9, 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LMSC-HREC PR D 306730	Bimonthly Progress Report	Grodzka/LMSC	Aug 1973

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FORECAST: During the next reporting period plans include: (1) Complete literature survey. (2) Determine materials for initial investigations. (3) Determine methods for analyzing effectiveness of separations. (4) Install Soret equipment and initiate testing. (5) Development of models (analytical) of convective patterns in Soret geometry and methods of experimentally determining flow and effects on separation.

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4. TITLE:

DIFFUSION ANALYSIS IN LOW GRAVITY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. Schafer, S&E-SSL-TR	453-3090	WCS W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract: None
Contractor: None

OBJECTIVE(S): To determine the degree to which processes associated with a low-gravity environment can be purely diffusion controlled.

APPROACH: Tabulate important parameters affecting mass transport in liquid metals which are candidates for low gravity processing applications. Additionally, measurements will be made on liquid gallium and liquid indium to determine mass diffusion coefficients.

STATUS: RFQ for sole source to Howard University issued 28 Sept. 1973. Response due on or before 24 Oct. 1973.

FORECAST: Contract should be signed by mid-November, 1973. Work will begin immediately thereafter.

7. REPORT NO.:	TITLE:	AUTHOR(S):	DATE TRANSMITTED
None			

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MSFC	01 04 73 to 30 09 73	179-21	975-90-95-80

4. TITLE:

Furnace Systems (Space Processing Equipment Technology - RTOP 179-20)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Aldrich, B. R.	205-453-2010	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Space Processing Furnace System Development (179-21-10-01)
NAS8-29769 ARTCOR, Irvine, CA 92707

OBJECTIVE: The major objective of this task is to develop furnace concepts, fabricate components and test furnace models for space processing facilities to be used on low-g testing facilities. The objective of the first contract will be to design and demonstrate a furnace capable of high temperature with an oxidizing atmosphere.

APPROACH: The contractor shall perform a study of electrically conducting ceramic heating elements for use in high temperature (2200°C) furnaces, design and fabricate a prototype furnace heating element and control system and deliver the prototype system to MSFC for space simulation experiments in the drop tower facility.

STATUS: Technical Progress: The analytical phase of the furnace design is nearing completion and sample heater elements have been tested.

Management Progress: NAS8-29769 was awarded on 25 April 1973 for eleven months duration.

Conclusions: None

Problems: None

Forecast: Contractual work is scheduled to be completed by 25 March 1974.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Fourth Monthly Letter Progress Report, "High Temperature Electrically Conducting Ceramic Heating Element Control System", C. R. Halbach, 13 September 1973.			

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MSFC	01 04 73 to 30 09 73	179-21	975-90-95-87

4. TITLE:

Furnace Systems (Space Processing Equipment Technology - RTOP 179-20)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Boese, A.	205-453-1661	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: M518 Multipurpose Electric Furnace Modification (179-21-10-00)
NAS8-30289 Westinghouse Electric Corporation, Pittsburgh, PA 15235

OBJECTIVE: The objective of this task is to redesign, fabricate, assemble and test a prototype model of the M518 Multipurpose Electric Furnace System.

APPROACH: The contractor shall modify the thermal radiation shields and heater support tubes, modify the heater windings, develop a mechanism for increasing the passive cool-down rate, modify the controlled cool-down circuit, provide system protection and deliver the modified furnace and all associated hardware to MSFC.

STATUS: Technical Progress: Contractor is performing work in accordance with the contractual scope of work for the delivery of hardware.

Management Progress: Contract NAS8-30289 was awarded on 17 August 1973 for an eleven month period of performance.

Conclusions: None - New Contract

Problems: None

Forecast: Delivery Schedule: Modified furnace and all associated hardware - 17 April 1974. All documentation and Final Report - 17 July 1974.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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4. TITLE:

Furnace Systems (Space Processing Equipment Technology - RTOP 179-20)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Aldrich, B. R.	205-453-5085	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Special Purpose Furnace Systems for Use on Low-G Test Facilities (179-21-10-03) In-House

OBJECTIVE: This in-house effort will be utilized to develop special purpose furnace systems capable of supporting space processing experiments of sufficient definition to be flown on the initial development flights in the research rocket programs.

APPROACH: Three or more special purpose furnace systems will be developed to support early experiments in crystal growth and glass processing. FY-74 effort will include the definition, design, development, test, integration and flight of the special purpose furnaces. Elements of the system will be extracted and used for drop tower studies.

STATUS: Technical Progress: Requirements are being established for the purchase of necessary materials, components, hardware and equipment.

Management Progress: FY-74 funds have been received for this in-house program.

Conclusions: None - New Task

Problems: None

Forecast: This in-house effort is expected to continue through FY-76.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None - New Task			

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4. TITLE:

Levitation Systems (Space Processing Equipment Technology - RTOP 179-20)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Berge, L. H.	205-453-1661	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Free Suspension System for Space Manufacturing (179-22-10-01)
NAS8-29680 General Electric Co., Space Sciences Laboratory, Philadelphia, PA 19101

OBJECTIVE: The objective of this effort is to build and test free suspension facility to perform containerless processing in zero-g. Heating and positioning will be induced in the material by high frequency fields emanating from multiple coils surrounding the material. This is part of the total effort of a program to obtain an electromagnetic levitation apparatus for space processing experiments.

APPROACH: The contractor will combine data from past contracts with data produced during this contract. This effort will be accomplished with the following tasks: (1) Define levitation system equipment and instrumentation required for space processing of materials and indicate which materials require melting/cooling, transferring, mixing and shaping and other processing activities which an electromagnetic levitation system is associated. (2) Consolidate process variables and facility requirements for material classes to be processed by levitation systems. Material data will be related to process variables effecting the selection of a configuration for further development. (3) Study levitation system elements individually and then combined into systems to select the recommended configurations. (4) Support MSFC for a minimum of four free fall tests of the six coil positioning system. These tests will also verify the performance of modifications made to eliminate "Cross Talk" between coils.

STATUS: Technical Progress: Contractor is performing work in accordance with the scope of work.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None during this reporting period.			

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TASK: Free Suspension System for Space Manufacturing

STATUS: (Continued)

Management Progress: Contract NAS8-29680 was awarded on August 2, 1973 for a six month period of performance.

Conclusions: None - New Contract

Problems: None

Forecast: Contractual work is scheduled to be completed by February 2, 1974.

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4. TITLE:

Levitation Systems (Space Processing Equipment Technology - RTOP 179-20)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Berge, L. H.	205-453-1661	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Acoustic Positioning for Space Processing Experiments (179-22-20-02)
Contract (To be established - DCN 1-4-65-48001 for continuation of work performed by the Interand Corporation, Chicago, Illinois on Contract NAS8-29030)

OBJECTIVE: The objective of this continued effort is to design, build and test a containerless processing system employing acoustic positioning and to conduct experiments on one or more component, acoustically levitated, materials to determine the influence of acoustical fields on factors involved in solidification and crystalization.

APPROACH: Contract NAS8-29030 established the feasibility of positioning materials within an acoustic field during processing in low-g. This continuation of effort will include: (1) Development of Low-g Processing Module for laboratory and drop tower testing and (2) Evaluation of acoustic forces on solifification in low-g. This contract will determine if acoustic levitation is likely to produce improved materials and is worthy of further definition. The contractor is also urged to obtain a consultant on the material aspects, processing specifications and experimental analysis of proposed chalcogenide glass samples.

STATUS: Technical Progress: The procurement action was written and forwarded to the Procurement Office. (Draft copy of Final Report for NAS8-29030 was reviewed and approved for publication.)

Management Progress: (Contract NAS8-29030 was completed on June 15, 1973) Funding has been approved for the continuation of this effort.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Fifth Monthly Progress Report	"Acoustic Processing Method for Space Processing",	Dr. R. R. Whymark,	March 30, 1973. (Contract NAS8-29030)
IC-726 Final Report for Contract NAS8-29030	"Acoustic Processing Method for Space Processing",	Dr. R. R. Whymark,	June 15, 1973.

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 179-22
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TASK: Acoustic Positioning for Space Processing Experiments

STATUS: (Continued)

Conclusions: Contract NAS8-29030 established the fact that positioning materials by acoustic fields during processing in low-g is feasible and available for application. Acoustic positioning will position conductors/nonconductors of any shape in an atmosphere or low gas pressure environment during heating and cooling. Material transfer, shaping and mixing is possible with controllable acoustic fields.

Problems: None

Forecast: This continuation of effort is scheduled to be completed within nine months after award of contract.

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4. TITLE:

CRYSTAL GROWTH TECHNIQUES IN ZERO GRAVITY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
M. Davidson, S&E-SSL-TR	453-3090	W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Contract No.: Not selected
Contractor: Not selected

OBJECTIVE(S): The objective of this task is to obtain methods of process heating and temperature sensing which do not involve contact with the melt, and to establish the feasibility of such techniques for space processing.

APPROACH: Analyze and test heating and temperature sensing methods not involving contact with the melt. Develop designs for working systems which are applicable to space processing applications.

STATUS: Funds not yet available.

FORECAST: Release RFQ when funds become available.

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None			

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4. TITLE:

ACOUSTIC MIXING FOR SPACE PROCESSED MATERIALS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
L. L. Lacy, S&E-SSL-NP	453-5135	R. Decher, S&E-SSL-N

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE(S): To determine the optimum conditions for achieving a dispersion or mixing of small particles in a molten metal using acoustic processing in space. This research will determine the best acoustic technique for the production of composite castings in the Shuttle Space Laboratory.

APPROACH: The influence of various acoustic and liquid parameters on acoustic mixing will be determined by laboratory simulation of space processing conditions. Several techniques will be investigated in order to define the necessary design parameters for acoustic mixing motors and chambers to be used for the production of composite castings in space. Molten metals will be simulated by using liquids of various densities and viscosities along with particles of different densities and diameters. The amount of dispersion obtained will be determined in real time by optical and acoustic means.

STATUS: Although this program was only approved in September, a great deal of work has been accomplished. For example, a novel technique of counting particles suspended in a fluid by using acoustics was developed, and a government patent has been applied for. This new technique will not only be valuable to space processing but also to such fields as pollution measurements in water and cavitation detection in liquid rocket fuels. A NASA Technical Report is in the preparation stage.

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NASA Technical Report is being prepared.			

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MSFC	01 04 73 to 30 09 73	179-31	975-90-95-33

4. TITLE:

Management and Operational Support (Ground Based Space Processing Tests - RTOP 179-30)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yost, V. H.	205-453-2013	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Drop Tower and KC-135 Program Support (179-31-00-01)
In-House

OBJECTIVE: The primary objective of this in-house effort is to maintain and improve necessary equipment and facilities to provide short periods of near zero-g environment for space processing experiments and to continue the design, development, test and evaluation of systems for processing materials and detecting and measuring experiment parameters.

APPROACH: In-house work and supporting contracts will be utilized to provide experimenters with a readily available low cost means of testing and evaluating experiments and to provide universal packages to experimenters which can be used in either the drop tower or KC-135 tests.

STATUS: Technical Progress: During this reporting period the following work was completed:

Thirty-three (33) Space Processing drop tower tests were conducted in support of MSFC Contracts NAS8-26157 (8), NAS8-28056 (5), NAS8-28267 (17), and NAS8-28762 (3).

A Sony AV-3400/AVC-3400 Battery Operated Videocorder/Video Camera Ensembly "Videorover 11" was purchased. Brackets and a voltage divider were made to connect the television system to the package. Several drops were made to verify system operation. Now the experimenters can look at a video tape replay of what happened during the drop, make the necessary adjustments and go one with testing. Before they had to wait at least

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No formal report issued during this reporting period.

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TASK: Drop Tower and KC-135 Program Support

STATUS: Technical Progress: (Continued)

two days to get black and white film developed.

A number of 16 mm high speed motion picture cameras were investigated for in-house support of NAS8-28604 (Grumman - Metal Drop Solidification) and other experiments. There does not appear to be one commercially available that operates on 28Vdc, has a 400 foot film magazine and will take 400 to 3000 or 5000 pictures per second. White Sands Missile Range is presently negotiating with the Redlake Corporation to modify nine Hycam cameras to operate on 28Vdc and if the modification is successful, we may be able to obtain one of the modified cameras from the Redlake Corporation.

Management Progress: FY-74 funding has been approved for this task.

Conclusions: This task is providing experimenters with a readily available low cost means of testing and evaluating their Space Processing experiments.

Problems: The MSFC High Pressure Gas Committee reviewed the Drop Tower operation, requested a 3000 psig manifold be x-rayed, and found cracks in several welds. Work orders have been issued to have a new manifold designed and built. Design is scheduled to start during the week of September 18th. Hopefully, the tower will be operational by November 9, 1973.

Forecast: Drop tower tests and KC-135 flights are planned and scheduled at least 90 days in advance. This in-house effort is scheduled to continue through FY-77.

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MSFC	01 04 73 to 30 09 73	179-42	975-90-95-79

4. TITLE:

Sounding Rocket Experiment Program (Space Processing Flight Systems - RTOP 179-40)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Yost, V. H.	205-453-2013	H. F. Wuenscher

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Rocket Payload Despin System (179-42-22-01)
In-House & Contract (To be establish - DCN 1-3-65-38035)

OBJECTIVE: The objective of this effort is to provide a rocket payload non-spin system which will have a platform to mount Space Processing experiments on it and will produce near zero-g in the roll planes by greatly reducing radial acceleration on the payload produced by the spin stabilization of the rocket.

APPROACH: The data obtained from in-house studies and investigations were utilized in developing the Scope of Work for a contract to design, develop, fabricate, test, evaluate and deliver two Non-spin Platforms for Research Rockets. After the platforms are received, tested and evaluated, a procurement action will be initiated for Rocket Payload Despin Systems.

STATUS: Technical Progress: In summary, during this reporting period the Non-spin Platform concept was reduced to an outline assembly drawing of the baseline Platform, instrumentation was prepared and flown of a research rocket to obtain design parameters for the Platform, and the Scope of Work developed for the purchase of the Platforms.

During June and July 1973, two Instrumentation Plates and their Telemetry System were conceived, designed, manufactured, tested, evaluated and flown on an Aerobee 200 research rocket from WSMR on July 25, 1973. Unfortunately, the rocket payload broke loose from the sustainer 31 seconds into the flight. The payload reached a maximum altitude of slightly over 30896m (102,137 ft.). At 20,000 feet on the downleg of the

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No formal report during this reporting period.			

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TASK: Rocket Payload Despin System

STATUS: Technical Progress: (Continued)

trajectory, an aneroid switch blew off the nose cone and the payload landed safely via the drogue parachute. Design parameters were obtained for all but the near zero-g portion of the flight.

Management Progress: FY-73 funding will be used for this procurement action.

Conclusions: Drop tower tests indicate that there is a real potential for processing materials in a low gravity environment to obtain characteristics not currently achieveable on earth.

Problems: None

Forecast: In-house work is expected to continue through FY-75. This contractual work is scheduled to be completed within six months after award of contract.

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MSFC	01 04 73 to 30 09 73	645-10-01	645-40-05

4. TITLE:

Zero-G Cloud Physics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-YE Otha H. Vaughan OHV	205-453-3272	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Zero-G Cloud Physics
Contract No. NAS8-27861
NAS8-27861 (Mod.)

McDonnell Douglas
5301 Bolsa Avenue
Huntington Beach, Calif. 92647

OBJECTIVE(S): The Zero-G Cloud Physics Program objectives are: complement and supplement terrestrial cloud physics research, provide scientific community with general purpose orbital laboratory, laboratory capability to encompass largest feasible range of research and beneficial applications experimentation, establish experiment program accommodation, formulate and implement efficient and effective method for scientific community participation, and implement cost laboratory by continual assessment of usage value.

APPROACH: The experiment definition effort will include engineering definition studies of the preliminary concept(s) and approaches developed as result of the scientific feasibility activity. Furthermore the approach will include selected detailed analysis and limited subcomponent breadboard and testing necessary to assess and define an acceptable zero-gravity cloud physics experiment facility and related carrier interface plus operational concepts.

STATUS: Technical Progress--During this reporting period the following milestones were accomplished:

(1) Summary report covering work period between April 1973 and August 1973. This report is now in publication and will be distributed as a NASA CR report.

(2) Program Review was held at MSFC in August 1973.

(3) Programmatic data on laboratory costs, schedules, and other estimates rela-

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA CR 129002	Zero-G-Cloud Physics Laboratory Candidate Experiment Definition and Preliminary Concepts Study	L. R. Eaton, R. V. Greco, & A. B. Hollinden, McDonnell Douglas Astronautics Co.	June 1973
NASA CR	Experiment Program Definition and Preliminary Laboratory Concept Studies	L. R. Eaton, R. V. Greco McDonnell Douglas Astronautics Co.	

FIRST BENEFITTING PROJECT: Shuttle Sortie Laboratory

PROGRESS REPORT RESEARCH AND TECHNOLOGY OPERATING PLAN (Continuation Sheet)	CURRENT NO./CODE: 645-10-01 PAGE 2 OF 3

STATUS (CONCLUDED): tive to 1981 flight were completed and sent to OA, NASA Headquarters.
(4) Scope of work written and now in process for FY-74 effort relative to indepth definition studies. The scope covers: 1. Experiment Laboratory Technology Development Task, 2. Experiment Laboratory Subsystem Definition Task, 3. Experiment Facility Subsystem Requirements Task, 4. Cloud Chamber Subsystem Evaluation Task, 5. Ancillary Subsystems Evaluation Task, 6. Experimental Laboratory Definition Trade-Off Task, 7. Data Management, and 8. Cost, Schedules, and SRT Requirements for laboratory. Program development plan has been rewritten to reflect latest programmatic information. Dr. H. Weickmann, NOAA, led a discussion on the Zero-G Program at the International Commission in Cloud Physics in Russia during September 1973. Work has continued on the proposed carry-on experiment, the NaCl Break-Up proposed for the ASTP flight. Although not presently selected for the ASTP flight, prototype hardware will be fabricated. Some simple cloud physics demonstration experiments were performed by Skylab crews 2 and 3. Some experiment demonstrations have been identified for Skylab 4.
Management Progress--Briefings were given to MSFC personnel in August this year. This briefing covered a review of the past 3 months efforts covering revised laboratory definition and chamber concept, experiment time line revisions, laboratory design features, and critical data sampling requirements, funding estimates, etc. Relative to the forthcoming RFQ to be released this month, MSFC management has established a team concept for management and review of the contract efforts in this new phase of effort. Increased manpower (4 manyears effort) has been authorized for more indepth penetration into the contractors efforts. Astronautics Laboratory will have the engineering responsibility in the forthcoming contract while Aero-Astrodynamics will maintain overall management, as well as science responsibility. A separate contract has now been established to support the Senior Science Board and it is planned to increase the number of members and/or use other consultants to provide a more critical view of the overall Cloud Physics Program and a more independent assessment on the contractors effort.
Forecast: The Zero-G-Cloud Physics Program is proceeding as scheduled toward the projected flight schedule of experimental hardware and experiments for the 1981 Shuttle flight schedule. As new experiments are identified, they will be added to the experiment class list and trade-off studies will be performed to establish how they could be incorporated into the present laboratory design or in revised laboratory designs for future flights. Simple carry-on experiments will be studied and identified for development. These experiments could provide engineering data and could take advantage of any flight opportunities prior to that main Shuttle Sortie Lab flight. A program development plan will be submitted to OA, NASA Headquarters, prior to April 1974 so that necessary actions can be taken at the OA, Headquarters level to establish authority for the FY-75 Phase B effort and the FY-76 Phase C/D effort to begin.

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Marshall Space Flight Center	01 04 73 - 30 09 73	CURRENT NO.: 645-30-01	PRIOR NO.: 645-20-01*

4. TITLE:

Mission Requirements for a Manned Earth Observatory

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
D. Weidner	453-3425	Herman P. Gierow

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Mission Requirements for a Manned Earth Observatory

OBJECTIVES: To develop information relative to the accommodation and development of Earth Observations sensor/equipment on Shuttle Sortie missions.

APPROACH:
(1) Conduct in-depth study of historical sensor evolution cases.
(2) Identify basic research operations that are necessary to the development of historical sensors.
(3) Assess Shuttle/Spacelab capabilities with respect to required sensor development operations for selected candidate sensors placing particular emphasis on the role of man.
(4) Develop conceptual accommodation layout drawings for each selected sensor on shared Shuttle missions.
(5) Develop detail cost/schedule data for Shuttle Sortie and historical modes.

STATUS:
(1) Study of sensor evaluation cases is 80% completed.
(2) Identification of basic research operations is 20% completed.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

No reports with the exception of the Monthly Progress Reports.

*Previously funded under RTOP 975-61-01.

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Marshall Space Flight Center	01 4 73 - 30 09 73	CURRENT NO.: 645-50-03	PRIOR NO.: 975-90-95

4. TITLE: Requirements and Concepts for Space Processing Payload Equipment

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
K. R. Taylor	453-3426	Herman P. Gierow

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Requirements and Concepts for Space Processing Payload Equipment

OBJECTIVES:
(1) Collect and organize experiment requirements.
(2) Identify payload equipment requirements and specifications.
(3) Design and systems engineering of payloads.
(4) Laboratory/Facility layouts.
(5) Cost and SR&T.

APPROACH: The approach is based on the Shuttle/Spacelab mode of operations which dictates a modular, reusable, reconfigureable design and integration of payloads.

STATUS: Two workable configurations have been designed and inputted into the Spacelab design activity. These modular configurations permit the flying of partial dedicated payloads. Current effort is centered on further establishment of the technical integrity of the modular design and integrated techniques.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
DCN 1-2-21-00172-52	Requirements and Concepts for Materials Science and Manufacturing In Space Payload Equipment	R. L. Hammel K. R. Taylor, et al	July 1973

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MSFC	01/04/73 - 30/09/73	680-40-05	680-40-05

4. TITLE:

Solar Electric Propulsion Stage (SEPS)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
C. H. Guttman	205-453-5585	H. Gierow

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Extended Definition Feasibility Study for a Solar Electric Propulsion Stage Concept Definition, Contract NAS8-27360, Exhibit "E".

OBJECTIVES: Major objective is to evaluate and select either a Maximum Planetary SEPS or the Common Planetary/Geosynchronous SEPS as a baseline concept, provide detail conceptual design for the 1979 Encke mission.

APPROACH: To accomplish the objectives, the following was accomplished: (1) Update the Max-Plan SEPS by updating the mission and analyses and system requirements and interfaces, conduct system trade studies, select a baseline Max-Plan concept. (2) Perform a Com-SEPS analyses by determining the functional, operational, performance, and design requirements of a Com-SEPS design concept that can accomplish both planetary and geosynchronous missions, perform system/subsystem analysis and configuration design, select a baseline Com-SEPS design concept. (3) Perform an evaluation of the Max-Plan and Com-SEPS designs and select a single concept. (4) Perform detailed system/subsystem analyses and definition for the selected concept.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
SD73-SA-0081-1	Extended Definition Feasibility Study for a Solar Electric Propulsion Stage Concept Selection (Midterm Briefing)	Rockwell International Space Division	June 20, 1973
SD72-SA-0131-13	Monthly Progress Rpt	"	April 1973
SD72-SA-0131-14	"	"	May 1973
SD72-SA-0131-15	"	"	June 1973
SD72-SA-0131-16	"	"	July 1973
SD72-SA-0131-17	"	"	Aug 1973
SD72-SA-0131-18	"	"	Sept 1973

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STATUS: By the June 20, 1973 midterm of contract NAS8-27360, Exhibit "E", the Max-Plan SEPS and Com-SEPS analyses were completed and the Com-SEPS design concept selected for detailed definition through the remainder of the contracted activity.

On June 20, 1973, MSFC redirected this study activity and the objectives. The objectives of the redirected study are to: (1) Examine and define potential SEPS mission roles in Earth orbit. (2) Examine potential incremental development of the SEPS or other approaches which would minimize funding required for proposed early planetary missions without incurring excessive incremental costs for later planetary and Earth orbital missions. (3) To continue, at a reduced level, analyses and design of Com-SEPS subsystems mission hardware, program planning, and cost analysis.

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 180-17-50	PRIOR NO.: 180-17-50

4. TITLE:

System Performance & Technology Assessment for Unmanned Missions

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-MFT Gerald Wittenstein	205-453-0359	J. P. Lindberg

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: System Performance and Technology Assessment for Unmanned Missions
Contract Number: NAS8-26491
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

OBJECTIVES: Our primary objectives for the year were to identify and assess future performance requirements for OSS launch vehicles and also for astrionics/avionics systems. One other objective was to obtain copies of the already developed programs for use inhouse.

APPROACH: OSS-SV will establish the priority of mission - launch vehicle combinations. Based on these priorities, tasks will be defined by the COR and issued to the contractor who performs the assessments. The resulting data will be reviewed by MSFC specialists and the data, including specialists' comments, submitted to OSS-SV for their use.

STATUS:

1. The conversion and operation of these computer programs (EOMP-I & II) was accomplished, and we presently have this capability inhouse. These programs basically generate L/V trajectory and dispersion analysis in extremely rapid fashion, using the concept of linear propagation of errors.

2. Due to the potential (earlier in the year) of having to look at a SATS class of missions, a study was initiated and completed which defined what orbital constraints would occur for a SATS size payload flying on a Scout vehicle. The results were published in VSPR-IM-73-5, on June 5, 1973. Briefly circular orbits up to 200 n. mi. through 80°

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
VSPR-IM-73-1	Matrix Routines Used in EOMP	Fred Rea	1-29-73
VSPR-IM-73-2	EOMP TBHS Prog	Fred Rea	1-29-73
VSPR-IM-73-3	-	-	
VSPR-IM-73-4	-	-	
VSPR-IM-73-5	Ann. of a Number of Pot'l Scout Missions (SATS)	Fred Rea	6-5-73
VSPR-IM-73-6	Scout Vel. Vernier System	Fred Rea	6-6-73
VSPR-IM-73-7	Rate Generation for EOMP Traj.	Fred Rea	6-6-73
VSPR-IM-73-8	Error Anal. of Lageos Mission	Fred Rea	6-8-73
VSPR-IM-73-9	Payload Weight to Perigee Sensitivity to Scout D	Fred Rea	6-20-73
VSPR-IM-73	Third Interim Scientific Report on Vehicle System Eval. Requirement	Fred Rea	10-1973

FIRST BENEFITING PROJECT: SPACE SHUTTLE UTILIZATION & SPACELAB

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(Continuation Sheet)

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inclination were available on Scout and through 100° of inclination for approximately circular orbits less than 250 n. mi. Another analysis concerning the Delta L/V assessing the Delta guidance errors was made concerning the Lageos Mission. These data were published on June 18, 1973, and were used to identify some problem areas in the orbital sensitivity for this mission. Major result was that the Delta could assure errors less than .01, 99.7% of the time.

3. Investigation concerning the improvement of overall mission reliability and orbital achievement accuracy was made on the Scout Vehicle. This study resulted in a potential improvement for the Scout in the form of a velocity vernier system in order to cut off the Scout more closely to the desired velocity. This study is still continuing with respect to other low cost, systems which could be added to the velocity vernier system to further improve the mission attainment reliability for Scout.

Management Progress --- The FY-74 purchase requirement is being developed.
Conclusions --- Studies are being carried out as planned.
Problems --- None
Cause of Problems --- Not Applicable
Suggested Solutions --- Not Applicable
Forecast --- With inputs from NASA Headquarters to define missions and launch vehicle configurations, efforts will proceed as planned.

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MSFC	01 04 73 to 30 09 73	180-17-52	

4. TITLE:

System and Trajectory Analysis

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. R. Parker - S&E-ASTR-GDA	453-4276	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Investigation of Strapdown Sensor Rebalance Loops and System Redundancy Concepts NAS8-27296 The University of Tennessee

OBJECTIVES:

(1) To develop a high reliability strapdown navigation platform using two-degree-of-freedom sensors and redundancy concept.

(2) To develop a width-modulated rebalance electronics loop for strapdown gyroscopes.

APPROACH:

(1) In a previous study, a technique has been proposed to use the concept of sensor redundancy to improve the reliability of a strapdown platform employing two-degree-of-freedom (TDF) sensors. Three important parts involved in the development of the sensor are the optimum configuration for sensor arrangement, data reduction, and the sensor performance management method. In the previous study, it is assumed that when a TDF sensor fails, measurement from both of its output axes are erroneous. The validity of this assumption is debatable.

This study proposes a solution to the same problem, but developed under the assumption that each axis of a TDF sensor can fail without affecting the other axis. Although the basic concepts used in this development are similar to the aforementioned development, the details are different. System reliability based on present assumption is studied, the optimum redundancy configuration is developed, associated measurement

(SEE ATTACHED SHEET)

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
S-25	"Development of a Width-Modulated Pulse Rebalance Electronics Loop for Strapdown Gyroscopes"	Blalock, Kennedy, McKnight	7-13-73
S-26	"New Development on High Reliability Strapdown Platforms Using TDF Sensors"	Hung, Tsuei	9-15-73

FIRST BENEFITTING PROGRAM: Non-Project Oriented

equations are given, data reduction methods are presented and discussed, and one concept of sensor performance management is presented.

(2) A new width-modulated pulse rebalance electronics loop was developed for use with strapdown gyroscopes. The decision to develop a width-modulated binary loop was based on the study reported last year in which a width-modulated and a ternary loop were compared, and also on additional results obtained in the first phase of the work reported here. The salient advantages of the width-modulated binary over the ternary loop which strongly influenced our decision are the following: (1) the H-switch is easier to implement, (2) torque is applied in finely quantized increments, (3) the analog-to-digital conversion for data generation is inside the loop and is directly determined by the torque pulse, (4) no part of the loop compensation network bypasses the gyroscope, and (5) the torquer is fed constant power.

The basic design goals for the new rebalance loop were (1) versatility for accomodating a number of different gyros with minimum change in loop parameters, (2) minimization of required number of power supply voltages, (3) at least a factor-of-two increase in error signal sampling rate, (4) improved performance with special emphasis on reduction of uncertainties in data output due to all sources of noise, (5) a wide range of available scale factors, (6) reduction of system complexity for improved reliability, and (7) amenability to microcircuit implementation.

The design theory needed to synthesize the rebalance loop is developed, details of the implementation of each part of the loop are discussed, and some experimental evaluation of a breadboard of the rebalance loop are reported.

STATUS: Technical Progress--

(1) Optimum redundancy configurations for systems using three, four, five, and six sensors are complete. Details of a sensor performance management technique which can perform failure detection, faulty axis identification, and system reconfiguration have been completed. The model for the 2 gimbal TDF gyro is progressing. A limit cycle problem still exists.

(2) The electronics design is complete. Hardware build of certain circuits is proceeding in-house but cannot be completed because of insufficient funds. An effort is continuing on a workable digital rebalance loop for the TDF sensor.

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4. TITLE:

System and Trajectory Analysis

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Bobby J. Gaines S&E-ASTR-GCC	205-453-0795	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Experimental Studies of Body-Mounted Gyroscope Design

NAS12-2033 MIT Draper Laboratory

OBJECTIVES: To devise and perform experiments to verify analytically derived error models for strapdown sensors.

APPROACH: The program intent is to conduct dynamic performance tests of strapdown gyros operating in a rebalanced mode. These tests include single-axis, constant and oscillatory and two-axis oscillatory inputs.

STATUS: Technical Progress - The following items have been completed. (1) The development and testing of an analytical model to explain lock-in phenomenon, (2) Dynamic testing of MIT 18 IRIG Mod B with a ternary loop, (3) The generation of a model for torque scale factor nonlinearities in a single-degree-of-freedom gyro and procedures for reducing them, (4) A review of the theory of the two-degree-of-freedom Teledyne tuned rotor gyro and the preparation of a test plan for dynamic testing, and (5) Dynamic testing of the Kearfott 2544 gyro.

Testing of the Teledyne gyro has begun; studies and tests of torque-to-balance loops interaction with a dynamic environment, and gyro modularity are in progress.

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NOTE: Monthly letter-type progress reports have been received during this reporting period.

FIRST BENEFITING PROJECT: Non-Project Oriented

MSFC - Form 350 (March 1973)

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RESEARCH AND TECHNOLOGY OPERATING PLAN
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STATUS: (cont'd)

Management Progress - A contract (NAS8-20355) covering testing of a laser gyro and a pendulous accelerometer has been signed.

CONCLUSION: Dynamic data which will show comparisons of gyros with a different OA suspension systems (dithered jewel, ball bearing, passive magnetic, and tuned rotor) is being acquired. Additionally, digital torquing loops (binary, forced binary and ternary) are being compared.

FORECAST: Testing of the Teledyne gyro is continuing. Testing of the laser gyro and pendulous accelerometer should begin in November 1973.

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4. TITLE:

Dynamic Test of Inertial Sensors

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Bobby J. Gaines S&E-ASTR-GCC	205-453-0795	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Procurement and Evaluation of Advanced Gyroscopes for Modular System
NAS12-687 Hamilton Standard

OBJECTIVES: The objective of this task is the design, fabrication, and testing of gyroscopes specifically designed for the environment inherent in strapdown systems.

APPROACH: The results of studies funded by NASA/ERC under contract NAS12-508 and other studies defining the inter-relation between gyroscope design parameters, strapdown system environment, and system errors have been used in the design and fabrication and will be used in testing of gyroscopes for strapdown application. The major phases of this work are: (1) compiling existing studies and initiating studies where needed, (2) design and fabrication of gyroscopes as a result of the studies, (3) testing the resulting gyroscopes for conformance to the design goals, and (4) based on the results of (3), the gyro system will be refined and/or the technology developed will be assessed and applied to suitable gyroscopes which have a production base.

STATUS: Technical Progress - Hamilton Standard contract NAS12-687 - Severe active magnetic suspension problems have surfaced which tend to preclude any useful test data. The result of this problem was a random motion of the output axis. Based on Hamilton Standard's recommendation

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NOTE: Monthly letter-type progress reports have been received during this reporting period.

FIRST BENEFITING PROJECT: Non-Project Oriented

MSFC - Form 350 (March 1973)

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STATUS: (cont'd)

and the results of NAS12-2033, the suspension system will be modified with precision ball bearings. This modification should allow an evaluation of the remaining salient features of this gyro concept.

Management Progress: A no-cost extension to NAS12-687 has been granted.

CONCLUSIONS: The ball bearing output axis will not maintain output axis definition to the accuracy of the design goals; however, tests on similar output axis suspension suggest that it will be adequate for evaluation.

PROBLEMS: 1. Ceramics - The problem area will be addressed during gyro refinement.

2. Electronics - The large number of power supplies contribute to the total noise in electronics. An effort is being made to limit the noise.

3. A severe problem involving integration of the hybrid electronics has surfaced and is being worked.

CAUSE OF PROBLEMS: 1. Ceramics - This appears to be due to improper handling that causes hairline fractures. DOD programs that utilize ceramics suggest that proper care in handling will correct ceramics cracking.

2. The gyro requires a large number of dc supplies to operate. Ground loops occur and require care in test setup.

FORECAST: Delivery has been rescheduled for Sept. 30, 1973.

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 180-17-53	PRIOR NO.:

4. TITLE:

Dynamic Tests of Inertial Sensors

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Bobby J. Gaines S&E-ASTR-GCC	205-453-0795	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Dry Gyro for Strapdown Systems
NAS8-27452 Teledyne Systems Corporation

OBJECTIVE(S): The need exists for a low cost, reliable, normalized gyro for strapdown system for launch vehicles. New techniques in gyro suspension systems have reduced the cost of platform gyros and this technology has the potential for reducing cost, reducing parts count, and increasing reliability of a strapdown gyro.

APPROACH: The technology developed in the dry gyro program for gimbal platforms has been applied to the design of a strapdown gyro. Two of these instruments have been procured and are being evaluated for application in a launch environment. This evaluation will be both analytical and experimental. Qualification of this type instrument for strapdown systems would allow NASA to meet the needs for inertial reference sensors from a large production base with potential for reduced cost.

STATUS: Technical Progress - Both gyros have been delivered and are being evaluated. One gyro has been GFEd to MIT under contract NAS12-2033 for dynamic testing. Dynamic testing is in progress and is scheduled for completion in 4 months.

CONCLUSIONS: Based on 400 hours of test time accumulated on the first gyro, the gyro meets the goals of thermal insensitivity within the band of a 0.01°/hr gyro. The data is currently being reduced to statistically

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

NOTE: Irregular letter-type progress reports have been received during this reporting period.

FIRST BENEFITING PROJECT: Non-Project Oriented

MSFC - Form 850 (March 1978)

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CONCLUSIONS (CONT'D)

characterize the gyro.

FORECAST: In-house testing will continue in order to get a larger data base for evaluation and characterization. Dynamic testing should be complete within 4 months.

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4. TITLE:

Dynamic Tests of Inertial Sensors

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. Kissel - S&E-ASTR-GDA	453-4276	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Strapdown Gyro and Accelerometer Test Methods
NAS12-678 The Analytic Sciences Corporation (TASC)

OBJECTIVE(S): To define and evaluate test methods and techniques for evaluation of strapdown gyros and investigate the vibration effects on strapdown navigation accuracy.

APPROACH: Take the fundamental laws of physics and apply them to different types of strapdown gyros in order to develop error models. Then note especially those error terms peculiar to strapdown application. New procedures and methods for evaluating these unique error terms can then be developed and evaluated.

STATUS: Technical Progress--None.

Management Progress--Negotiation is underway to redirect this effort toward defining specific improvements in the Teledyne dry gyro and studying the feasibility of an all-digital loop on this gyro.

Conclusions--Redirection of effort preferred.

Problems--Lab test data is required for this task and the lab has been tied up with other priority work.

Forecast--Effort will be redirected so as not to waste any more time waiting for lab data.

Publications--None this period

Remarks--None

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
TR-147-4	Strapdown Sensor Test Simulation and Test Plan Recommendations	Bard S. Crawford	1 June 72
TR-147-5	Dynamic Errors in a Tuned Flexure-Mounted Strapdown Gyro	John E. Bortz, Sr.	Sept. 72

FIRST BENEFITTING PROJECT: Non-Project Oriented

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 180 17 54	PRIOR NO.:

4. TITLE:

GUIDANCE COMPUTER TECHNOLOGY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
G. S. Jobe, S&E-ASTR-CGG	453-3633	C. N. Swearingen, S&E-ASTR-C

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Reconfigurable Modular Digital Computer Development NAS8- 27926 Hughes Aircraft
NAS8- 26930 Auburn Univ.

OBJECTIVE: To develop a highly reliable modular computer system which is adaptive to various mission requirements. The system is to be capable of configuring itself into various modes of operation, including those which require automatic masking of errors (such as triple modular redundancy), of parallel or multiprocessing for extremely high computational requirements, and into a standby redundancy mode where failed modules are isolated and automatically replaced with a working module. The various modes are compromises between system reliability and computational capacity. In the mode of automatically masking errors, computational capacity is sacrificed for maximum system reliability. In the mode of parallel or multiprocessing, a lesser reliability is accepted to obtain the maximum computing capability. One objective is to design the system logically and mechanically such that, for a particular mission, a system configuration can be provided that satisfies the requirements of that mission without undue penalty of hardware that is not needed. The system is to be known as an Automatically Reconfigurable Modular Multiprocessor System (ARMMS). The reliability goal for the system is 0.99 for a five-year mission, having at least one processor functioning correctly at the end of that time. The goal for computational capability is five million operations per second.

APPROACH: Phase I - Preliminary Design - During this phase the system architecture will be defined. Such items as how many processors will be in the system, how many switchable modules there will be within each processor, what type of system controller there will be, and how all these various modules are to be interconnected will be defined in this phase. Also, specific problem areas are to be investigated in detail. This includes error

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First Benefitting Project: Possible Application on SEPS or other long life missions.

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detection and correction (with special emphasis given to detecting intermittent failures) system reconfiguration, the system controller, and the switches between modules. The Central Processor Unit (CPU) has been defined as the Space Ultrareliable Modular Computer (SUMC) which was designed in-house at MSFC. This allows the major emphasis to be placed on the system architecture and not have to spend time and money designing another CPU. During this phase the software requirements related to error detection, error correction, reconfiguration, and system reinitialization are to be identified. Also, the mechanical requirements as they relate to making the system adaptable to various mission requirements are to be investigated.

Phase II - Breadboard Design and Fabrication - The system architecture as defined in Phase I will be implemented in a breadboard model to enable the investigation of problems in both hardware and software. The technology utilized will be one which will permit changes to be installed without undue expense or time delay. To conserve cost of the breadboard unit, some modules such as the central processors and input/output processors will be existing designs. This approach does not compromise the investigation of the modular concept.

Phase III - Flight Prototype Design and Fabrication - The necessary design changes for both hardware and software resulting from Phase II will be incorporated into the system. The flight prototype will be implemented with the total logic design and technology that would be utilized in the flight unit. This system would be used to verify the total system, including the fabrication techniques of the technology chosen.

STATUS: Technical Progress - Hughes has essentially completed the Phase I effort. Register level designs for the Block Organizer and System Scheduler (BOSS), the CPU, the Input/Output Processor (IOP), and the Memory Modules have been delivered. The system architecture is defined and consists of an internally redundant BOSS, seven CPU's, four IOP's, and sixteen Memory Modules. Each Memory Module is eight thousand words by thirty-two data bits plus six Hamming Code bits for single error correction and double error detection and a simple parity bit to detect all odd numbers of errors. The various modules are connected by four processor-to-memory busses, four memory-to-processor busses (time shared between CPU's and IOP's) and redundant boss-to-module busses. Executive software has been defined and executive memory requirements have been estimated at approximately eleven thousand words. The full ARMMS System described above is only required for a mission requiring a 5 year life expectancy and multiprocessing. The system design is modular so that fewer modules could be used for shorter duration missions or for missions requiring less computational capability.

Management Progress - An RFQ has been issued to Hughes for a one year extension to the present contract for design and partial construction of a BOSS-less breadboard. The construction of the breadboard will be funded on an annual basis as RTOP funds are approved.

Conclusions - Internal partitioning of modules is not required in order to meet reliability requirements. In the area of the CPU and IOP the number of interface lines and the difficulties of reinitialization make internal partitioning impractical.

The large memory requirement for executive software indicates that multiprocessing may not be practical. Multicomputing (multiple dedicated processing streams) may be a better solution for increased throughput.

Problems - Problem areas are being investigated in more detail as they are identified. None have yet been identified that indicate the approach is not feasible.

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4. TITLE:

Solar Electric Propulsion Stage (SEPS) Technology

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S&E-AERO-GA J. R. Duncan, Jr.	205-453-1096	Clyde D. Baker

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Interplanetary Low Thrust Guidance and Performance Error Analysis
NAS8-29666, Martin Marietta Corporation
P. O. Box 179
Denver, CO 80201

OBJECTIVE(S): A necessary part of any solar electric propulsion stage design is a knowledge of total system interaction with guidance and navigation subsystems. The role of guidance and navigation is especially critical in solar electric missions because the long thrust durations and related performance errors introduce trajectory dispersions which are orders of magnitude larger than ballistic missions. Under this contractual effort, a computer program will be developed which will enable the user to realistically analyze the relationship between (ground and vehicle) system requirements and guidance and navigation requirements. This program will contain realistic models of physical processes, will be computationally efficient and fast, will be flexible in application, will have clear and meaningful output, and will be sufficiently modular to permit future growth.

APPROACH: The objective outlined above will be met by following an eight step plan as follows. (1) The program (developed under NAS1-11686) from which the new development began will be reviewed for consistency, efficiency and flexibility; and, it will be updated as required. In addition, test case data and verification methods for major routines and program modes will be defined. (2) The necessary macrologic will be developed. This includes COMMON blocks, overlay structure, functional input/output, initialization sequences, and executive logic. (3) All utility routines and trajectory routines will be constructed and tested. (4) A targeting and optimization module

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APPROACH (CONCLUDED): (TOM) will be developed and checked out. (5) A trajectory error analysis module (TEAM) will be developed and checked out. (6) A trajectory simulation module (TSIM) will be developed and checked out. (7) A program utilizing combinations of the modules developed will be constructed and tested. (8) The finalized program will be completely documented and this documentation, along with a source deck or tape of the program, will be provided to MSFC. Concurrently with the development of the program, the contractor will communicate with the MSFC Computation Laboratory and provide them with the information needed to facilitate the program conversions which are necessary for operation on MSFC computer systems.

STATUS: Technical Progress: A review was held with MSFC to solidify program design, verification and conversion. A number of changes from the baseline design were recommended including: separate input of trajectory parameters through the main routine, integration of ephemeris variational equations as part of the state transition matrix (formerly done by numerical differencing), optional user control weighting schemes, separation of the generalized covariance option such that a filter gain file will be written during "assumed" error analysis and read during "true" error analysis, different options for handling ephemeris uncertainties, and capability to write the data generated by each simulated trajectory onto a disk file for later statistical processing. The verification test data centered around three SEP missions: Encke flyby, Mercury Orbiter, and Jupiter flyby. These missions will be used to verify major clusters of subroutines. The basic macrologic has been completed. Primary common blocks, overlay structure and functional input/output have been defined. Preliminary structure for each mode has been developed such that dummy routines will be replaced by operational ones as they are completed. Utility routines are approximately 70% coded and verified. Trajectory routines are about 80% coded and 40% verified. Trajectory verification has been concentrating on thrusting logic, computation of augmented state transition matrix (ephemeris, thrust bias, etc.), and covariance integration. The print modules are about 50% completed.

Management Progress: An initial contract using FY-73 funds was negotiated with Martin Marietta Corporation with an effective date of May 10, 1973. On August 16, 1973, an expansion of this effort to include the total package outlined in the objectives section of this report was finalized using FY-74 funding. The total effort has a ten-month schedule from the initial effective date of May 10, 1973, and has a cost plus fixed fee of approximately 75K.

Conclusions: All work is progressing on schedule.

Problems: None.

Causes of Problems: None.

Suggested Solutions: None

Forecast: An efficient and flexible program for conducting the studies required for future SEP stage design work will be developed on schedule.

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4. TITLE:

Comet and Asteroid Rendezvous and Docking (CARD) (Summary)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. D. Ellsworth/H. Waites	453-4584/4717	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

Objectives:

a. Develop techniques, analysis and synthesis tools to aid in the design and development of a simulation plan for stability and dynamic analysis of a control system insensitivity to the plethora of variations encountered in unmanned rendezvous and docking in the CARD mission.

b. The objective of this study effort is to develop an autonomous or ground-supplemented target-relative navigation system capable of use on spacecraft which would fly by, orbit/land on a planet, a comet or an asteroid. Only conventional sensing devices such as radar (microwave and laser), star sensors, sun sensors, inertial platforms, televisions, etc. are to be considered for the navigation concept. As a part of this study determine the navigation system functional requirements including measurement types, dynamic ranges, accuracy and reliability.

Approach:

This program is being conducted under the following two separate tasks:

a. Stability and Dynamic Analysis of a Control System Insensitivity to Parameter and Environmental Variations

b. Autonomous Target Relative Navigation

Status: See individual tasks.

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4. TITLE:

Comet and Asteriod Rendezvous and Docking (CARD)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. D. Ellsworth S&E-ASTR-SG	453-4583	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Autonomous Target Relative Navigation
NAS8-28241 University of Tennessee, Knoxville, Tenn.

OBJECTIVE(S): The objective of this study effort is to develop an autonomous or ground-supplemented target-relative navigation system capable of use on spacecraft which would fly by, orbit/land on a planet, a comet or an asteroid. Only conventional sensing devices such as radar (microwave and laser), star sensors, sun sensors, inertial platforms, televisions etc., are to be considered for the navigation concept. As a part of this study determine the navigation system functional requirements including measurement types, dynamic ranges, accuracy and reliability.

APPROACH: Eight potential navigation system concepts were identified in the course of the study. These ranged from very simple systems which would give range only information, to more complex concepts which can furnish all required information of vehicle state relative to the target body. As would be expected, the more complex systems require the use of more measurements in the computation process. Each of these concepts were then analyzed by first deriving the system equations and then performing numerical/analytical studies to determine system performance and sensitivities. Using this information and the trade criteria of system cost, weight, reliability, performance, flexibility and complexity a baseline concept was selected.

STATUS: Technical Progress - None
Management Progress - The final study report has been delivered and distributed.
Conclusions - Of the eight concepts identified and investigated in the study three showed the capability to perform the fly by, orbit/landing missions. All three

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Scientific Report #S-24	Autonomous Target Relative Navigation Final Report Contract NAS8-28251	James C. Hung	May 1, 1973

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6. Accomplishments

STATUS:

(Conclusions, cont'd)

concepts were similar with the differences being in the reduction of system weight through lighter hardware. The baseline concept selected consists of an inertial measurement unit, three star sensors, a microwave radar and a microwave altimeter.

Weight reduction could be achieved by substituting lasers for the microwave radar. However, this requires advancements in laser technology to achieve the long range (200KM) capability.

Problems - None
Forecast - None

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4. TITLE:

Comet and Asteroid Rendezvous and Docking (CARD)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
H. Waites, S&E-ASTR-SD	453-4717	J. L. Mack

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Stability and Dynamic Analysis of a Control System Insensitivity to Parameter and Environmental Variations
NAS8-28110 Auburn University

OBJECTIVE: Develop techniques, analysis and synthesis tools to aid in the design and development of a simulation plan for stability and dynamic analysis of a control system insensitivity to the plethora of variations encountered in unmanned rendezvous and docking in the CARD mission.

APPROACH:
(1) Investigate and determine the system configuration for CARD.
(2) Examine and delineate the models of the environments for the asteroid (Eros) and the comet (Encke).
(3) Develop the models of the environments and the equations of motion for the system configuration.
(4) Select the type or types of control system or systems to be used in the CARD operation of rendezvous and docking.
(5) Synthesize the type or types of control system or systems to be used in the CARD operation.
(6) Prepare a simulation plan that will incorporate all of the above five items.

STATUS : Technical Progress: Progress was made in the following areas:

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(1) Computer programs have been developed to implement: (a) the equations of motion of the spacecraft including fuel sloshing, spacecraft flexibility and moving parts on the spacecraft; (b) planar docking problem for two flexible spacecraft; and (c) weighted "least squares" CMG control law.
(2) The equations of motion for a thrust vector control system with translating and gimbaling engines have been derived, checked out, and programed.
(3) Attitude controllers have been developed using the weighted "least squares" CMG control law and the thrust vector control system. These controllers have been implemented in the linear equations of motion. These are subprograms of items (1) and (2).

Management Progress: A presentation was held at MSFC to discuss the status of the technical progress and to enlighten MSFC personnel to the work that has been accomplished so that said personnel could use these computer programs in their area of work.

Conclusions: The computer programs can be used for the following projects: (a) SEPS; (b) LST; and (c) Sortie Lab.

Problems: The sensitivity study of the weighted "least square" CMG control law had to be discontinued because of its complexity.

Forecast: These computer programs will be used in the NASA projects listed above.

Publications: None

Remarks: None

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MSFC	01-04-73 - 30-09-73	186-68-65	

4. TITLE: Study of Effects of Uncertainties on Comet and Asteroid Encounter and Contact Guidance Requirements

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. P. Hethcoat	453-5584	Herman P. Gierow

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Same as title.

NAS8-27664, Auburn University, Auburn, Alabama

OBJECTIVE(S): Develop a comet and asteroid rendezvous guidance algorithm that can handle target ephemeris errors within solar electric propulsion (SEP) limits. Develop statistical filtering of spacecraft on-board measurements and determine required measurements and measurement accuracies. Investigate SEP thrust magnitude and pointing error and the effects of thrust deviations.

APPROACH: The work will focus on the development of a rendezvous scheme using on-board measurements and also on-board processing of measurements to estimate spacecraft state and generate control commands. On-board measurements are required whether processed on-board or on the ground because weak target ephemerides and relatively low earth-based target tracking accuracies make sufficiently accurate determination of relative state of the spacecraft and target impossible without the on-board measurements. On-board processing will not only reduce delay time in critical situations but will, importantly, greatly increase the frequency of measurements that can be made and immediately processed.

STATUS: A successful algorithm has been developed which deterministically accomplishes comet and asteroid rendezvous with SEP. The algorithm requires

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None in the period covered.

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knowledge of all state variables. A first cut at a Kalman type filter has been completed and the formulation of a modified filter working in measurement coordinates has been developed. Some preliminary results have been generated which give preliminary specification of system requirements. More complete results will be forthcoming from further analytical studies. The second year of investigation was scheduled to terminate on September 15, 1973 but due to computer facility problems was extended to December 15, 1973.

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4. TITLE:

Magnetospheric-Physics-Particle and Particle/Photon Interactions

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. E. Smith, S&E-AERO-YS	205 453-3140	William W. Vaughan

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Airglow Research, Contract No. NAS8-29543
University of Alabama in Huntsville, Alabama

OBJECTIVE: To obtain a better understanding of the effects of wave propagation in airglow emissions.

APPROACH: 1) Develop a model of wave propagation through the ionosphere.
2) Combine with an already developed static model of the 6300Å OI emission.
3) Adjust model parameters until agreement is reached with observational data recorded by MSFC Airglow Observatory System.

STATUS: Technical Progress: 1) A theoretical model of a three fluid ionosphere is approximately 75% complete.
2) A theoretical model of wave propagation through the topside ionosphere has been completed and work has begun on adjusting the model parameters so that it is applicable to the lower ionosphere.
3) A static theoretical model of the 6300 Å OI emissim has been completed.

Management Progress: A contract was awarded to the University of Alabama in Huntsville in February 1973.

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None.

FIRST BENEFITING PROGRAM: Atmospheric Science and Space Plasma Physics Laboratory

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CONCLUSIONS: Objectives are technically feasible; however, three dimensional model appears to be far downstream.

PROBLEMS: Length and level of effort of contract will not permit the indepth work needed to develop the full scale model originally envisioned.

FORECAST: Project will require same level of support in FY 74 and FY 75.

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4. TITLE:

REAL TIME SOLAR MAGNETOGRAPH (RTSM)

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
W. C. Snoddy, S&E-SSL-T	453-3103	E R Miller for W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Real Time Solar Magnetograph

GO #H-45646A

OBJECTIVE(S): To develop a solar magnetograph capable of real time, high-resolution measurements having a field of view of several arc minutes. Such instrumentation will be used to study small-scale, rapid variations of the solar magnetic fields. This information is needed, for example, to support the scientific data evaluation of the ATM and to aid in the prediction of flares in connection with such manned missions. It will provide a capability of the Space Sciences Laboratory of MSFC to support solar astronomical missions.

APPROACH: The RTSM is representative of magnetograph systems which use a narrow-band birefringent filter plus an assembly of polarizing optics to uniquely determine the state of polarization of a narrow wavelength interval of the light emerging from a small element of the sun's surface by measuring the Zeeman effect in chromospheric absorption lines. The specific problems to which the RTSM is addressed are (1) to establish the relationship between measured polarization and solar magnetic fields, and (2) to correlate measured magnetic field distributions with distributions calculated theoretically from various assumptions concerning the solar plasma. In regard to the first problem, calibration is approached by solving the radiative transfer equations for the line profiles of the Stokes parameters and computing the percentage of linear and circular polarization across the line profiles. Correspondingly, if it is assumed that the polarization of the light is caused solely by the presence of a homogeneous magnetic field in

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
TMX-53984	Calculations of Astrophysical Partition Functions	M. J. Hagyard	Feb 1970
TMX-64556	The Continuous Absorption Coefficient Per Gram of Stellar Matter with Neutral Hydrogen & the Negative Hydrogen Ion as Sources of Opacity	M. J. Hagyard	Sept 1970
TMX-64541	Calculations of the Stokes Parameters and the Degree of Line Polarization: An Application of the Solutions of Moe to the Unno Transfer Equations	M. J. Hagyard	Aug 1970
NAS8-30148	Two Solar Intensity Calculations	A. R. Dunn	July 1970

FIRST BENEFITTING PROJECT: SKYLAB

APPROACH: Continuation

the process of formation of the absorption line in the relevant layers of the sun's atmosphere, this magnetic field can be determined both in magnitude and direction from measurements of the degrees of linear and circular polarization of the light transmitted by the narrow-band filter. In connection with the second problem, the shock calculation for infalling prominence material in the infall-impact model of a solar flare yields appropriate conditions for hydrogen-alpha emission. As an extension of the infall-impact theory, a theoretical model for type II and type IV solar radio bursts has been developed and numerical calculations made.

The 30.48-cm (12-in.) Cassegrainian telescope collects light for the RTSM optics, Zeiss filter, and secondary electron conduction (SEC) vidicon detector. The data is digitized and processed on a real time basis by a UNIVAC 1108 third generation computer. Results are immediately displayed on a digitat to television (D/TV) system and on high-speed printers and plotters. The Zeiss filter is a specially built birefringent filter designed to have a bandpass of about 0.01nm (0.125Å) at the 525.02nm (5250.2-Å) iron line wavelength. Magnetograph measurements are made by using polarizing optics consisting of two $\lambda/4$ plates, two potassium-deuterium-phosphorus (KD*P) crystals, and a linear polarizer. The analysis of the polarized light is accomplished with six combinations of these elements with the retardance of the KD*P crystals being electrically controlled by varying the plate voltage. The effect of each of these six combinations on a beam of partially polarized light can be described in terms of the Stokes parameters and Mueller calculus.

STATUS: Technical Progress - All components of the hardware have been installed at the observing site. The system became operational in the longitudinal mode on May 30, 1973. Magnetograms have been taken 71 out of the 93 days during the period to August 31, 1973, for 76.3 percent of the time. Because the RTSM is the most eastern ground-based facility, it has the capability of providing the earliest magnetograms for ATM planning for the next day's execution. Since August 15, 1973, magnetograms have been transmitted via wirephoto to the NOAA forecaster in the Science Room at JSC. A capability for taping of raw digital data has been developed by the Computation Laboratory. The taping hardware and corresponding software for processing the taped data are working satisfactorily; however, there are still some minor problems concerning housekeeping data and taping format to be worked out. An analog taping system will be installed at the observing site before the launch of SL 4 as a backup to the digital taping system.

Management Progress - Contract Number NAS8-28456 has been signed under which Electro-Mechanical Research, Inc. (EMR) will provide field engineering and technical support services for the RTSM.

Problems - A serious problem exists because of lack of access to the UNIVAC 1108 third generation computer for real time data processing.

Causes of Problems - The RTSM has not been given adequate time on the 1108 for real time data processing because of the work load on the computer system and the multitude of problems connected with real time support of Skylab. Modifications have been made to the UNIVAC 1108 EXEC-VIII so that in theory the RTSM and Skylab real time programs can run in parallel, but problems with the Computation Laboratory interface equipment have not allowed this to be done satisfactorily to date.

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CONCLUSIONS: The system appears to have the desired capability and flexibility required for initial measurements of solar magnetic fields on a continuing real time basis.

7. REPORT NO.:	Continued TITLE	AUTHOR(S)	DATE TRANSMITTED
NAS8-20166	Corrections to Observations of Intensities on the Sun(Tech. Note).	A. R. Dunn	Apr 1970
NAS8-20166	Corrections of Observed Umbral Spectral Lines,(Interim Report).	A. R. Dunn	Dec 1969
NAS8-20166	Umbral Line Profile Corrections Interim Report.	A. R. Dunn	Mar 1970
	Analytic Solutions to the Unno Transfer equations for the Stokes Parameters in a Milne-Eddington Atmosphere, Solar Physics.	M. J. Hagyard	(In Press)
	Profile & Polarization of the Zeeman Triplet 5250.22 Å, O.K. Moe, G.E. Brueckner, and M.J. Hagyard, 132nd meeting of the American Astronomical Society, Boulder, Colo.	M. J. Hagyard	June 1970
	A Compressible MHD Model of the Development of a Sunspot, 1st meeting of the Solar Physics Division of the American Astronomical Society.	M. J. Hagyard Y. Nakagawa S. T. Wu	Nov 1970
NAS8-25101	Electro-Magnetohydrodynamic Description of the Infall-Impact Model of the Solar Flares. Final Report	S. T. Wu	Nov 1970
	On the Prediction of the Magnetic Field Strength Associated with Solar Flares. Information Zur Kernforchung & Kerntechnik.	S. T. Wu K. O. Thompson	(In Press)
	Real Time Solar Magnetograph (First Generation) Edited by J. R. Watkins, MISC-SSL-70-5	M. J. Hagyard E. J. Reichman N. P. Cumings W. C. Snoddy J. R. Watkins	Dec 1970

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7. REPORTS Continued

NAS8-26376	Analysis of Sunspot Spectral Data, Interim Report SE-SSL-1428	A. R. Dunn	Oct 1971
	H_2 Flares: The Response of the Chromosphere to a Downward Shock Wave. Meeting of the Solar Physics Divison of the American Astronomical Society, University of Maryland.	S. T. Wu S. M. Han Y. Nakagawa	Apr 1972
	Calculation of 5250.216 Å Line Profiles in Sunspots; Meeting of the Solar Physics Division of the American Astronomical Society, University of Maryland.	A. R. Dunn	Apr 1972
	Non-Linear Study of the Dynamical Behavior of a Force-Free Magnetic Field; Meeting of the Solar Physics Division of the American Astronomical Society, University of Maryland.	M. J. Hagyard Y. Nakagawa S. T. Wu	Apr 1972

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MSFC	01 04 73 to 30 09 73	188-41-51	188-41-01

4. TITLE:

UV and OPTICAL ASTRONOMY

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. R. Miller, S&E-SSL-TE	453-3103	W. C. Snoddy, S&E-SSL-T

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

RTOP TITLE: UV and Optical Astronomy - The objectives of this RTOP are to perform ground-based visible and infrared observations on selected objects. The overall objective is to perform astronomical publishable research that has bearing on MSFC projects, both on-going and future. For instance, the latest observations of eclipsing binary stars were chosen such that the planned observation by S-183 on Skylab would include these objects; and the studies of optical and infrared emissions from energetic processes will benefit HEAO.

Also, the overall effort will provide MSFC with active knowledge of observational and theoretical problems, thereby contributing to MSFC's role in producing payloads to carry out such observations from space.

TASK: Visible and IR Photometry of Variable Stars and Other Stellar Objects in Support of MSFC Astronomy Flight Projects

OBJECTIVE(S): To provide ground-based photometric data in support of S-183 (Skylab) and other MSFC projects such as HEAO and CVT on selected objects. Cost of such a ground-based program is negligible compared to a flight experiment and can add greatly to the scientific return of the experiment, such as obtaining near IR data on objects observed in the UV.

APPROACH: Optical and infrared narrow-band photometric observations are performed on such stellar sources as a) binary stars, b) long period mira variables, and c) Seyfert galaxies. Such data establish periodicity, mass ratios, limb darkening and magnitudes.

7. REPORT NO.: TITLE:	AUTHOR(S):	DATE TRANSMITTED
PASP, Vol 79, 74. The Period of HD 10783	Hardie, Lieberman, Reichmann	
The Development of Two Photoelectric and Two Infrared Photometers and the Reduction of the Photoelectric Light Curve of the Eclipsing Variable Star VV Orionis Uof Georgia Masters Thesis, 1971	H. Atkins	
IAU Circular 2407, 1972e Supernova	Wisnieski, Lee, Wdowiak, and Michlovic	
Photometry of Supernova 1972 in NGC 5253 The Astrophysical Journal Vol 177, No. 2 Part 2, October 1972	Lee, Wamsteker, Wisnieski and Wdowiak	
Recent Supernova in NGC 5253 and the Supernova Rate, Nature-Physical Science, Vol. 241, January 1, 1973	Wamsteker, Wisnieski, Lee, and Wdowiak	

STATUS: A lead-sulphide JHKL infrared photometer and a dual-channel UBV optical photometer have been built. Data have been obtained on several binary star systems including HS Hercules, VV Orionis and Beta Lyrae. In addition, data have been taken from OAO tapes to supplement above data. Data reduction and analysis on the above observations is essentially completed and papers are in writing. However, due to commitments on Skylab, final publication will be delayed until several months after Skylab is completed. No funds are being expended on this task during Skylab activities.

Conclusions - Flight projects can be aided by ground-based observations by both determining magnitude to be expected and obtaining additional spectral data needed for better interpretation of the object. The above can be accomplished by coordinated programs in which the ground-based effort can produce independently publishable research.

Problems - Active participation in Skylab prevents observation during its flight to obtain simultaneous measurements.

Forecast - Begin publications and resume observations after Skylab.

TASK: Photoelectric Photometry of Magnetic Variable Stars

OBJECTIVE(S): To establish, by photometric measurements in the UBV narrow bands, variability in light intensity and to check for correlation of light variability with magnetic field strength and with radial velocity variations.

APPROACH: Optical (UBV, H-alpha, and Stromgren) narrow-band photometry will be used to examine selected magnetic variable stars to establish light curves, metal line indices, and Balmer-discontinuity indices.

STATUS: Instrumentation and optical components, being used currently in support of ATM, have been obtained and will eventually (after Skylab) be used on this program. No observations have been performed since the work on HD10783 in concert with Dyer Observatory. Funds are not being expended on this effort until after Skylab.

Conclusions - Data from HD10783 observations have been produced and reported.

Problems - None

Forecast - Resume observation after Skylab.

TASK: The Relationship of Certain Celestial Optical and Infrared Emitting Objects and High Energy Radiation

OBJECTIVE(S): To perform optical and infrared observations and theoretical studies of galactic and extragalactic steady state and transient energetic processes on such objects as novae, supernovae, x-ray sources, and galactic H II regions.

APPROACH: The work is carried out with the 1.5-meter NASA(GSFC/MSFC) telescope located on Mt. Lemmon, Tucson, Arizona, and 0.4-meter telescope at MSFC. Joint work is being done at Vanderbilt (Dyer Observatory) and Case Western Reserve. All components of the instrumentation are on hand and the TV systems will be put into use in the winter of 1973.

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STATUS: Continued

Extensive work on Supernova 1972 e has been carried out in optical and infrared photometric observations. The IR measurements are believed to be the first ever attempted on such an event and resulted in several publications. A program to observe peculiar galaxies is under way with the goal of detecting energetic events. Measurements of galaxy 1c/62 indicate an infrared excess. Joint programs with Vanderbilt and Case are under way to study IR emissions from Seyfert-type galaxies and to look for UV excess sources, respectively.

Instrumentation to date consists of low and high dispersion spectrographs modified to use image tubes and low-light-level TV systems, infrared radiometer and polarimeter using both photo and bolometer infrared detectors.

Conclusion - Some ideas on supernovae events and rates were published (see publications). Also, from this work with electronic detection systems such as image tubes and low-light-level TV systems even moderately sized telescopes (40-90cm) become suitable for 17th and 18th magnitude objects, and techniques such as video subtraction can be used to enhance signal differences such as caused by polarization.

Problems - Conference attendance is extremely limited by budget constraints, making scientific interchanges difficult.

Forecast - Continue observations, including using more electronic techniques, and continue publication in the literature.

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7. REPORTS: Continued

A Video Data Acquisition System for Ground-Based Astronomy ASEE-NASA Summer Faculty Fellowship Program, MSFC	K. Honeycutt	Aug. 1973

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MSFC	01 04 73 to 30 09 73	188-41-54	188-41-01

4. TITLE:

SUPPORTING STUDIES FOR RELATIVITY EXPERIMENT

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. Decher, S&E-SSL-N	453-5130	R. Decher, S&E-SSL-N

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

OBJECTIVE(S): To develop techniques and methods for the implementation of the Gyroscope Relativity Experiment in collaboration with the principal and co-investigators at Stanford University. To perform theoretical analysis for various aspects of this experiment and to set up a laboratory experiment to test the different components of this experiment.

APPROACH: In-house experimental and theoretical work is performed in several laboratories (PE, SSL, ASTR), including support from contractors (UAH), to develop the technology and to solve instrumentation problems. Technology development is concentrated in the following areas: (1) design and precision manufacturing of a quartz rotor and quartz gyro housing; (2) development of more accurate measuring techniques for quartz gyro parts; (3) thin-film coating of quartz gyro parts with titanium and niobium; (4) development of a London Moment readout system for the gyro, including a highly sensitive squid-type magnetometer; (5) suspension, spin, and readout testing of the gyro at room and liquid helium temperatures; (6) optical contacting of quartz parts for the gyro assembly; (7) development of a low-temperature microelectronic amplifier for the gyro signal. In addition, a continuous error analysis is being performed to investigate error sources causing gyro drift and to optimize gyro design parameters.

STATUS: Technical Management - Suspension and spin-up tests with a hollow aluminum ball in a quartz gyro housing have been performed at room temperature. Maximum spin speeds between 50 and 100 rps have been achieved. Design of a low-temperature (liquid helium) apparatus for gyro spin tests has been started. Uniformity of metal coatings on the gyro rotor has been improved by modified sputtering techniques. A new design for a gyro housing and shielding structure has been completed, and corresponding parts

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No publications this reporting period.

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are now being made. Sputtering techniques have been developed which permit the reliable preparation of thin superconducting niobium films on special glass substrates.

Management Progress - The first room temperature spin-up in a quartz gyro housing is a major achievement. OSS reviewed the status of the experiment in June 1973. OSS would like MSFC to direct the development effort toward a possible Scout vehicle flight mission in 1978/79. A presentation to Dr. Naugle of such a plan was requested by the program manager.

Conclusion - As the result of various successes in the experiment development at Stanford University and MSFC, a flight of the gyro experiment in 1978/79 seems to be feasible.

Problems - This effort is a most difficult instrumentation development program, and many technical problems have to be solved.

Forecast - Work in the above areas will continue, with a first low-temperature gyro test expected during the first half of 1974.

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4. TITLE:

Relativity Celestial Mechanics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. A. Potter	453-3431	Herman P. Gierow, Director PD-MP-DIR

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Gyro Test of General Relativity

OBJECTIVE: Research, development and testing of a precision gyroscope capable of measuring relativistic precession. The gyro will be accurate enough to establish which of the present relativity theories best describe our physical universe.

APPROACH: An electrostatically suspended, cryogenically cooled, all quartz gyroscope is being developed. The gyroscope, when placed in earth orbit will be capable of measuring precessions of 0.1 arc seconds per year.

STATUS: Very significant progress has been made during this reporting period. The suspension system, the dewar, electrodes, magnetometer and all other subsystems were brought to the point where spinup of a quartz rotor in the ceramic house was accomplished. The rotor was suspended, spun to 16 Hz at cryogenic temperatures, with magnetic readout of trapped flux and correlated with the suspension error signals. Later runs resulted in "bucking" circuits reducing cross talk between the suspension system and magnetometer.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Status Letter for April		C. W. F. Everitt	April 30, 1973
Status Letter for May		C. W. F. Everitt	May 31, 1973
Status Letter for June		C. W. F. Everitt	June 29, 1973
Status Letter for July		C. W. F. Everitt	July 30, 1973
Status Letter for August		C. W. F. Everitt	August 31, 1973
Status Letter for September		C. W. F. Everitt	October 4, 1973

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4. TITLE:

Relativity Celestial Mechanics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. A. Potter	453-3431	Herman P. Gierow, Director PD-MP-DIR

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Mission Feasibility for Stanford Relativity Experiment on Scout.

OBJECTIVE: To determine if a meaningful scientific gyro relativity experiment could be performed on a satellite that could be launched by a Scout vehicle.

APPROACH: Given the experiment requirement, do a preliminary design of a spacecraft that can support the scientific requirement.

STATUS: The study concluded that significant science can be accomplished on a Scout launched spacecraft. The spacecraft parameters are:

Weight	168 kilograms
Power	90 watts
Data Rate	32 bits/sec
Orbital Inclination	37^{o}
Orbital Altitude	500 X 600 km
Launch Date	CY-79
Mission Life	3 months

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
F 73-03	Final Report	W. Follett T. Spencer W. Davis	June 22, 1973

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4. TITLE:

Relativity Celestial Mechanics

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. A. Potter	453-3431	Herman P. Gierow, Director PD-MP-DIR

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK TITLE: Helium Dewar Technology Studies

OBJECTIVE: Define and test critical areas of dewar design such as the superfluid plug, dewar instrumentation and the neck design.

APPROACH: Survey and evaluate existing components, breadboard and test most favorable approaches. Evaluate test results and incorporate into BBRC present dewar fabrication and testing program.

STATUS: The three areas, superfluid plug, instrumentation and neck design, have been surveyed. Laboratory apparatus has been fabricated for the superfluid plug studies and is being "debugged" and tested. No porous plug materials have been tested to date.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
Monthly Progress Reports		W. Davis	-

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MSFC	01 04 73 to 30 09 73	CURRENT NO.: 188-45-52	PRIOR NO.:

4. TITLE:
Meteor Astronomy

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
S. Clifton, S&E-SSL-PA	453-0183	R. J. Naumann, S&E-SSL-P

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: 1 Electro-Optical Support
TASK: 2 LLL TV Meteor Spectral Analysis

OBJECTIVES: Task 1: (a) To give electro-optical support of NASA airborne observations. (b) Improved definition and analysis of astronomical and atmospheric phenomena.
Task 2: (a) To determine the composition of shower and sporadic meteors. (b) To relate this data to the overall knowledge of meteor streams. (c) To develop techniques for the automated analysis of spectra.

APPROACH: Task 1: (a) To make observations with LLL TV systems aboard Convair 990 expeditions. (b) To use closed-circuit TV systems to transmit the data to other experimenters, expedition personnel, and pilots. (c) To video tape data for possible analysis and correlation with other experimenters.

Task 2: (a) LLL Sec vidicon systems will be used to record meteor spectra to as faint a magnitude as possible. (b) Analysis of spectra will be attempted both in-house and with a working agreement with the National Research Council of Canada. (c) Analysis techniques will be tested and developed to provide automated analysis of meteor spectra to be correlated with manual techniques. (d) Data from spectral studies will be correlated with photometric, orbital and other data pertaining to any shower.

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
NASA TND-6303, Airborne Meteor Observations at High Latitudes	K. S. Clifton	1971
NASA SP (paper in publication) Mass Influx Obtained from LLL TV Observations of Faint Meteors, presented at 13th IAU Colloquium	R. J. Naumann & K. S. Clifton	1972
NASA TMX Mass Influx from Low Light Level Television Observations of Faint Meteors	R. J. Naumann & K. S. Clifton	1972
Application of Coherent Optical Matched Filtering for Detection of Meteor Trails, in Proceedings of the Conference on Holography and Optical Filtering	Gee, Allen & Clifton	1973
Television Studies of Faint Meteors, submitted to the Journal of Geophysical Research	K. S. Clifton	1973

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STATUS: Task 1: LLL TV systems have been utilized aboard the 1969 NASA Airborne Auroral Expedition, the 1971 Barium Ion Cloud Expedition, and the 1972 Giacobinid Shower Expedition. Purchases in 1973 included video quantizer, scan converter, and bandwidth compressor to provide a wide analysis capability. Auroral tapes from the 1972 mission have been sent to ARC for redubbing and transmission to the University of Alaska.

Task 2: (a) 150 Perseid meteors have been obtained of which at least 30 should be analyzable. (b) An unspecified number of Orionid and Quadrantid meteor spectra have been obtained. (c) Analysis of the Perseid spectra is presently being accomplished by Dr. P. Millman of the National Research Council of Canada. (d) Investigations into automated analysis procedures are continuing.

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MSFC	01 04 73 30 09 73	CURRENT NO.: 188-46-64	PRIOR NO.:

4. TITLE:

COSMIC-RAY AND GAMMA-RAY ASTRONOMY INVESTIGATIONS

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
Thomas A. Parnell	453-5130	R. Decher, S&E-SSL-N

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Cosmic-Ray Astronomy

OBJECTIVE(S): To perform high resolution charge composition measurements of the cosmic-ray flux in the Z greater than 15 range; to develop instrumentation, methods and data analysis techniques for very large area detector systems for use in the Z greater than 30 range; to develop low cost, large area proportional counter hodoscopes; to perform calculations and analyses of particle energy deposition in thin dE/dx detectors; and to continue theoretical work on the energy loss of highly charged relativistic particles. A study will also be made of the feasibility of extending this class of detector systems to very large areas (≈ 25 m^2) for use in the Shuttle era experiments for high charge resolution measurements in the Z greater than 30 range. The balloon flight experiment will also be used in the CVT program.

APPROACH: Using detectors developed for the HEAO, a large area (0.25 m^2) multi dE/dx Cerenkov counter system will be assembled and flown on a balloon to perform a high resolution measurement of the iron group nuclei. The goal will be the determination of individual abundances from Z = 22 to Z = 30. Work will be continued to examine the energy deposition distributions (vice energy loss distributions) for high Z particles in very thin detector systems (such as ion chambers). These calculations will treat the statistical fluctuations (Vavillov distribution) and the transport of high energy delta rays with completeness so that accurate energy loss distributions will be available for use with data analysis techniques such as likelihood-ratio methods.

7. REPORT NO.: TITLE:	AUTHOR(s):	DATE TRANSMITTED
"Corrections to the Bethe-Block Formula for Average Ionization Energy Loss of Relativistic Heavy Nuclei-Close Collisions," Nuclear Instruments & Methods.	Peter B. Eby Samuel H. Morgan, Jr.	Mar 1973
"Nuclear Gamma Rays from Li^7 in the Galactic Cosmic Radiation," The Astrophysical Journal.	G. J. Fishman D. D. Clayton	Dec 1972
"Measurements of Cosmic-Ray Trajectories with a Proportional Counter Hodoscope," presented at 13th International Cosmic-Ray Conference, Denver, Colorado.	T. A. Parnell Godehard Guenther Udo Pollvogt	Aug 1973
"Predicted Intensities of Cosmic-Ray-Produced Gamma-Ray Lines," presented at 13th International Cosmic-Ray Conference, Denver, Colorado.	T. A. Rygg G. J. Fishman	Aug 1973

STATUS: Technical Progress

1. A detector system for investigating the Fe group CR has been prepared for a balloon flight and currently is in Palestine, Texas, awaiting the flight.

2. A study of appropriate gas mixture for high resolution parallel plate ion chambers has been made. The present balloon instrument uses an 8-cm dual gap with a 93% Xenon/7% methane mixture.

3. Calculations have been continued on the energy loss and energy deposition of trans iron cosmic rays. A computer code has been developed to calculate energy deposition as a radial function of distance from the track of a very, very high (VVH) cosmic ray in emulsion, etc.

4. Three papers were presented to the 13th International Conference on Cosmic Rays.

Management Progress -- Contract NAS8-24953 with the Research Institute, Unversity of Alabama, Huntsville, will be extended.

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7. (Continued)

"Calculation of Energy Loss by Highly Charged Particles and the Interpretation of Cosmic-Ray Data," presented at 13th International Cosmic-Ray Conference, Denver, Colorado.	Peter B. Eby Samuel H. Morgan Jr. T.A. Parnell	Aug 1973
Large Volume, High Efficiency Scintillation Detectors using Multiple NaI (Tl) Crystal Pieces, "Nuclear Instruments and Methods"	G. J. Fishman D. M. Walker	Mar 1973
Induced Radioactivity Contributions to Diffuse Gamma-Ray Measurements, "NASA SP Publication" (in progress).	G. J. Fishman	May 1973

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TASK: Gamma-Ray Astronomy

OBJECTIVE(S): To implement a program to increase the sensitivity of gamma-ray astronomy experiments and to incorporate these advances in a balloon-borne detector system. The results of this investigation will be used in the definition of future space shuttle gamma-ray astronomy experiments. The program will include; the development and balloon flight testing of lower cost, large area crystal scintillation detectors; testing of active shielding systems; calculations and measurements of cosmic-ray-induced background; development of an on-board spectral memory and analysis system for telemetry rate reduction; and a continuation of theoretical calculations in gamma-ray astrophysics.

APPROACH: Large Area Detector Development - A new technique for producing large volume, high efficiency scintillation detectors using NaI (Tl) crystal pieces will be evaluated for use as a large area gamma-ray astronomy detector. By combining this type of detector with large plastic scintillators and using the pulse shape discrimination, it is believed that high gamma-ray efficiency as well as good charged particle rejection could be obtained. This concept will be utilized in the design of a balloon-borne detector system which will also include several new data compression schemes to preserve high spectral and time resolution with a large counting rate while maintaining a reasonable telemetry rate. The detector will then be used in a gamma-ray astronomy program to determine the spectral characteristics of various celestial objects and the galactic plane. Of special interest will be the measurement of a gamma-ray line feature near 470 keV from the galactic center region reported recently by the Rice University group. An attempt to measure the nuclear excitation lines from carbon and oxygen will also be made. Other scientific objectives of the balloon flight program will include the measurement of gamma-ray pulses for the objects Her X-1, NP0532, and PSR0833.

The present plan of research will continue the analytical and experimental investigation of the local background radiation. Of particular importance for low altitude orbiting experiments is the activation of spacecraft materials during passes through the trapped radiation belts. The spectral and time characteristics of the activation radiation will be computed using codes developed at Oak Ridge National Laboratories (ORNL) and MSFC. The experimental work on this program will consist of gamma-ray spectral measurements of spacecraft materials which have been irradiated by protons. This experimental work is already in progress.

STATUS: 1. A successful balloon flight experiment was conducted August 11, 1973, from Palestine, Texas. The sun and the Crab Nebula were observed in the energy range from 50 keV to 6 MeV. The payload was at float altitude for 9 hours and landed in good condition near El Paso, Texas. Data analysis is now in progress.

2. Measurements of induced radioactivity by neutrons and protons are continuing using a recently acquired high efficiency Ge(Li) detector. Several samples from Skylab are scheduled to be measured as well as artificially irradiated samples from particle accelerators and nuclear reactors. Computer programs used in calculating induced radioactivity have been written and debugged.

3. A neutron activation experiment for the SL-4 mission has been tentatively accepted by the Flight Management Team (FMT) meeting in Houston. Experiment integration is now under way.

4. A new large area detector is being designed for balloon flight use. A prime objective of this detector is to search the entire sky for low intensity gamma-ray bursts. The detector will also be used for studying other time-varying gamma-ray phenomena such as solar flares and pulsars.

5. The feasibility of flying a small Ge(Li) detector on a superpressure balloon for at least 2 months is being studied.

6. The application of recently developed gamma-ray astronomy (instrumentation and data handling) techniques for Shuttle payloads is continuing.

Management Progress - Contract NAS8-26343 has been extended with Brown Engineering Company, Inc., Huntsville, Alabama.

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4. TITLE:

Interdisciplinary Space Research

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
E. Stuhlinger	205-453-3033	E. Stuhlinger

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Interdisciplinary Space Research

OBJECTIVE: To conduct space research in various scientific disciplines with a capability of directing "quick reaction" efforts towards significant problems or promising areas of research.

APPROACH: Under the direction of the Associate Director for Science, Dr. Ernst Stuhlinger; research is initiated in scientific and technical areas that influences the scientific missions of the MSFC. Projects are selected which, within available resources, contribute significantly to in-house scientific capabilities and state-of-the-art advancement. Four projects were funded in FY-71: (1) support to a balloon-borne gamma ray astronomy research project, (2) design study and concept verification of a three-element glancing incidence mirror for an X-ray telescope, (3) support for design of a telescope in a phased array radar system which offers advancement of crossed beam technology and possibilities for space ranging, (4) continuing support to the MSFC millimeter wavelength solar astronomy program. In FY-72, three concepts were funded: (5) a new project, testing of thermal control concepts, primarily in heat pipe technology. A test article simulating a space telescope consists of a mirror blank within a 112-inch structural tube. The thermally instrumented test article would be placed in a space simulation chamber to then evaluate thermal control concepts (primarily in heat pipe technology) that promise to reduce gradients to an acceptable level. Also in FY-72, support was continued to the gamma ray astronomy project (1) and the three-element X-ray telescope project (2). In FY-73, four new projects were

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selected: (6) research on graphite epoxy materials applicable to Large Space Telescope (LST) structural use, (7) a study on constructing the LST to metric dimensions, (8) support to complete elements of the phased array laser radar system, (9) refinement of a three-dimensional holographic motion picture system. Support continued to the thermal control, gamma ray astronomy and three-element X-ray telescope projects. For FY-74, the graphite-epoxy research project (6) received additional support. Other potential FY-74 projects are being evaluated.

STATUS: Technical Progress: (1) Gamma Ray Astronomy - A successful balloon flight was made August 9, 1973, with 10 hours at float altitude, observing the Crab Nebula and the Sun. Data from the flight is being analyzed, with completion anticipated in early 1974. A large area gamma ray detector is being designed. (2) Three-Element X-Ray Mirror - An aspheric abberation free third-element mirror was fabricated and received; it will be used with existing ATM Experiment S056 hardware to verify the three-element concept. (3) Telescope Design - The design of a laser radar cassegrain telescope, funded partially by Space Research funds, is completed. (4) Millimeter Astronomy - Observations are continuing at the 3-millimeter wave lengths at the MSFC facility and at the 8-millimeter wave lengths at the Naval Electronics Laboratory's La Posta, California, observatory. (5) Heat Pipe Technology - The test article was thermally cycled within the space simulation chamber. Resulting data is being analyzed; preliminary results indicate that adequate thermal control of the primary mirror may be possible without using heat pipes. (6) LST Materials Research - Graphite epoxy resin materials with high elasticity modulus and low expansion coefficients were procured, made into laminates and evaluated for certain physical properties. Preliminary results indicate good potential for LST structural use with outstanding dimensional stability. (7) LST Metrication - The completed study contract concluded that metrication is feasible with little impact upon schedule or cost, and furnished guidelines for achieving metrication. (8) Phased Array Laser Radar System Support - Funds were provided to develop data acquisition electronics in-house and to check out the design of the single aperture coaxial cassegrain telescope. The acquisition electronics are being completed and tested, and the calibration of the telescope and the electronics integration with the telescope are being performed. TM X-64753, "Phased Array Laser Radar, Concept and Application," was published in this period. (9) Three-Dimensional Holographic Motion Picture System - Equipment was procured with Space Research funds; one item, a film transport unit, was defective and was returned to the vendor. Work has been delayed, pending return of the unit.

Management Progress- Not applicable.

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MSFC	01 04 73 to 30 09 73	188-78-51	

4. TITLE:

HOLOGRAPHY TECHNIQUES AND APPLICATION

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
R. L. Kurtz, S&E-SSL-PO	453-0941	R. J. Naumann, S&E-SSL-P

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Holographic Particle Analysis

OBJECTIVE(S): To pursue and develop, both experimentally and theoretically, the technique of holographic particle detection and evaluation to be applied to the problems of optical and space contamination and to the problems of Earth resources and pollution.

APPROACH: To employ existing expertise in the field of holography to the development of a field-ready system capable of particle and particulate analysis of a large volume. To be able to capture the entire volume and its particles simultaneously with one exposure and then to be able to reconstruct this entire volume for investigation at a later more convenient time. To incorporate an automatic computerized system (presently existing) into this holography system so as to completely and automatically analyze the entire particle volume quantitatively.

STATUS: Technical Progress - 1. Several holographic particle analysis systems have been employed by MSFC to study problems of optical/space contamination on large space programs such as Skylab. 2. Numerous reports have been published on various prototype techniques. 3. This present existing experience and knowledge may be used to develop a useable field-ready composite technique to be applied to multiple and various problems of contamination and pollution.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
None			

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TASK: Real-Time Three-Dimensional Motion Picture Camera System

OBJECTIVE(S): To pursue and further develop a new holographic moving scene camera system which has demonstrated its ability to provide real-time images from moving scenes in three dimensions and to provide front surface detail from these images which is readily viewable without special glasses.

APPROACH: To further research and develop, improve and refine this unique camera system so as to improve its performance. To incorporate several already patented improvements into the system so as to allow the camera to investigate larger and more rapidly moving scenes. To provide and obtain the necessary additional subsystems, (laser, film transport, etc.) to fabricate a prototype system which will have virtually unlimited application to space and environmental research problems as an optical instrumentation tool.

STATUS: Technical Progress - 1. The basic system was successfully demonstrated in October 1972 by the reconstruction of real-time 3-D motion images from a 100-ft roll of 70-mm film. 2. The system has received national and international press coverage as well as a commendation from the Nobel prize winner for holography, Dr. Dennis Gabor. 3. The basic system presently is multiply patented and published. 4. Several foreign countries are already employing this basic system in their applications. 5. The system is being employed in the Zero "g" Cloud Physics program at MSFC/NASA. 6. The additional applications of the more advanced version of this system will be virtually unlimited; e.g., application to meteoroid impact simulation studies, earth resources, medicine, biology, etc., and providing basic optical instrumentation for all high-transient, large-volume investigations.

TASK: Composite Mobile Holographic Nondestructive Testing System

OBJECTIVE(S): To pursue and further develop a MSFC-patented technique for holographic nondestructive evaluation. To develop this system to its patented design of being a mobile technique capable of performing nondestructive evaluation outside the laboratory in a field environment. To additionally develop a prototype of this system capable of performing all modes of nondestructive testing from one basic mobile system; presently several different systems are required, none of which is mobile.

APPROACH: Using the basic design for the patented system, a prototype will be fabricated and tested as a mobile system capable of composite holographic evaluation. Theoretical and analytical studies will be conducted to further elucidate the quantitative aspects of its evaluation potential. Calibration techniques will be developed so as to expedite the composite testing techniques of the system. Finally, the prototype system will be field tested on the evaluation of large and small objects.

STATUS: Technical Progress - 1. The basic system has been designed and the uniqueness of the design has been verified by patent disclosure and search. 2. Several publications on the technique already exist, including a NASA Tech Brief and an invited paper in an international journal. 3. The basic system has already been successfully applied to the radome problems of the Army's Pershing Missile System, providing a quantitative evaluation of debonds in a sandwich structure. 4. The basic system is presently being applied to the Space Shuttle Main Engine (SSME) to quantitatively detect debonds and "near debonds" of electro-plated coatings on the surface of the engine housing.

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STATUS: Continued

This system is felt to be the only system in existence having potential for the detection of "near debonds" vital to the successful operation of the SSME.

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4. TITLE:

Large Space Telescope

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
J. R. Parker - S&E-ASTR-GDA	453-4276	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Fine Guidance Sensor
NAS8-29918 ITT Gilfillan

OBJECTIVE(S): The LST requirements are ±5 microradians, pointing, and 0.024 microradian rms, stabilization, over a 40 hour observation period. From this a 0.012 microradian error for stability, based on 2 Hz. control gain crossover frequency, is allocated to the fine guidance sensor. This task will investigate ways of obtaining the desired accuracy and develop a sensor to perform to the given specifications.

APPROACH: (1) Investigate electromagnetic and electrostatic image dissector tube performance as potential candidates for the sensing element. Under contract make modifications to the ITT 4012RP image dissector tube to improve linearity, resolution and uniformity across the photocathode. (2) Investigate charge coupled device (CCD) technology for possible implementation into the fine guidance sensor. CCD's are in the development stage but appear to have great possibilities as the sensing element. (3) Design, in-house, a stable current regulator and drift tube voltage regulator that have regulation of 200 parts per million or better. (4) Build and test a breadboard configuration of a fine guidance sensor.

STATUS: Technical Progress--(In-house) A current regulator has been designed, breadboarded, and tested. This device has a change of 500 PPM over a 40°C temperature range. This should be adequate over the LST temperature but additional refinements are being investigated.

A breadboard sensor design has been tested for linearity and sensitivity. (See

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	"Monthly Progress Report" For Period 23 July 1973 to 31 Aug. 1973	ITT Gilfillan	

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Using two inch optics 6th magnitude stars were detectable and non-linearities of less than 1% were measured over 0.5 inch of photocathode.

Management Progress--A contract was awarded to ITT, NAS8-29918 for construction of an improved 4012RP image dissector tube and a mated deflection coil assembly. Design goals were specified and the hardware is in the build stage.

The Naval Electronics Laboratory is coordinating the Government effort in charge coupled device technology. A briefing was held in September with nine of the companies involved in CCD development. Competition is very keen between companies and information is slow in being released. Fairchild has marketed a CCD and plans are underway to obtain one of these devices.

Problems--Design verification is very difficult without an engineering model of LST. Tests are very long and must be repeated many times to approach the high accuracy required for pointing and stabilization. Analysis must then be performed to scale the results.

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4. TITLE:

Large Space Telescope

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
P. Golley S&E-ASTR-GM	453-5755	R. H. Tutt

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Dual-Spin Gas Bearing Reaction Wheel
NAS8-29013 Martin-Marietta; Denver, Colorado

OBJECTIVE: To provide a bi-directional momentum exchange device which has sufficient torque resolution and produces sufficiently little noise and vibration that it can be used to provide the extremely precise pointing control required for astronomical observations.

APPROACH: This task consists of development, fabrication, and test of +5 ft-lb-sec reaction wheel in which the rotor is supported by hydrodynamic pressure generated by a small self-pumping inner spin-structure concentric with the inertia rotor axis. The inner spin-structure is driven by a constant speed ac motor. The inertia rotor is driven by a variable speed ac motor. Speed will be measured by an optical tachometer. The motors and speed transducer are all brushless to minimize frictional effects.

STATUS: Technical Progress - All parts have been manufactured. Unit has been assembled and is undergoing testing without the full rotor mass. Preliminary test results are very encouraging. Unit has been run with spin axis horizontal. Full speed has been reached in both the co-rotating and counter-rotating directions, and the orbits of the spinning elements are stable. Delivery is now expected in December 1973.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED

NOTE: Only fragmented letter-type progress reports are available at present. A final report will be issued at the end of the effort.

FIRST BENEFITTING PROJECT: Large Space Telescope

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4. TITLE:

LST

5. RESPONSIBLE INDIVIDUAL:	TELEPHONE:	APPROVAL:
G. S. Nurre S&E-ASTR-A	453-4718	Hans H. Hosenthien

6. ACCOMPLISHMENTS (Milestones, Problems, Near term activities):

TASK: Fine Pointing Control System, NAS8-28983, Bendix

OBJECTIVE: The objective is to show the feasibility of achieving the required pointing accuracy ($\sim .005$ sec) for the LST of body-pointing as opposed to an image motion controller within the telescope itself.

APPROACH: A baseline system will finally be selected that is based on the results of previous studies. The system characteristics and disturbances will be accurately modeled, and a large scale digital simulation will be developed to solve the nonlinear equations. This work will be supported by a simplified single axis system analysis and analytical work. Computer runs will be made to show pointing accuracies for realistic system characteristics and to determine system sensitivities to control parameters. These results will show whether or not the required accuracies can be achieved by body-pointing.

STATUS: All cases for the momentum actuator control fine pointing system have been run and the data is being compiled. The secondary mirror controller is presently being programed so that its performance can be assessed and compared to the body pointing system. A no-cost overrun is the result of numerous interuptions due to the Skylab mission.

7. REPORT NO.:	TITLE:	AUTHOR(s):	DATE TRANSMITTED
LST-PC-201	Imbalanced Double Gimbaled CMG	S. C. Rybak	Dec. 19, 1972
LST-PCS-204	Nonlinear Model for Reaction Wheel	S. C. Rybak	Dec. 19, 1972
LST- PCS-205	Sensor Noise	S. C. Rybak	Dec. 19, 1972
LST-PCS-204	RW Actuator Model for Fine Pointing	S. C. Rybak	Dec. 19, 1972
LST-PCS-200	Imbalanced SGCMG	R. A. Mayo	Jan. 1973
LST-PCS-202	Verification of Model for SGCMG	R. P. Headley	Jan. 1973
LST-PCS-203	Verification of Model for DGCMG	R. P. Headley	Jan. 1973
LST-PCS-206	Reaction Wheel Actuator Model	R. P. Headley	Jan. 1973

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