JPL Capabilties for the

Railroad Wheel Failure Mechanisms and Test Facility Project

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The Federal Railroad Administration
Office of Rail Safety Research
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by

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

FORWARD

JPL is pleased to present to the U.S. Department of Transportation, Federal Railroad Administration, Office of Rail Safety Research this document that describes some of JPL's applicable capabilities for the Railroad Wheel Failure Mechanisms and Test Facility Project.

Additional information concerning the contents of this document may be obtained by telephoning the undersigned at (213) 354-4080 or FTS 792- 4080.

W. A. Edmiston
Proposal Manager

CONTENTS

1. INTRODUCTION TO JPL

The Jet Propulsion Laboratory (JPL) is a federally funded research and development center. The California Institute of Technology (CIT) is a private, non-profit, educational institution chartered under the laws of the State of California. The Jet Propulsion Laboratory is an operating division of Caltech. Under contract NAS7-100 with NASA, CIT/JPL is responsible for the NASA deep space exploration program and performs selected R&D tasks utilizing facilities provided by the U. S. government. Unique among research laboratories, JPL has worked within the framework of various Federal programs for 40 years, and has had long, successful affiliations with government and industry in managing major projects in defense, aerospace and civil systems. These relationships have resulted in generating capabilities applicable to the reduction of technical and economic uncertainties related to new technologies.

Although the Laboratory's primary role is the scientific investigation of planets, using automated spacecraft, JPL does conduct selected projects to develop and apply new technologies to the solution of problems on earth. More than 100 tasks are currently being studied and developed in transportation, energy, pollution and bio-medical technology.

JPL's affiliation with Caltech, and the lack of connection with any commercial interests , has permitted JPL to maintain an objective position in considering technical issues.

2. THE CALIFORNIA INSTITUTE OF TECHNOLOGY

In the advancement of science and technology, the best is vastly more important than the next best. The California Institute of Technology attempts to meet the highest standards in education and basic research. Faculty members are selected with great care--their skills in individual and cooperative research are vital to maintaining Caltech as a center for excellence. Seventeen Nobel Prizes have been won by faculty and alumini of Caltech. Four Nobel Prize winners are now in residence. Forty-four current faculty members have been elected to the National Academy of Sciences and twenty-one to the National Academy of Engineering, both the highest percentages for any university faculty.

The research interests of the Caltech faculty are in fields of particular challenge and opportunity. There are six academic divisions:

Biology
Chemistry and Chemical Engineering
Engineering and Applied Science
Geological and Planetary Sciences
The Humanities and Social Sciences
Physics, Mathematics and Astronomy

Caltech operates the Owens Valley Radio Observatory, the Hale Observatories (jointly with the Carnegie Institution of Washington), and the Jet Propulsion Laboratory (for the National Aeronautics and Space Administration). The Environmental Quality Laboratory (EQL) was created in 1971 to seek solutions for some of the most pressing environmental problems.

Of particular value to JPL's programs are interactions between JPL and the Caltech faculty, and between JPL and the Caltech Industrial Associates Program.

3. JPL HISTORY

The Laboratory can trace its history back to 1936, when a group of Caltech students led by Theodore von Karman began to experiment with rocket techniques. By the end of the decade, this embryonic organization was doing work for the U.S. Army Air Corps and performing experiments in support of high-altitude meteorological research. In 1944, JPL began a long association with the Army Ordnance Corps, which culminated in the design and development of the Nation's first operational surface-to-surface ballistic guided missile system and the first inertially guided solid-propellant missile. In 1958, with the assistance of the Army, JPL developed and orbited Explorer I -- the first U.S. Earth Satellite.

During the latter part of 1958, sponsorship of the Laboratory was assumed by the National Aeronautics and Space Administration. Since that time, JPL's primary mission has been to design and develop automated spacecraft to support the NASA program of lunar and planetary exploration. In penetrating beyond the immediate terrestrial environment, JPL developed technical capabilities responding to a unique set of mission requirements: sophisticated analytical methods and guidance concepts which enable the navigation of payloads into precise orbits to the planets; microelectronic circuits and computerized control systems of the highest order of reliability; structures and instrumentation meeting the most exacting standards of operation; and communications techniques and components for monitoring spacecraft over the vast distances to the planets, controlling their operations, and recovering scientific and engineering data at extremely high rates.

The Jet Propulsion Laboratory, located in Pasadena, is situated in the foothills of the San Gabriel Mountains. This 165 acre site houses offices, equipment, test and operations facilities to support the activities of a technical staff numbering close to 4,000 people.

Other JPL installations include an astronomical observatory at Table Mountain, California, a major test station at Edwards Air Force Base, California and a launch operations site at Cape Canaveral, Florida.

The technological demands of in-house programs have necessitated an acquisition of test and analysis equipment which inventories well above $100M. Associated supportive skills combined with this, have placed JPL in the position of participating in a selective, but broad range of "civil applications" activities under the Energy and Technology Applications Program.

JPL continues to demonstrate the ability to manage large projects involving industry, government and universities. Such projects require in-house hardware and software development, facilities development and utilization of industry in the most effective manner during each phase of activity.

Adding to the success of the varied tasks is the Laboratory's record of completing projects on schedule and within alloted budgets.

4. ENERGY AND TECHNOLOGY APPLICATIONS PROGRAM

The rapid development and application of new technology to national needs is a major activity of the twentieth century. The explosion of technical progress applied to military and social purposes in production of foods and goods, transportation and communication, shelter and comfort, and medicine has changed our lives greatly in the past years.

More recently the need to place all this in balance -- to clean up the environment, conserve resources, and improve transportation -- has taken the spotlight.

The developments have occured at a time when the reach of new technology has expanded beyond the surface of the earth, and the means of measurement and study have been enhanced by machines such as the spacecraft and the computer. JPL is aiming these capabilities toward home.

JPL was exploring earth-based use of solar-electric energy conversion devices developed for spacecraft and studying alternatives to the internal-combustion automobile engine before the energy "crisis" of 1973. These, along with adaptations of rocket combustion research, spacecraft instruments and data processing systems, space communications, special materials research, and system analysis, were part of the endeavor to apply space technology to terrestrial applications. In recent years, energy technologies, especially in the solar field, have grown to be an important part of the Laboratory's effort, which is now called Energy & Technology Applications.

JPL has developed strong skills in energy systems analysis and engineering. Originally derived from space mission planning and operations, these skills have been augmented in the course of JPL's energy activities, in the area of solar energy, and now transportation.

As the energy crisis grows, all aspects of conservation must be analyzed -- in particular, transportation. The transportation sector of our economy is the major user of petroleum in the United States, and highway vehicles have been the largest consumers. One outgrowth of this will be a closer look at the efficiencies offered by rail transportation.

JPL led the recent review of alternative automobile engines with a 1974 study sponsored by the Ford Motor Company and, at about the same time, developed a low-pollution, low-waste, hydrogen-injection device for automobile enginees. Now it is managing an Electric and Hybrid Vehicles R&D Project for the Department of Energy. The Laboratory is also pursuing several efforts to improve the efficiency of vehicle systems, including trucks and buses.

Considering the total transportation system, JPL is developing an automated traffic sensor system, and performing studies of rail and subway systems and technology, for the Department of Transportation. In addition to energy conservation, this kind of research and development also considers reliability, economics, safety, environmental protection and institutional factors.

5. TRANSPORTATION ACTIVITIES

The Transportation Systems Office (of the Energy and Technology Applications Program at JPL) has had responsibility for a number of tasks related to the subject project. A summary of these pertinent tasks is given below. Additional details can be supplied to FRA, if desired.

- Automotive Test Facility (ATF)

  In the early 1970's JPL converted one of its laboratory buildings that previously supported space exploration into an automotive test facility. This capability includes engine development testing and complete automobile propulsion system testing, as well as basic research in combustion and catalytic fuels conversion.

  Originally the ATF was used for gasoline reforming and internal combustion engine developments for NASA, EPA and ERDA. At present, a Stirling Laboratory Research Engine is under test in the ATF for NASA and numerous tests are being performed on complete electric and hybrid vehicles for the DOE.

- Detonation Arrester Test Facility (DATF)

  Because of the hazardous nature of the tests desired by the U.S. Coast Guard, JPL relocated its six-inch shock tube facility from the main Pasadena facility to a converted rocket engine test stand at the JPL Edwards Test Station (ETS). The current two year project will be followed immediately by another 16 months Coast Guard project (which has already been approved and funded) using the DATF. In all, both fundamental tests projects will exceed three years in duration at the same dedicated test facility.

- Pueblo Linear Motor Reaction Rail Analysis

Cracking developed in the aluminum reaction rail. JPL was called in to assist the team at the FRA Transportation Test Center Near Pueblo. Weld metallurgical studies and stress and thermal analyses yielded both quick-fix and permanent solutions to the rail failures.

- Electric Traction Studies

For the last four years JPL has been supporting FRA, Office of Passenger Systems in studies and simulations. The overall thrust has been to study new developments in railroad technology abroad, select promising technologies in electrification and traction, and assess their potential impact if introduced into North American operations. Studies of foreign literature, often in the author's native language, and visits with European railroad researchers has provided JPL with an excellent data base and broad range of contacts.

Initially, JPL used a large, complex existing computer program for simulation runs. To cut costs and run time, JPL wrote a simple performance simulation program which checked out when compared to an American and a French program.

- Future Propulsion Systems for Railroad Locomotives

JPL is conducting a three phase investigation for the Department of Energy which addresses the feasibility of alternate heat engines and fuels for locomotive propulsion. Phase I, which has recently been completed, develops performance and cost analysis methodology and focuses on the diesel-electric locomotive as a "moving baseline".

FRA personnel participated in a status review last January shortly after the project was initiated. Mr. Robert Parsons (Associate Administrator for Research and Development, FRA) agreed to serve as a member of a review board for this project which is convened at the end of each phase.

- Effects of the Physical Properties of Non-Metallic Materials on Rail Vehicle Dynamic Characteristics

This study for the FRA, Office of Rail Safety Research, consists of studies, tests and analyses of elastomeric materials. The initial focus is on locomotive pads and pad materials as a function of loading conditions, temperature and load history.

A great deal of the required capabilities to perform this project are already available at JPL (e.g., 3-D finite element, visco-elastic stress analysis program, the environmental test facility, and the materials test facility).

6. SELECTED JPL CAPABILITIES

The scope of JPL capabilities is wide ranging, however, the following are presented as pertinent to supporting a "Railroad Wheel Failure Mechanisms and Test Facility Project."

6.1 Structural, Dynamics and Thermal Engineering
6.2 Materials Engineering and Laboratory
6.3 Environmental Testing and Laboratories
6.4 Instrumentation Engineering
6.5 Facility Design/Construction/Operation

6.1 STRUCTURAL, DYNAMICS AND THERMAL ENGINEERING

The engineers and scientists in the Structures, Dynamics and Thermal Science disciplines provide structures and dynamics, and thermal analysis, design, and test support to various activities including the JPL Flight Projects and the Energy and Technology Applications Office. In addition to technical support, task management and contract monitoring are provided. Tasks, which are frequently interdisciplinary in nature, include developing and applying new technologies in the fields of solid mechanics, structures, dynamics, and structural dynamics as well as radiation, conduction and convection heat transfer.

Extensive experience has been compiled by our staff of about 100 personnel in all phases of their disciplines. Specific experience lies in the following areas:

- Analysis

  Static and dynamic analyses of structural systems using finite element techniques and thermal analysis using lumped parameter, Taylor's and Allen's finite difference techniques. Applications range from spacecraft to power plants, submarines, and a variety of science instrument packages. Includes applications of aerospace technology to problems in terrestrial energy such as the analysis of geothermal reservoirs, thermomechanical analyses of photovoltaic encapsulants, thermal/photovoltaic interactions, thermoelectric devices for power or cooling, and cryotechnology.

- Design

  Design of space and terrestrial structures, including design for fracture mechanics criteria of pressure vessels.

- Testing

  Experience in static and dynamic testing of spacecraft structures, modal testing, forced vibration testing, static testing, material evaluation testing, and thermal simulation testing including effects of vacuum, solar, and planetary influences.

- Rigid Body Dynamics Analysis

  Analysis of Spacecraft separation dynamics.

- Research in Structural Dynamics

  Development of new tools for the analysis of linear and non-linear structural systems. An application is large space structures.

- Research in Thermal Areas

  Development of new methodologies, algorithms, and computer programs for which existing software proves inadequate. Areas of application of this capability include terrestrial solar collectors, terrestrial solar irradiance studies and Stirling engines. Space applications include photovoltaics, thermoelectrics and cryotechnology and large space structures..

- Task Management and Contract Monitoring

  Task management expertise in the area of structures and dynamics for flight projects such as the Infrared Astronomical Satellite (IRAS) and the Internal Solar Polar Mission (ISPM) and terrestrial energy projects such as the advanced solar concentrator.

CHUNG KIN CHAN

EDUCATION: B.S.M.E., University of California, Berkeley (1969)
M.S.M.E., University of California, Berkeley (1970)
Ph.D.M.E., University of California, Berkeley (1972)

CURRENT ASSIGNMENT: Design of cryogenic refrigeration system for regions below 100^{o}K.

EXPERIENCE: (1974 to 1975) Assistant Professor in Residence, School of Engineering and Applied Science, University of California (UCLA). Research projects include theoretical and experimental study of two phase phenomenon in Pressure Suppression Pool, containment heat transfer, risk and benefit of containment design, emergency core cooling heat transfer and hydrodynamic, LWR transient, LMFBR safety, and fusion safety. Teaching assignments include undergraduate and graduate courses of thermodynamic, reactor kinetics, boiling and two phase flow, thermal reactor safety, fast reactor safety and heat transfer.

(1973 to 1974) Engineer, Nuclear Services Corporation. Developing analytical methods and computer codes for loss of coolant and other light-water-reactor safety analyses, computer codes to evaluate blowdown force, building pressure and environmental impacts due to a pipe rupture in the secondary system of Pressurized Water Reactor.

(1969 to 1972) Research Assistant, University of California, Berkeley. Research projects include theoretical and experimental study of cryogenic super-insulation (Multilayers and Microspheres), anomalous radiation phenomenon at low temperature and infrared radiation of thin films.

CHUNG KIN CHAN (continued)

SELECTED PUBLICATIONS:

1. "Infrared Radiation of Thin Plastic Films," with C. L. Tien and G. R. Cunnington, Journal of Heat Transfer, 94, 1:41-45 (February 1971).

2. "Lateral Heat Transfer in Cryogenic Multilayer Insulation," with C. L. Tien and P. S. Jagannathan, Advances in Cryogenic Engineering 18 (1972).

3. "Conductance of Packed Spheres in Vacuum," with C. L. Tien, Journal of Heat Transfer, 95, 3:302-308 (August 1973).

4. "Radiative Transfer in Packed Spheres," with C. L. Tien, Journal of Heat Transfer, 96, 1:52-58 (February 1974).

5. "Combined Radiation and Conduction in Packed Spheres," with C. L. Tien, Proceedings of the Fifth International Heat Transfer Conference, Tokyo, Japan, September 3-7, 1974.

6. "Containment Pressurization from Helium Pipe Rupture in a Tokamak," ANS Transactions, 22 (November 1975).

7. "Failure Modes of Ice Condenser Containment Designs Following Postulated Core Meltdown," with D. Okrent, ANS Transaction, 23 (June 1976).

JAY C. CHEN

EDUCATION: Ph.D. in Aeronautics - 1971, California Institute of Technology.
M.S. in Aeronautics - 1964, California Institute of Technology.
B.S., M.E. - 1962, Taiwan Cheng-Kung University.

CURRENT ASSIGNMENT: Engaged in various aspects of JPL flight projects, developing sophisticated analytical tools for the analysis of structures and spacecraft separation dynamics. Recently engaged in various research activities, specifically in developing methodology for cost effective loads prediction. Also been engaged in adapting aerospace technology for the analysis of terrestrial systems.

JAY C. CHEN (Continued)

SELECTED PUBLICATIONS:

1. "On the Dynamic Stability of Multilayer Sandwich Plates", the Journal of Structure Mechanics, Vol. II, No. 4, June 1974.
2. "Determination of Propellant Effective Mass Properties Using Modal Test Data," presented at the 45th Shock and Vibration Symposium, Dayton, Ohio, October 22-25, 1974; also published in its Bulletin.
3. "Criteria for Analysis--Test Correlation of Structural Dynamic Systems" Journal of Applied Mechanics, Vol. 42, No. 2, pp 471-477, June 1975.
4. "The Nonlinear Vibration of Cylindrical Shells," AIAA Journal, Vol. 13, No. 7, pp 868-876, July 1975.
5. "Experience in Using Modal Synthesis within Project Requirements," 46th Shock and Vibration Symposium, San Diego, California, October 21-24, 1975. JPL TM 33-729.
6. "Use of Fracture Mechanics to Design A Viking Orbiter Pressure Vessel," presented at JANNAF Combined Annual Meeting, February 25-28, 1975, Presidio of San Francisco, California.
7. "Matrix Perturbation for Structural Dynamic Analysis," AIAA Journal, Vol. 15, No. 8, pp 1095-1100, August 1977.
8. "Finite Element Solutions for Geothermal Systems," Journal of Energy, Vol. 1, No. 6, pp 364-369, Nov-Dec., 1977.
9. "On the Launch Vehicle Payload Interface Response, Journal of Spacecraft and Rockets, Vol. 15, No. 1, pp 7-11, January 1978.
10. "Estimation of Payload Loads Using Rigid Body Interface Acceleration," Journal of Spacecraft and Rockets, Vol. 16, No. 2, pp 74-80, March 1979.
11. "Summary of Voyager Design and Flight Loads," JPL Publication 78-74, Jet Propulsion Laboratory, Pasadena, California, September 1, 1978.
12. Voyager Design and Flight Loads Comparison," Journal of Spacecraft and Rockets, Vol. 16, No. 1, Jan-Feb. 1979, pp 27-34.

JOHN A. GARBA

EDUCATION: MSME - 1961, California Institute of Technology
BSME - 1958, University of Illinois
Registered Professional Mechanical Engineer, State of California, Certificate No. M14617.

CURRENT ASSIGNMENT: Supervisor of Dynamics Analysis Group.

EXPERIENCE: Responsible for the structures and dynamic analysis for the IRTF in the time period of December 1974 to the present. From 1969 to 1975, cognizant engineer for the Viking Orbiter spacecraft dynamics, responsible for Viking structural models and dynamic loads. Prior to 1969 the various responsibilities included cognizant engineer for the Capsule Advanced Development Martian Aerospace Analysis and Testing, cognizant engineer for the Surveyor Landing Dynamics Program, and Structural Analysis support to the Large Area Solar Array Study.

JOHN A. GARBA (continued)

SELECTED PUBLICATIONS

1. Wada, B. K., Garba, J. A., and Chen, J. C., "Development and Correlation: Viking Orbiter Analytical Dynamic Model with Modal Test," The Shock and Vibration Bulletin, Bulletin 44, Part 2, August 1974, pp. 125-164. Also published as JPL Technical Memorandum 33-690, June 1, 1974.
2. Brownlee, G. R., Day, F. D., and Garba, J. A., "Analytical Prediction and Correlation for the Orbiter During the Viking Spacecraft Sinusoidal Vibration Test." The Shock and Vibration Bulletin, Bulletin 45, Part 3, Naval Research Laboratory, Washington, D.C., June 1975, pp 35-57.
3. Chen, J. C., and Garba, J. A., "Determination of Propellant Effective Mass Properties Using Modal Test Data," The Shock and Vibration Bulletin, Bulletin 45, Page 3, Naval Research Laboratory, Washington, D.C., June 1975, pp. 15-23.
4. Garba, J. A., "Flight Data Obtained from Viking A During the Titan and Centaur Powered Flight," JPL Project Document 611-126, Pasadena, California, October 1975.
5. Garba, J. A., "Flight Data Obtained from Viking B During the Titan and Centaur Powered Flight," JPL Project Document 611-128, Pasadena, California, November 1975.
6. Garba, J. A., Wada, B. K., and Chen, J. C., "Experiences in Using Modal Synthesis within Project Requirements, JPL Technical Memorandum 33-729, Pasadena, California, June 1, 1975.
7. Wada, B. K., and Garba, J. A., Dynamic Analysis and Test Results of the Viking Orbiter," ASME Winter Annual Meeting, ASME Paper 75-WA/Aero 7, Houston, Texas, November 30-December 4, 1975.
8. Garba, J. A., Wada, B. K., Bamford, R., and Trubert, M. R., "Evaluation of a Cost-Effective Loads Approach," Journal of Spacecraft and Rockets, Vol. 13, No. 11, pp 675-683, November 1976.
9. Garba, J. A., "Structural Analysis of the NASA Infrared Telescope Facility," JPL Project Document 900-146, Pasadena, California, October 1, 1977.
10. Garba, J. A., and Wada, B. K., "Application of Perturbation Method to Improve Analytical Model Correlation with Test Data," SAE Paper 770959, Society of Automotive Engineers, Aerospace Meeting, Los Angeles, California, November 14-17, 1977.
11. Chen, J. C., Wada, B. K., and Garba, J. A., "On the Launch Vehicle Payload Interface Responses," Journal of Spacecraft and Rockets, Vol. 15, No. 1, pp 7-11, January 1978.
12. Chen, J. C., Garba, J. A., and Wada, B. K., "Estimation of Payload Loads Using Rigid Body Interface Accelerations" to be presented at the 19th AIAA/ASME Structures, Structural Dynamics and Materials Conference, Betheseda, Maryland, April 3-5, 1978.
13. Garba, J. A., Gayman, M., Barr, L., Ghozeil, I., Pearson, E., and Schrage, D., "Structural Analysis and Design of a Large Infrared Telescope" (in preperation) to be submitted to Applied Optics.

MOKTAR A. SALAMA

EDUCATION: Ph.D., C.E. - 1965, University of Colorado
M.S., C.E. - 1961, Stanford University
B.S., Engineering - 1958, Ein Shaws University, Egypt

CURRENT ASSIGNMENT: Engaged in various aspects of JPL flight projects, developing tools such as a generalized shock spectra-impedance method for cost-effective loads predictions for spacecraft structures. Also active in adapting aerospace technology for the analysis of solar energy systems, and currently developing new ideas to apply to parallel processing in computerized, non-linear, finite element analysis.

EXPERIENCE: (1965-1969) - Oklahoma State University: Assistant and Associate Professor, Oklahoma State University. Taught courses and supervised research and several theses in the area of structural mechanics including mechanics of materials, elasticity, plasticity, dynamics, and stability of structural systems.

MOKTAR A. SALAMA (continued)

SELECTED PUBLICATIONS:

1. "Material and Design Considerations of Encapsulants for Photovoltaic Arrays in Terrestrial Applications," Conference Records of the 12th Photovoltaic Specialists Conference, Baton Rouge, Louisiana, November 1976.
2. "Results of Accelerated Thermal Cycle Tests of Solar Cell Modules," Conference Records of the 12th IEEE Photovoltaic Specialists Conference, Baton Rouge, Louisiana, November 1976.
3. "Stress Computation in Displacement Methods for Two-Material Elastic Media," Computer Methods in Applied Mechanics and Engineering, Vol. 10, 1977.
4. "A Generalized Modal Shock Spectra Method for Spacecraft Loads Analysis," Paper to be presented at the AIAA-ASME-ASCE-AHS Structures, Dynamics, and Materials Conference, April 1979.
5. "Second Order Nonlinear Equations of Motion for Spinning Highly Flexible Line Elements," Paper to be presented at the AIAA-ASME-ASCE-AHS Structures, Dynamics and Materials Conference, April 1979.
6. "On the Thermoelastic Analysis of Solar Cell Arrays and Related Material Properties," JPL TM-33-753, February, 1976.
7. "Nonlinear Deformations and Loads in the Truss Cable Structure for the Square Solar Sail," JPL Solar Sail Study Document No. 662-39, August 1977.
8. "Approximate Analytical Solution for Stresses and Large Deformation of the Square Solar Sail," JPL Solar Sail Study Document No. 662-38, August 1977.
9. "Nonlinear Equations of Motion for the Rotating Solar Sail," JPL Solar Sail Study Document No. 662-41, October 1977.

MARC TRUBERT

EDUCATION: Ph.D. in Engineering Mechanics - 1962, University of Florida.
M.S. in Engineering Mechanics - 1960, University of Florida.
B.S. in Mechanical and Electrical Engineering - 1951, Ecole Speciale des Travaux Publics, Paris, France.
Certificate of Mathematics, University of Paris, France, 1950.

CURRENT ASSIGNMENT: Group Supervisor, Dynamics Group engaged in analysis, design and development testing.

EXPERIENCE: 1965 to present (JPL). Structural design, analysis and development testing for research and advanced development (R/AD) and flight projects: frequency domain application to structures, loads analysis and structural testing on Surveyor, Mariner 67, 69 and 71 using digital and analog computers, development of special purpose analog computer for structural dynamic simulation, attitude control/structure flexibility interaction problem, leading role on modal testing of Mariner 71, leading role on furlable antenna concepts R/AD program, group supervisor since 1970.

Major recent assignments of the group include: management of two furlable antenna programs, structural analysis, and mass property support to Voyager, structures support to Flight Science projects; for E&TA managed various small tasks on biomechanics, automobile crash barrier, application of finite element method to earthquake engineering and development of computer model for automotive system study program.

(1952-1965). Aeronautics R/AD for aircraft flutter and development of dynamic testing instrumentation at Office National d'Etudes et Recherches Aeronautiques, Paris, France. Power electron tube and thermal relay development at Compagnie Generale de TSF, Paris, France.

Conducted jet noise research and taught structures and dynamics and random processes courses at graduate and undergraduate level at University of Florida and University of California, Berkeley.

MARC TRUBERT (continued)

SELECTED PUBLICATIONS:

"A Practical Approach to Spacecraft Structural Dynamics Problems," paper presented at the AIAA/ASME/SAE, 13th Structures, Structural Dynamics, and Materials Conference, San Antonio, Texas, April 10-12, 1972; also published in Journal of Spacecraft and Rockets, Vol. 9, No. 11, pp 818-824, November 1972.

"Large Spacecraft Antennas: Conical Ring-Membrane Reflectors," JPL Quarterly Technical Review, Volume 2, Number 2, July 1972.

"Structural Dynamics Analog Simulator," JPL Document 900-648, December 5, 1973.

"A Shock Spectra and Impedance Method to Determine a Bound for Spacecraft Structural Loads," paper presented at AIAA/ASME/SAE 16th Structures, Structural Dynamics, and Materials Conference, Denver, Colorado, May 27-29, 1975, JPL TM 33-694, September 1, 1974.

Helios TC-2 Stage Zero Ignition Pulse Reconstruction for MJS'77 Loads Analysis," JPL PD 618-426, August 1, 1976.

"Evaluation of a Cost-Effective Loads Approach," Journal of Spacecraft and Rockets, Vol. 13, No. 11, pp 675-683, November 1976.

"Nonlinear Deformations and Loads in the Truss Cable Structure for the Square Solar Sail,: JPL Solar Sail Study 662-39, August 1, 1977.

"Finite Element Structural Analysis of a Square Membrane for a Solar Sail," JPL Solar Sail Study 662-35, August 15, 1977.

"Thrust and Moments on the Square Solar Sail," JPL Solar Sail Study 662-41, October 1, 1977.

"A Generalized Modal Shock Spectra Method for Spacecraft Loads Analysis," JPL Publication 79-2, also presented at the 20th Structures, Structural Dynamics and Materials Conference, St. Louis, April 1979.

BEN K. WADA

EDUCATION B.S. - 1958, UCLA.
M.S. - 1963, UCLA.
NASA's Exceptional Service Medal, 4/19/77.
Award for Excellence in Oral Presentation, 1975, Aerospace Engineering and Manufacturing Meeting.

CURRENT ASSIGNMENT: Section Manager, Applied Mechanics Section. Manages 100 professional engineers in structures, thermal, dynamics, materials, material laboratory engineers supporting NASA, DOE, AF, DOD, and other sponsors.

EXPERIENCE: 1964-1978 - (JPL). Cognizant engineer, responsible for computer program development, representative of Applied Mechanics discipline, responsible for qualification, criteria, specification data analysis, and test related to Structures and Dynamics, research in space vehicle dynamics, responsible for structures, dynamics, and mass property analysis and test of the Viking Orbiter, energy related activities such as geothermal, coal, terrestrial solar, solar concentration/Stirling engine, solar thermal, and others.

BEN K. WADA (Continued)

SELECTED PUBLICATIONS:

Wada, B. K., "Viking Orbiter-Dynamics Overview", The Shock and Vibration Bulletin, Bulletin 44, Part 2, August 1974, pp. 25-39.

Chen, J. and Wada, B., "Criteria for Analysis-Test Correlation of Structural Dynamic Systems", American Society of Mechanical Engineers, Journal of Applied Mechanics, June 1975.

Wada, B. K., Garba, J. A., and Chen, J. C., "Development and Correlation: Viking Orbiter Analytical Dynamic Model with Modal Test", The Shock and Vibration Bulletin, Bulletin 44, Part 2, August 1974, pp 125-164, (also JPL TM 33-690).

Leppert, L., Wada, B., and Miyakawa, R., "Modal Test of the Viking Orbiter", The Shock and Vibration Bulletin, Bulletin 44, Part 2, August 1974, (also JPL TM 33-688).

Bamford, R., Wada, B., Garba, J., and Chisholm, J., "Dynamic Analyses of Large Structural Systems", Synthesis of Vibrating Systems, The American Society of Mechanical Engineers, New York, N. Y., November 1971.

Wada, B. K., and Larson, C. N., "Design and Qualification of Presure Vessels by Use of Fracture Mechanics Concepts", Chemical Propulsion Structural Integrity Survey 1972, Chemical Propulsion Information Agency (CPIA Publication 229), The John Hopkins University, Applied Physics Laboratory, Silver Springs, Maryland, 1972.

Wada, B. K., Bamford, R., and Garba, J. A., "Equivalent Sprung-Mass: A Physical Interpretation", The Shock and Vibration Bulletin, Bulletin 42, January 1972.

Snyder, R. E., Trummel, M., Wada, B. K., "Specification and Correlation of the Sine Vibration Environment for Viking 1975", presented at SAE National Aerospace Engineering and Manufacturing Meeting, 9/30/74-10/3/74, SAE paper 740814.

Day III, F. A., and Wada, B. K., "Unique Flight Instrumentation/Data Reduction Techniques Employed on the Viking Dynamic Simulator", published in The Shock and Vibration Bulletin, Bulletin 45, June 1975.

Wada, B. K., Bamford, R. M., Alper, M. E., and Gayman, W. H., "The Use of Large Matrix Techniques to Obtain Dynamic Models of Spacecrafts", presented at the ASA meeting, Washington, D.C., 1970.

Day III, F. D., and Wada, B. K., Strain Gaged Struts and Data Reduction Techniques to Maximize Quality Data from Spacecraft Flight Measurements", presented at the 21st International ISA Symposium, 5/19-21, 1975 in Philadelphia. Published in the 21st International Instrumentation Proceedings, Vol. 21 and Vol. 12.

BURTON ZELDIN

EDUCATION: B.S. in Mechanical Engineering - 1961, Penn State.
Ph.D. in Mechanical Engineering - 1969, Penn State.

CURRENT ASSIGNMENT: Involved in math modelling, numerical analysis, computer programming, heat transfer and fluid flow. Design and analysis experience on a number of tasks, studies, and projects such as the Gregorian furlable antenna, bimodal rocket engine, SAGE, SEPSIT, ION Drive and Voyager.

EXPERIENCE: 1969 - Present (JPL). Performed thermal simulation tests for Voyager science Plume Shield and separation connectors. Generated computer programs for use by MVM, Viking, and Voyager mission operations. Developed math models and computer codes for flat plate solar collectors for project SAGE and other studies including advanced concepts for collectors using vacuum, low pressure, high molecular weight gases, and selective coatings--with and without concentrators. Participated in design of solar collector system for Governor's Mansion. Other tasks include analysis of photovoltaic (solar cell), thermionic, and thermoelectric devices and systems, and Stirling engine design, analysis, and material selection.

(1964-1969) While a graduate student at Penn State, performed research in Mach-Zehnder interferometry, taught several M.E. courses including heat transfer, and assisted in teaching a short course for practicing engineers in numerical analysis techniques in heat transfer and fluid flow.

(1961-1964) - General Electric, Missile and Space Division. Lead heat transfer engineer on O.A.O. (Orbiting Astronomical Observatory). Analysis, testing, computer programming in a variety of tasks including long term space storage of cryogens and radioisotope fuel containers.

BURTON ZELDIN (continued)

SELECTED PUBLICATIONS:

1. Schmidt, F. W., and Zeldin, B., "Laminar Flow in the Inlet Section of a Tube," Proceedings, Fluidics and Internal Flows, The Pennsylvania State University, Department of Mechanical Engineering, Part II, 1968, pp. 211-251.

2. Zeldin, B., "Developing Flow with Combined Forced-Free Convection in an Isothermal Vertical Tube," Ph.D. thesis, The Pennsylvania State University, University Park, PA., 1969.

3. Schmidt, F. W., and Zeldin, B., "Laminar Flows in Inlet Sections of Tubes and Ducts," AIChE Journal, Vol. 15, No. 4, 1969, pp. 612-614.

4. Schmidt, F. W., and Zeldin, B., "Laminar Heat Transfer in the Entrance Region of Ducts," Applied Scientific Research, Vol. 23, No. 1/2, 1970, pp. 73-94.

5. Zeldin, B., and Schmidt, F. W., "Calibrating a Hot Film Anemometer for Low Velocity Measurement in Non-Isothermal Flow," Review of Scientific Instruments, Vol. 41, No. 9, 1970, pp. 1373-1374.

6. Zeldin, B., and Schmidt, F. W., "Developing Flow with Combined Forced-Free Convection in an Isothermal Vertical Tube," Journal of Heat Transfer, Trans ASME, Series C, Vol. 94, No. 2, May 1972, pp. 211-223.

7. Zeldin, B., "Tubeless Flat-Plate Solar Collector", NASA Tech. Brief, Winter 1977.

8. French, J., Stuart, J. R., and Zeldin, B., "New Concepts for Mercury Orbiter Missions", AIAA 16th Aerospace Sciences Meeting, Huntsville, Alabama, January 16-18, 1978.

6.2 MATERIALS ENGINEERING AND LABORATORIES

JPL's Materials Engineering area provides a versatile capability in research, development, evaluation and utilization of a broad spectrum of materials and their associated processes with over 50 professionals. Additional activities include conceiving, marketing, conducting and managing research and development tasks as self supporting efforts and in support of design, development, fabrication and testing of equipment, materials and structures for flight, energy, and transportation systems. The Materials specialists have expertise in the fields of metallurgical, chemical, polymeric, and ceramic engineering and materials science. Areas of special skills encompass fracture mechanics, failure analysis, mechanical properties, fatigue, stress corrosion, hydrogen embrittlement, advanced composites, thermal control coatings, high temperature ceramics, polymers and thin films. Expertise exists in the area of advanced materials evaluation and characterization.

Materials specialists support flight projects by selecting, evaluating, assuring adequcy of materials, processes, and associated controlling documentation used for JPL and contractor designed equipment. This is accomplished by laboratory test and evaluation, consultation on hardware fabrication problems, and by analysis of parts failures during testing. The organization prepares and controls institutional documentation to regulate materials procurement, processing and usage, for flight and other projects, in the form of materials and processes specifications. Results from E&TA supported projects have included improved blood bags, an asceptic blood transfer method and equipment, and a heat sterilizable breathing apparatus.

JPL has extensive experience in metallurgical failure analysis and fracture mechanics. Fracture mechanics techniques were used to generate design data for hydrogen with 2219 aluminum alloy. This data was subsequently used by JPL to design the first pressure vessels ever to have their wall thickness determined solely from fracture mechanics data. These pressure vessels contained hydrogen at 5400 psig for the Infrared Spectrometers for Mariners 6 and 7 which flew by Mars in 1970. Failure analyses and fracture mechanics analyses for energy systems using plain carbon steels and stainless steels have also been performed. Systems such as coal handling equipment and geothermal energy facilities are among those analyzed.

JPL's materials technologists are active participants in professional societies of their respective disciplines. Several members are officers and sub-committee members at the national and local levels.

Table 1

Materials Laboratory Capabilities

Materials	Services
Metals	X-ray analysis
Ceramics	Heat-treatment
Polymers	Metallography
Composites	VCM
	Mechanical Testing
Areas of Application	Vibration
	Micro-hardness
Failure analysis	Compressive strength
Fracture mechanics	Impact
Material characterization	Tensile strength
Thermal control coatings	Fracture toughness
Structures	Fatigue crack propagation
Insulation	Abrasion test for wear
Compatibility	Flexural strength
Bio-medical	Permanent set
Thermo-optical	Thermal expansion
Lubrication	Adhesive testing
	Non-destructive evaluation
	Thermal environment
	Electron microscope
	Electron microprobe
	Chemical analyses

MARC A. ADAMS

EDUCATION: B.S. in Metallurgy - 1967, Case Institute of Technology
M.S. in Engineering - 1972, University of California
Ph.D. in Engineering - 1975, University of California

CURRENT ASSIGNMENT: Materials Specialist supporting Solar Thermal Power Systems Project.

EXPERIENCE: (JPL) Supported ATSP project - Survey up-date of materials aspects of alternative engines - Materials support to Solar Stirling Engine Project, Stirling Laboratory Research Engine Project, LSA Project.
IBM - (1975-1976) - Staff Engineer - Direct Materials and processing support to advanced product development activities, fatigue of alloys, characterization of ceramics, computer modeling of statistically complex failure mechanisms.
UCLA - (1972-1975) - Graduate Research Engineer, Research Engineer and Post Doctoral Scholar - Responsible for the management of a NASA research contract to measure compressive strength of materials.
Xerox Data Systems Consultant (1971-1972) - Developed and executed a program, long term reliability of thin film, resistor fuse devices.
JPL (1967-1970) - Engineer - General materials support to spacecraft projects. Conducted programs in various areas of solid state materials and electronic devices, solar cells, photodetectors, long term reliability, integrated circuits.
TRW Materials Research Center (1966-1967) - Engineering Assistant - Designed equipment and conducted tests for high temperature, solid lubricants development program and laser machining program.
Case Institute of Technology (1965-1966) - Technician - Worked on a program investigating nodular cast iron. Responsibilities include sand molding, casting and metallography.

WILLIAM A. EDMISTON

EDUCATION: M.S. in Metallurgical Engineering - 1964, Purdue University
B.S. in Metallurgy - 1962, Massachusetts Institute of Technology.
Registered Professional Metallurgical Engineer-State of California #MT 1590.

CURRENT ASSIGNMENT: Proposal Manager for "Railroad Wheel Failure Mechanisms and Test Facilities.

EXPERIENCE: (1971-present) - Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. Technical Staff - Materials and Processes Engineering.
(1964-1970) - Rockwell International, Space Division, Downey, California. Technical Staff progressing to Responsible Engineer (Group Leader) of Metallurgy Unit in Division Laboratory.
Extensive Materials Science, Materials & Processes, and Materials Resource Availability/Economics experience applied to aerospace, energy, and transportation systems. Experience encompasses laboratory investigations, hardware production and technology assessment studies. Technical Manager, Automotive Composite Materials Evaluation Project which is a study of the potential future applicability of advanced composite materials for automotive applications. Manager, Materials, Processes, and Natural Resources for the ERDA-sponsored Automotive Technology Status and Projection (ATSP) Project. The ATSP Project continues JPL's technology assessment activities in the automotive arena initiated by the Ford-sponsored Automotive Power Systems Evaluation Study (APSES). As Manager, Materials, APSES Study and co-author of the book (Should We Have a New Engine?) summarizing the study, I had responsibility for all materials considerations, both technical and non-technical including material resource availability, economics and cost. Served as the NASA representative on the Fuels and Materials Panel of the Interagency Task Force on Motor Vehicle Goals for the 1980's.
On the Geothermal Program Definition Project, geothermal experience was gained in the areas of materials science, materials corrosion, scaling, erosion, brine chemistry, materials & process selection, non-electric market and application analyses, and mineral recovery potential.
Extensive materials and processes experience in Research and Development, Manufacturing Process Engineering, Manufacturing Trouble Shooting, Design Selection of Materials and Processes, Specifications, and Proposals over a wide range of materials and processes. Defined, planned, directed, budgeted, evaluated test results, and wrote final reports of major laboratory research and development programs resulting in design improvements and cost reductions. Aerospace programs include Apollo, Saturn, MVM'73, VO'75, MJS'77, SEP, and Bi-Mode Engine. Responsible for the technical direction of 12 people (6 engineers and 6 technicians) at Rockwell at the Apollo/Saturn program peak.

WILLIAM A. EDMISTON (continued)

SELECTED PUBLICATIONS:

"Kinetics of Near-Equilibrium Reduction of Wustite", Trans. Met. Soc. AIME, 1966, vol. 236, pages 1547-50.

"Kinetics of Near-Equilibrium Reduction of Wustite in Damp Hydrogen". Presented at the 95th AIME Annual Meeting, February 28 - March 3, 1966, Americana Hotel, New York, New York.

"New Ultra-High Strength Aluminum Alloys". Presented at Los Angeles Chapter American Society for Metals Round Table Workshop, November 8, 1972, Los Angeles, California.

"Geothermal Energy Development Status", Jet Propulsion Laboratory, Report 1200-205, April 1975.

Should We Have a New Engine? An Automotive Power Systems Evaluation, 2 volumes, Jet Propulsion Laboratory SP 43-17, August 1975. Available to the public as Society of Automotive Engineers Special Publication 400 Set.

"Program Definition for the Development of Geothermal Energy", 3 volumes, Jet Propulsion Laboratory Report 5040-6, August 1975.

"Evaluation of Alternative Power Systems for the 1980's - Material Requirements and Manufacturing Costs". Presented at the 1975 Society of Automotive Engineers Automotive Engineering and Manufacturing Meeting, October 13-17, 1975, Detroit, Michigan.

"Fuels and Materials Resources for Automobiles in the 1980-1990 Decade", Report of the Fuels and Materials Resources Panel of the Federal Interagency Task Force on Motor Vehicle Goals Beyond 1980, DOT, March 1976.

Outlook for Space: A Forecast of Space Technology 1980-2000, NASA SP-387, January 1976. Contributing author to Part V, "Management of Matter".

"Impact of Ceramic Materials Application on Engine Design", ASME Vehicular Gas Turbine Forum, Presented at 21st Annual International Gas Turbine Conference, March 21-25, 1976, New Orleans, Louisiana.

"Materials for Use in Manufacturing Automobiles - 1980 and Beyond". Presented at 1977 SAE Fuels and Lubricants Meeting, June 6-9, 1977, Tulsa, Oklahoma.

"Automotive Technology Status and Projections", 2 Volumes, Jet Propulsion Laboratory Publication 78-71, June 1978.

"Measurement of Coefficients of Thermal Expansion for High Temperature Polymers". Presented at American Physical Society Meeting, May 11-12, 1979, Youngstown, Ohio.

KENNETH EVANS

EDUCATION: B.S.E.E. - 1962, California State College of Los Angeles.

CURRENT ASSIGNMENT: Scanning Electron Microscope - operator and maintenance of equipment. Past 6 years responsible for facility.

EXPERIENCE: 1963 - present (JPL). Reliability Test Engineer for outside contracts. Parts Reliability Test Engineer at JPL.
1961-1962 - Autonetics, Div. North American Aviation - Environmental Test Engineer.

SELECTED PUBLICATIONS:

1. The SEM as a Diagnostic Tool for Radiation Hardness Design of Microcircuits, C. G. Thomas and K. C. Evans, Scanning Electron Microscopy/1978/Vol. I, pp. 735-740.

2. High Volume Wafer Level Inspection for High Reliability Integrated Circuits, C. G. Thomas and K. C. Evans, Scanning Electron Microscopy/1976 (Part IV), pp. 557-564.

LOIS L. TAYLOR

EDUCATION: B.S. in Chemistry - 1942, University of Connecticut.

CURRENT ASSIGNMENT: Analytical chemistry techniques including computerized infra-red, ultra-violet and atomic absorption spectroscopy, gas chromatography and classical wet chemical methods. Physical determinations include heats of combustion, material densities, molecular weight determinations, etc.

EXPERIENCE: Senior Scientist in the Energy and Materials Research Group at JPL.

Thirty-four years of varied experience, including 30 years at JPL, in analytical chemistry. Experience in materials analysis has included metals, soils, solid and liquid rocket propellants, petroleum products, polymers and a wide variety of coals. Analyses for sulfur and chlorine compounds were included in the coal analyses including total chlorine and total sulfur determinations.

WALLACE M. ROWE

EDUCATION: B.S. in Engineering Metallurgy - San Jose State University.
Graduate work in Business Administration - Cal State University - Fullerton
Professional License: Registered Professional Metallurgical Engineer - State of California

CURRENT ASSIGNMENT: Technical Contract Manager of Solar Sail Materials AST investigations for sail film materials and their properties.

EXPERIENCE: (JPL) - Materials support for spacecraft science instruments, developed non-magnetic housing for Pioneer Magnetometer. R & AD materials properties programs on large space telescope and silicon solar array development. Cognizant Materials Engineer for VO'75. Technical Contract Manager of ERDA sponsored R & D on encapsulant materials for low-cost silicon solar arrays. Preparation of material and process specifications.
Supervisor of manufacturing engineering group supporting the fabrication of silicon solar array and spacecraft batteries. Member of Technical Staff responsible for planning and directing metallurgical laboratory material evaluation and failure analysis studies on high reliability electronic components and associated hardware. Developed Nondestructive test methodology and acceptance criteria for electronic components, printed wiring boards and electromechanical parts. Developed test plans, interpreted material test results, prepared test reports and consulted with design and manufacturing engineers. Lead engineer in Metallography and X-ray Laboratories. Prepared material and process specifications and technical research and development proposals.

CHARLES H. SAVAGE

EDUCATION: B.S. in Metallurgical Engineering - Lehigh University, Bethlehem, Pennsylvania.

CURRENT ASSIGNMENT: Technical Group Supervisor, Materials and Processes Engineering. Manage specialists possessing capabilities in research, development, evaluation and utilization of a broad spectrum of materials and their associated processes. Conceives and implements research and development tasks as self supporting efforts and also supports the design, development and testing of equipment for space, energy, and transportation systems. The materials areas represented in these activities are metals, ceramics, polymers and composites. Special skills encompass the technology associated with fracture mechanics, fatigue, stress corrosion, hydrogen embrittlement, high temperature materials, advanced composites, and space processing.

EXPERIENCE: North American Aviation, Inc. - Materials Engineer. Planned and managed company- and government-sponsored research and development programs on metallic materials for advanced aerospace vehicles. Provided support to preliminary design groups in the selection and efficient utilization of structural alloys and fabrication processes for the development of advanced aerospace vehicles, such as manned and unmanned lifting reentry vehicles, large boosters, and lunar and interplanetary vehicles.
General Dynamics - Process Engineer, Materials and Processes. Provided design consultation in application and selection of metals and manufacturing processes for Terrier, Tartar and Redeye Missiles. Initiated and conducted research and development programs on advanced alloys and fabrication processes pertinent to improved missile designs.
Aerojet-General Corp. - Ordinance Division - Research Engineer, Ordnance Research. Planned and conducted developmental programs on techniques for explosive forming of metals and for explosive compaction of refractory metal powders. Evaluated explosively formed components and compacts.
Pacific Tube Co. - Los Angeles, Calif. - Assistant Chief Metallurgist. Directed the efforts of laboratory personnel in process development and quality control testing required in the manufacture of seamless and welded steel tubing.
Crucible Steel Co. of America - Research Laboratory - Research Metallurgist. Initiated and conducted research and development programs on all types of alloy and stainless steels and super-alloys. Studied transformation of austenite in alloy steels. Developed high-temperature, corrosion resistant steels. Studied microstructural and property changes in high-temperature alloys at elevated temperatures.

Patents: Heat Treatment of Cobalt-Base Alloys, U.S. Patent No. 2,486,576, November 1, 1949.
Heat and Corrosion-Resisting Alloy Steel, U.S. Patent No. 2,518,715, August 15, 1950.

CHARLES H. SAVAGE (Continued)

SELECTED PUBLICATIONS:

"Martensite Reactions in Alloy Steels", Transactions, American Society for Metals, 1944.

"Changes in Austenitic Chromium-Nickel Steels During Exposures at 1100 to 1700 F". Transactions, American Society for Metals, 1947.

"Determination of Mechanical and Thermophysical Properties of Coated Refractory and Superalloy Thin Sheet", RTD-TDR-63-4068, 1963.

"Space Processing of Ceramic Materials", Proceedings of ESRO Space Processing Symposium, 1974.

PAUL P. TUNG

EDUCATION: Ph.D. in Metallurgy & Materials Science - University of California, Los Angeles.
M.S. in Materials Science - University of California, Los Angeles.
B.S. in Mechanical Engineering - Taiwan University, Taiwan.

CURRENT ASSIGNMENT: 1978 - present (JPL) - Materials Engineer in charge of fracture mechanics related tests and analyses in spacecraft and civil systems. Responsible for failure analysis involving systems and parts, metallic or non-metallic. Provide metallurgical consultation to various programs and projects.

EXPERIENCE: 1971 - 1978 - Rockwell International, Los Angeles Division. Metallurgist in charge of fracture control plan of the B-1 aircraft. Responsible for failure analysis in the B-1 qualification test program and flight test program. Conducted thermomechanical and microstructure studies 2024, 2219 alluminum alloys, Ti-6Al-4v titanium alloy, and HP13-8Mo steel. Conducted also fracture mechanics study programs for fatigue crack propagation properties in welds (in steels and titanium alloys), and new test and analysis methods for defining and obtaining material fracture mechanics properties.

PAUL P. TUNG (continued)

SELECTED PUBLICATIONS:

1. Dislocation Energetics in Alpha Titanium, Metallurgical Transaction, Vol. I, April 1970.
2. Influence of Oxygen Concentration on the Internal Stress and Dislocation Arrangement in Alpha Titanium, Metallurgical Transaction, Vol. 3, November 1972.
3. Diffusion of Silver into Nickel Single Crystals, Journal of Applied Physics, Vol. 42, December 1971.
4. A Study of Dislocation Hydrogen Interaction in Titanium Aluminum Alloys via Internal Friction Measurements, Titanium Science and Technoloyg, New York, Plenum Publishing Company, 1973.
5. A Study of Dislocation Hydrogen Interaction in Alpha Titanium via Internal Friction Measurements, Acta Metallurgica, Vol. 22, February, 1974.
6. Effect of Thermal Mechanical Treatment on the Mechanical Properties of 2124 and 7050 Aluminum Alloys, Technical Report, Rockwell International Los Angeles Division, TFD-73-136, October 1973.
7. "Fracture Toughness Evaluation by R-Curve Method using Compact Specimens", Technical Report, Rockwell International Los Angeles Division, TFD-74-128, March 1975.
8. Failure Analysis of B-1 Line Replaceable Unit Tray, Technical Report, Rockwell International Los Angeles Division, TFD-73-1643, December 1973.
9. Failure Analysis of Aircraft 3 R/ FMCS Vane Actuator Fitting Assembly, Technical Report, Rockwell International Los Angeles Division, TFD-76-31, January 1976.

6.3 JPL ENVIRONMENTAL TESTING AND LABORATORIES

The environmental testing activities at JPL are centered around prediction, specification and simulation of the earth and space environments. Specific technologies include dynamics, thermodynamics, vacuum, electromagnetic, magnetic and radiation.

The major test facilities currently being operated by JPL are described in the following paragraphs.

- Ion Space Chamber

  This thermal-vacuum test facility can accept test articles up to a nominal 8-feet in diameter and 10-feet long inside the thermal shrouds. High-vacuum pumping is provided by 9,000 liters per second of baffled ion pumps which can maintain a pressure in the $7 \times 10^{-6} N/m^2$ (5×10^{-8} torr) region with an average test article installed and the thermal shrouds at ambient temperature. The thermal shrouds can be varied from -184°C (-300°F) to +121°C (+250°F) by a recirculating nitrogen temperature conditioning system. The chamber is equipped with a 28-inch clear aperture window manufactured from Optosil T12 quartz and has excellent optical transmission characteristics. the chamber also has a cryogenic panel completely shielded from the test zone which provides an effective contamination collection surface. The chamber door and large ports can be sealed either by polymer gaskets or crushable metal seals as required.

- 10 Foot Space Simulator

  The simulator chamber is a stainless-steel cylindrical vessel 13 ft. in diameter and 45 ft. high. The bottom of the cylinder is located 17 ft. above the building floor. THe lower head or "endbell" moves up and down on a 20,000 lb. capacity hydraulic lift for chamber entry of test hardware. The 10 ft. Space Simulator is capable of maintaining a pressure level of 1.3 x 10^{-4} N/m^2 (1 x 10^{-6} torr) with the three 50,000 liter per second, LN_2 trapped oil diffusion pumps. The chamber is lined with a cryogenic shroud that can be temperature controlled through a range of -184°C (-300°F) to +93°C (+200°F) using liquid and gaseous nitrogen.

The chamber is equipped with an off-axis solar simulator capable of producing an irradiance of up to two solar constants using compact xenon lamps as an energy source.

- 25 Foot Space Simulator

The simulator chamber is a stainless-steel cylindrical vessel 27 ft. in diameter 85 ft. high; a 16 ton, 15 x 25 ft. side-opening access door is provided for test-item loading. A personnel door provides entry through the access door. The minimum operating pressure of the chamber is 1.3 x 10^{-4} N/m^2 (1 x 10^{-6} torr). The walls and floor are lined with thermally opaque aluminum cryogenic shrouds controlled over a temperature range of -184°C (-300°F) to +93°C (+200°F) using liquid and gaseous nitrogen. An off-axis solar simulation system is provided by an array of 37 xenon 20/30 kW compact arc lamps. This array provides a simulated solar beam that is reflected down into the test volume by a collimating mirror, which is temperature-controlled with gaseous nitrogen through a range of -73°C (-100°F) to +93°C (+200°F).

A variety of solar beams is available, capable of irradiances up to 12 solar constants over an 8 ft. diameter circle. In excess of two solar constants can be provided over an area of 18 ft. 6 inches. The beam size is determined by the selection of the proper optical mixer and collimating mirror.

- 10 Foot Space Molecular Sink

The chamber is a vertical-axis cylindrical pressure vessel, 10 ft. in diameter and 15 ft. high. The facility produces an ultra-high vacuum 10^{-11} N/m^2 (10^{-13} torr) environment with a unique internal trap to reduce molecular fluxes to spacelike levels. Operating at about -258^{o}C (15^{o}K), active titanium is sputtered on the trap to achieve chemisorption. This very clean environment has proven to be useful in space mechanism development as well as for instrument testing, contamination studies, thin film research, and other applications.

- Temperature/Humidity Equipment

There are seven temperature chambers ranging in size from two cubic feet to 180 cubic feet. A range of temperatures from -184^{o}C (-300^{o}F) to 316^{o}C (600^{o}F) is available. Six of the chambers have a combined temperature humidity capability. The test cycle in these six chambers can be programmed. All chambers can be nitrogen purged for inert atmosphere during high temperature testing.

- Radiation Test Facility

The High Flux Radiation Test Facility is located in building 277. It consists of a controlled access test cell which contains two 14,000 Curie Cobalt 60 radiation sources. One smaller 50 Curie source is also available.

These sources can be remotely exposed from a control console to produce a test environment for a variety of user requirements.

- Vibration Facilities

There are twenty-two electrodynamic exciters and one electro-hydraulic exciter in the JPL Pasadena facility. In addition, a complete vibration test system is available at the Edwards Test Station. The Edwards Test Station vibration system is used almost exclusively to perform hazardous tests.

The primary means of control for this equipment (except for electro-hydraulic exciter) is the TIME DATA TDV-53A digital system. This system is capable of sinusoidal, random and shock control.

- Acoustic Facility

This facility consists of a 10,000 cubic foot concrete reverberation chamber and digital control system. An adjacent preparation area, used for hardware assembly and checkout, has a ten ton bridge crane and is a humidity and clean room (Class 10,000) facility. JPL's responsibility for the design, construction and checkout of this facility was discussed previously.

- Shock Facilities

Most shock testing on spacecraft hardware is performed on the electrodynamic exciters. Control is accomplished with the TIME DATA TDV-53A digital system.

A second shock test machine is also available. This machine is used to simulate high amplitude, high frequency transients similar to those generated by pyrotechnic events. The machine consists of a hardened steel piston that is pneumatically accelerated down a barrel onto an impact plate. Piston size and pneumatic pressure are varied to produce the desired amplitude and pulse characteristics. The design, fabrication and checkout of this machine was performed by JPL.

- Edwards Test Station (ETS)

In recognition of the anticipated scope of a Railroad Wheel Failure Mechanism and Test Facility Project, strong consideration is being given to use of the Edwards Test Station.

In general, the ETS facility is ideal as a test site for any type of equipment that might be hazardous or require large configurations.

The JPL Test Facility at Edwards Test Station is located approximately 80 miles northeast of Pasadena. This facility was established in 1954 for the purpose of conducting development firings of the Corporal liquid rocket engine. The ETS has since been used to perform chemical propulsion supporting research and development tests and also to perform environmental tests on equipment in which potential hazards such as fuel propulsion hardware, pressurized vessels and loaded pyrotechnic devices are present.

Supporting the ETS operation is a large control and recording center located in an air conditioned, remotely located building. This building is connected with each of the test areas by a system of walk-through tunnels containing instrumentation and control cables.

A functional group of instrumentation professionals provide all the electronic and electro-mechanical instrumentation services, installation and operations necessary to support test activities at any of the remote test sites.

The vibration test facility is a building containing a 28,000 force-pound electrodynamic exciter and power amplifier. The control complex is housed in a console trailer about 1,200 feet from the test building. Data from accelerometers, strain gages, temperature sensors, and other transducers are recorded in the recording center.

DAVID J. BOATMAN

EDUCATION: BS in Physics/Chemistry, University of Wisconsin; 1962
Working toward MS Degree in Computer Science at West Coast University

CURRENT ASSIGNMENT: Senior Engineer in Dynamics Environmental Test Laboratory. Conduct Vibration, Shock, Acoustic and Modal Tests on component, subsystem and system (full spacecraft) level. Familiar with operation of most state-of-art digital and analog test equipment.

EXPERIENCE: McDonnell Douglas Corporation/Test Engineer. Dynamics and Acoustics Laboratory. Performed functions of both Test Conductor and Test Director at various times. Did extensive travelling as MDC representative monitoring subcontractors doing dynamic testing.

JOHN W. HARRELL

EDUCATION: Associate of Arts Degree

CURRENT ASSIGNMENT: Establish criteria for the design and fabrication of a new generation space simulation facility for the Rockwell International Corporation, Seal Beach, California. Technical tradeoffs and options are to be identified for the purpose of establishing a design to meet current and future flight projects.

EXPERIENCE: 1956 to present (JPL) - California Institute of Technology, Jet Propulsion Laboratory, Pasadena: Wind Tunnel Operations, Crew Chief, 21" Hypersonic Tunnel.
Operations Engineer, 25' Space Simulator. Operations representative for A & E modifications to facilities. Member of SEB for Technical Support Contract Selection. Technical contact with numerous JPL and non JPL flight projects including some foreign governments. Involved in facility design work such as Vacuum and Cryogenic systems, control consoles, clean room design and construction, humidity and temperature control systems, etc. Conducted Facility Operational Readiness Reviews prior to each major test program. Served as test observer in contractor test facilities at Hughes (Surveyor) and Boeing MVM-73.
Technical Group Supervisor, Mechanical Technical Group. Activities included administrative responsibility for two group leaders and forty mechanical technicians.
Supervisor, Solar/Thermal/Vacuum Test Group. Responsibilities include the operation and maintenance of JPL's Solar Thermal Vacuum and Environmental Test Laboratory Facilities. Included are: The 25' Space Simulator; the 10' Space Simulator; the 10' Ion Chamber; the 7 x 14' Thermal Vacuum Chamber; the 10' Molsink Facility, and the Thermal/Vacuum and Climatic Test Lab. A 14000 Currie Gamma Radiation test facility is also operated in support of Flight Project requirements.

CHARLES D. HAYES

EDUCATION: B.S. in Physics - 1965, Brigham Young University, Provo, Utah.
M.S. in Mechanical Engineering - 1967, University of Southern California, Los Angeles, California.
Graduate Courses in Engineering - 1959 - 1961, University of California at Los Angeles, Los Angeles, California.
Courses in Computer Sciences - 1972, Pierce College, Woodland Hills, California.
Graduate Courses in Engineering - 1975 - 1976, University of Southern California, Los Angeles, California.

CURRENT ASSIGNMENT: Responsibilities include the determination and evaluation of flight/launch dynamic environments, and the specifying and controlling of environmental design and test requirements in support of Flight Projects utilizing computer data analysis techniques.

EXPERIENCE: McDonnell Douglas Corporation - performing acoustic, shock and vibration testing of aircraft systems and components.
Jet Propulsion Laboratory - The design and operation of High Intensity Acoustic Test Facilities. Performance of advanced acoustics research studies in support of acoustic testing of spacecraft systems and components. Providing technical support for shock and vibration environmental testing.
Singer-Librascope - system analysis tasks for Fire Control Systems for the U.S. Navy.
Southern Company Services - design and assembly language coding of various monitoring and control algorithms for power plants in the Southern Electric System.
North American Aviation - designing and testing Antenna systems for the SB-70 Supersonic Aircraft.

CHARLES D. HAYES (continued)

SELECTED PUBLICATIONS:

"Octave and One-Third Octave Acoustic Noise Spectrum Analysis", by C. D. Hayes and M. D. Lamers, Report No. 32-1052, Jet Propulsion Laboratory.

"Power Spectral Density Analysis", by C. D. Hayes, Report No. 32-928, Jet Propulsion Laboratory, June 15, 1966.

"Acoustic Spectrum Shaping Utilizing Finite Hyperbolic Horn Theory", by C. D. Hayes, Report No. 32-1141, Jet Propulsion Laboratory, July 1967.

"Low Frequency Plane Wave Sound Generator and Impedance Measuring Device", by C. D. Hayes and M. D. Lamers, JPL Technical Memorandum No. 33-376, Jet Propulsion Laboratory, March 1, 1968.

"Use of An/BQS-14 as a Target Data Sensor for Target Motion Analysis", by G. J. Archer and C. D. Hayes, LReport No. 6248, Librascope, October 15, 1968.

SUSAN JEAN KOVACH

EDUCATION: University of Pittsburgh at Johnstown, Johnstown, Pennsylvania, 1972-1973, Engineering curriculum.
Gannon College, Erie, Pennsylvania, 1973-1976, BME, Major: Mechanical Engineering.
1976-Present, Company courses, General Electric Company, Erie, Penna: Engineering Training Program, Motors and Controls.

CURRENT ASSIGNMENT: Engineer on Wide Field Camera task. Studying mass properties and Pert.

EXPERIENCE: General Electric Company (7/76 to 1/79)

- Locomotive Department - Mechanical Systems Design Engineer. Designed components of diesel locomotive fluidic systems (lube oil, water, and fuel). Job required knowledge of material, shop capabilities, cost, and product reliability. Organized and conducted operating performance tests on locomotive fluidic systems. Job involved direct contact with shop and product support functions to resolve manufacturing and field complaints. Also performed failure analysis of present cooling systems.
- Control Products - Device Engineering Design (Mechanical). Analyzed test results of the cooling capacity of louvered versus non-louvered locomotive dynamic braking resistors. Also resolved manufacturing problems.
- Transit Vehicle Products - Mechanical Design Engineer. Designed structural assemblies for mounting of under-car equipment. Resolved assembly problems particular to car interiors; provided on-line engineering support. Resolved field problems. Organized and performed tests on car heating and air conditioning systems and brakes.
- Diesel Engine Department - Mechanical Design Engineer. Initiated and performed development engine tests on fuel injection systems for emissions and fuel consumption. Analyzed test records of production engines. Performed tests in Engine Development Laboratory.

CHARLES E. LIFER

EDUCATION: Mississippi State University, 1955
Bachelor of Science, Civil Engineering

CURRENT ASSIGNMENT: Acting supervisor of the Environmental Technology Group. Responsible for derivation and specification of environmental requirements for design and test, and for supporting analytical evaluations.

EXPERIENCE: NASA/MSFC - (1961 - 1979) Engineering Manager. Vibration, acoustic, and shock analysis, testing, and specification; structural strength, fracture mechanics, and fatigue analysis of launch vehicle and spacecraft structures and components; thermal and fluid dynamics analysis of launch vehicles and spacecraft; structural, dynamic, thermal and flow test requirements and specifications for launch vehicles and spacecraft.

Lockheed Aircraft - (1955 - 1961) Aircraft Research and Test Engineer. Dynamic, structures, and materials testing of aircraft assemblies, components and materials.

TAD W. MACIE

EDUCATION: M.Sc. E.E. Vienna Institute of Technology

CURRENT ASSIGNMENT: Manager JPL Electrical Traction Studies sponsored by the Federal Railroad Administration, Office of Research and Development. These tasks have included identification, translation and assessment of foreign technology developments in electrified railroads and electric traction and more recently system studies of advanced traction equipment performance on the Northeast Corridor. Also participated in urban transportation related projects, acting as traction equipment specialist.

EXPERIENCE: Powertronic Ltd. and Electronic Controls Ltd. - Designed and manufactured various types of industrial battery chargers, regulators, etc.
General Electric in Philadelphia - Developed and built the prototype of a 100 HP-size solid state power drive for Dupont, Synthetic Fiber Mills in West Virginia.
AiResearch Manufacturing Company - Responsible for developing and building the prototype of a solid state one-megawatt AC train drive for the Bay Area Rapid Transit in San Francisco. Operating from three phase 4160 V, 60 Hz power the unit supplies variable sinusoidal voltage and variable frequency to four traction motors.

EDWARD J. MARION

EDUCATION: BS in Engineering, 1960; University of California at Los Angeles

CURRENT ASSIGNMENT: JPL - Environmental Requirements Engineer for (1) Comet Rendezvous Pre-project Activity and (2) Projects associated with the Energy and Technology Applications Office. Responsibilities include programmatic support to the projects for both natural and induced environments for flight systems (ground, launch, space and planetary/cometary environments) and terrestrial projects. This responsibility includes preparation of environmental design and test requirements documents and specifications.

EXPERIENCE: Rockwell International Los Angeles Division - Project Engineer, General Dynamics ALCM Rotary Launcher Program. Responsible to the Program Manager to assure that system requirements defined by the Customer were thoroughly understood.
Assignment included assuring that requirements specified in the launcher specification and interface control documents were compatible with the rotary launcher and B-52 interfaces; coordinated engineering and test/logistics efforts required to support future proposals and design changes. Prepared, planned and coordinated preliminary and critical design reviews, PDR's and CDR's.
Project Engineer, B-1 Aircraft Program - Responsible to the A/C General Project Manager for general activities such as, S/V, Reliability, Mass Proportions, System and A/C Prime Item Development Specifications, Configuration Management, Safety, Waivers and Deviations, Standards and Flight Test Instrumentation.

PROFESSIONAL SOCIETIES: Institute of Environmental Sciences, Chairman of the International Electrotechnical Commission, Subcommittee SE-50B on Climatics.

JAMES W. SMITH

EDUCATION: BSME from The University of California at Berkeley, 1960. Degree options were Heat Transfer and Stress Analysis.
MSME from The University of Missouri at Rolla, May 1967. Major areas of study were Heat Transfer, Thermodynamics and Fluid Flow.
Licensed ME State of California #14708.

CURRENT ASSIGNMENT: Current position as a Thermal Requirements Engineer is to define the design and test levels for assemblies on the Galileo Orbiter.

EXPERIENCE: Nineteen years in the Aerospace industry as a Thermal Analyst and Thermal Requirements Engineer. Job responsibilities were those of formulating thermal design, performing analysis and thermal vacuum testing from the component level to the system level. Tasks that have been worked on were: The Atlas Missile, Gemini A and B, Surveyor, Lunar Science Instruments, Multi-Mission Planet Spacecraft, Viking, Voyager and Galileo.

JOHN O. STOKER

EDUCATION: B.S. E.E. University of California Los Angeles
A.A. E.E. Los Angeles City College

CURRENT ASSIGNMENT: Member Technical Staff, Solar Thermal Vacuum Testing Group of Test and Mechanical Support Selection. Environmental Testing of Galileo Spacecraft hardware. Budget preparation for future spacecraft environmental testing.

EXPERIENCE: Technical Group Supervisor and Engineer in a group testing complex spacecraft equipment from module level through complete systems under various environmental conditions. Developed performance requirements and environmental tests to be performed including preparation of specifications, procedures and reports. Monitored performance of assembly level and system contractors. Supervised design, construction and testing of special test fixtures and environmental simulation equipment including high-vacuum chambers, solar simulation systems, temperature and humidity control systems, cryogenic systems, etc.

PREVIOUS WORK EXPERIENCE PRIOR TO JPL: Design Engineer - Caltech Campus, Atomic Weapons Assembly - U.S. Army, Albuquerque and White Sands, New Mexico.

6.4 INSTRUMENTATION ENGINEERING

Introduction

Instrumentation engineering personnel support all scientific and engineering ground test activities which require measurements of physical phenomena to a specified accuracy in a given environment. Their tasks include investigation and analysis of the measurement to be made, the selection of sensors, their design, procurement, construction, installation and operation of complete data acquisition and recording systems. Also, provided are services for data analysis, instrument repair and calibration.

These professionals have extensive knowledge and experience in the application of measurement techniques including a wide range of sensors, instruments, and instrumentation systems. Commercially available equipment is normally used, but if required, is modified to suit the new use. The capability exists to design and construct special purpose sensors .

Strain Gage and Thermocouple Laboratory

The Strain Gage and Thermocouple Laboratory (SGTL) consists of a highly specialized group of experts and equipment in the fields of strain and temperature measurement. The SGTL provides applications engineering and fabrication services for the class of sensors. In the field of stress and strain measurement, the lab has personnel and facilities for selection, and application, curing and wiring of strain gage systems. A variety of gages is normally kept on hand for tasks requiring quick response. Specialized curing and testing equipment assures the required performance capability of strain gage measurements for the JPL user. Thermocouple measurements of temperatures encountered under normal as well as special conditions are handled in this lab. A stock of calibrated, NBS traceable thermocouple wire is on hand.

Special application techniques include welded couples, couples shielded from irradiance, and differential temperature measurement couples.

Transducer Calibration Laboratory

Transducer Calibration Laboratory provides the services required to calibrate the various transducers used in the measurement of force, pressure, vacuum, and displacement.

In addition to the normal ambient calibration of all transducers, calibration of pressure transducers with respect to temperature can also be provided. Minor repairs of transducers are performed. The Transducer Lab maintains a stock of transducers.

Standards Laboratory

JPL's Standards Laboratory maintains and operates basic calibration standards and provides calibration services on a high accuracy level in order to ensure the traceability of all electrical, electronic, temperature, time, frequency and thermal and special radiation measurements at JPL to the National Bureau of Standards.

Data Analysis

The Data Analysis Facility (DAF) processes time series data, such as sine sweep data, transient data, and random data. Analyses are performed in the time domain, Fourier transformed into the frequency domain, or analyzed as the response of a series of single degree of freedom systems to a transient. These data are presented as shock response data analyses, sine sweep amplitude analysis and, in the case of random data, direct Fourier transforms, inverse fourier transforms, power spectral density, cross spectral density, transfer function, coherence function, auto correlation, cross correlation, and probability density. The data are normally vibration and acoustic but can be any form of dynamic phenomena. The equipment available can output the data on X-Y plotters and oscillographs or to the JPL computer for further data processing. Output to the computer is done when the quantity of data is so large that it becomes unfeasible to handle it with the DAF equipment.

The DAF has all equipment necessary to playback analog magnetic recording tapes and data recorded from standard analog tape recorders, frequency multiplexed telemetry, and constant bandwidth data acquisition systems. All pheripheral test equipment is included to make the facility self-sufficient.

Edwards Test Station Instrumentation

A functional group of instrumentation professionals is located at Edwards Test Station. This group provides all electronic and electro-mechanical instrumentation services, installation and operations for ground testing at this facility. The staff and equipment are available for performing hazardous tests and other test activities that are best accomplished at a remote location.

ROBERT R. PURVES

EDUCATION: B.E. in Electrical Engineering 1948 University of Southern California, M.S. in Electrical Engineering 1950 University of Southern California.
Registered Professional Control System Engineer - State of California, #3483.

CURRENT ASSIGNMENT: Technical Group Supervisor, Environmental and Structural Test Instrumentation Group. Responsible for development and operation of the following instrumentation facilities: Dynamic Data Recording Center, Data Analysis Facility, Space-Simulator/Thermal-Vacuum Instrumentation Center, Structural Static Test Instrumentation. Also have been involved in developing the following types of instrumentation: rocket motor six-component thrust, photo-optical missile tracking, telemetry from moving vehicles, and acoustic weapon sensors.

EXPERIENCE: 1950-1975 (JPL) Instrumentation Engineer, Guidance Analysis Section: supervised acquisition and reduction of Corporal missile ground-guidance data, developed recording station at W.S.P.G. for flight tests of Corporal, designed Corporal doppler ground guidance control servo and warhead arming switch, analyzed doppler data and evaluated control system performance.

STEVE ROGERO

EDUCATION: B.S.E.E. 1956 University of Louisville

CURRENT ASSIGNMENT: Cognizant instrumentation engineer for the MJS77 test program at ETS.

EXPERIENCE: (JPL) Involved with instrumentation development, calibration as used on propulsion test programs. Experience in most common types of physical measurements as well as such specialty areas as high response measurements, recording, analysis, etc., and laser holography.

(1957 - 1961) Chance Vought Aircraft: Primarily concerned with airborne flight test instrumentation and checkout systems. Performed assessment of the state-of-the-art of sensors for measuring safety status of highway vehicles

JAMES H. WISE

EDUCATION: BA in Physics, New York University, 1951

CURRENT ASSIGNMENT: In charge of the Data Analysis Facility. DAF has the capability of interfacing with the JPL computer for rapid processing and manipulation of data on spacecraft environmental tests. Other capabilities are shock response and modal analyses.

EXPERIENCE: (JPL) Data acquisition and electronic analysis of vibration and acoustic data. The analysis included frequency vs. amplitude analysis, power spectral density, cross spectral density, transfer function coherence, auto and cross correlation, and probability density. Field data acquisition and analysis.

(U.S.N. Mine Defense Laboratory, Panama City) Tested acoustic sea mine countermeasures equipment.

(Aerojet General Corp.) Five years in Anti-Submarine Warfare Division. In charge of several projects for the design, development and testing of low frequency sound generations for use in acoustic sea mine countermeasures. Acquired, reduced and analyzed the data. Responsible for writing proposals, project administration, work schedules, budgets, contractual obligations, vendor and customer liaison. 5 years in vibration analysis, magnetic tape recording, and the design and development of test data acquisition systems.

(Measurement Analysis Corporation) Specialized in vibration and acoustic data analysis and acquisition systems.

6.5 FACILITY DESIGN/CONSTRUCTION/OPERATION

The Technical Staff at JPL has, for the past 20 years, been responsible for planning, design, construction, maintenance and operation of specialized technical facilities. These facilities include such complex systems as ground station antennas, solar simulators, acoustic chambers, modal test structures, liquid propulsion test sites (Edwards Test Station) and numerous other administrative and engineering laboratories.

A brief description of some of the JPL design and construction experience is included in the following paragraphs.

- Tracking Antenna

  These systems consist of large diameter tracking antennas and support facilities used by the NASA/JPL Deep Space Network (DSN). The DSN provides communication capability for the NASA Deep Space Probes, such as Voyager and Viking. The outstanding features of the network are the 64M (210 ft.) two axis parabolic antenna located at Goldstone, California; Madrid, Spain; and Canberra, Australia.

- Solar Simulators

  JPL's major solar simulator facilities consist of 10 ft. and 25 ft. diameter vacuum chambers, each housed in separate buildings. Each facility is equipped with vacuum capabilities to 1 x 10^{-6} torr, off-axis solar simulators and separate control console rooms.

  JPL was responsible for designing the entire 10 ft. solar simulation facility. In addition JPL provided the solar optics design for the 25 ft. simulator and directed an architectural and engineering firm in the design and construction of the 25 ft. vacuum system.

- Acoustics Facility

This facility consists of a 10,000 cubic foot concrete reverberation chamber and digital control system. An adjacent preparation area, used for hardware assembly and checkout, has a ten ton bridge crane and is a humidity and clean room facility. JPL was responsible for the design, construction and checkout of this facility. The control system is a unique digital system that was designed and built at JPL.

- Automotive Research and Test Laboratory

The Caltech/Jet Propulsion Laboratory has an Automotive Research Laboratory which was designed for systematic non-routine diagnostic testing of automotive power systems. The facility has a variable speed Cooperative Fuels Research (CFR) engine, two engine dynamometer test cells, two chassis dynamometers, an Integrated Data Acquisition and Control (IDAC) data system, and emissions analysis equipment.

One of the engine dynamometer test cells has an eddy-current engine dynamometer with dynamic test capability. The dynamometer can be electrically programmed to simulate the road load power requirements of a vehicle with the vehicle inertia being simulated by inertia wheel weights which can be attached to the dynamometer. Engine/transmission systems can be tested over driving cycles from this test cell. This facilitates access to the engine/transmission system for development activities.

One key strength of the JPL Automotive Research Laboratory is the instrumentation capability which is based on the IDAC data system. The system has a capacity large enough to allow real-time output of not only engineering units data, but also key calculated parameters such as equivalence ratio and engine thermal efficiency. The data acquisition time is very rapid, with the recording time for over 100 channels being less than 20 seconds. The IDAC has both analog and digital data input capability. Real-time engineering unit output data is provided by a printed paper tape, eight video displays, and 16 digital-to-analog converters. In addition, test data is recorded on magnetic tape for later data reduction and analysis.

A constant volume sampling (CVS) system is available for making the standard EPA tests for exhaust emissions. It is located so that it can be used for either the chassis dynamometer or eddy-current engine dynamometer test cells. An emissions bench is available for continuous or batch measurement of exhaust emissions. The following emissions measuring instruments are used: non-dispersive infrared (NDIR) analyzers for carbon monoxide and carbon dioxide; chemiluminescence (CL) analyzer for oxides of nitrogen; and a flame ionization detector (FID) for hydrocarbons.

JPL's automotive propulsion experience includes successful projects in the following areas:

a. Hydrogen Enrichment
b. Lean Burn Engine
c. Fuel Economy/Emissions Tradeoffs
d. Fuel Injection Device Evaluation
e. Stirling Laboratory Research Engine
f. Electric and Hybrid Vehicle Evaluation
g. Automotive Propulsion Systems Evaluation Study
h. Engine Modeling (Detailed Modeling of Physical Process and Systems Modeling)
i. Automotive Technology Status and Projections Study

- Shock Facility

    Several unique shock test facilities have been recently constructed at JPL. One facility is used to simulate high amplitude, high frequency transients similar to those generated by pyrotechnic events. The basic facility consists of a hardened steel piston that is pneumatically accelerated down a barrel onto an impact plate. Piston size and pneumatic pressure are varied to produce the desired amplitude and pulse characteristics.

    The other facility is used to produce hailstones for testing solar panels. It includes the equipment necessary to make hailstones from .75" to 5.0" diameter and to hurl these at velocities greater than 100 miles per hour. This facility was designed and built at JPL to meet the unique test requirements for evaluating solar panels.

The JPL team that has been responsible for the construction of the facilities is also available for other selected projects. This team is skilled in all phases of the implementation of technical facilities. The critical phases of a project that are normally within the scope of team activities include:

1. Project planning - The preliminary analysis and conceptual designs required to develop an understanding of what is needed to meet the customers' requirements. Life cycle cost tradeoff studies can be included along with detailed cost estimates and schedules for an agreed-upon conceptual design.

2. Design - The JPL team is experienced either in doing the design in-house or in managing and supporting the design effort at selected competent engineering firms. The translation of a customer's particular requirements into a set of detailed design requirements is a necessary speciality of the JPL team.

3. Construction - For new designs or first installations that involve specialized requirements, the JPL team will normally assume the role of construction management and system integration. The task will be separated into major assemblies or component parts and procured from subcontractors that are experienced in the particular discipline. In addition, each subcontractor's work can be inspected and tested to well-defined standards. It has been our experience that this method provides both the lowest cost and the lowest risk for new and highly specialized technical facilities.

4. Transfer to operations - The last critical phase in the development of a technical facility is the transfer to the operations team. This phase includes not only the demonstration tests of the integrated system, but also the supplying of operations and maintenance documentation and the procuring of spare parts down to the replaceable module level. Well established procedures and standards have been evolved at JPL to govern this phase of the project.

5. Operations - The major technical facilities at JPL, such as the DSN, the Mission Control Center and the General Purpose Computing Facility are operated by JPL and/or contractor personnel. Other facilities are operated either by JPL employees or contractors at the

discretion of the Program Manager. JPL has many years of experience in the managing of the operations of highly specialized facilities.

The JPL engineering team that has been responsible for the development of facilities is very broad-based in capabilities and experience. The major disciplines are represented by civil, structural, thermal, mechanical, materials, electrical, electronics, and control engineers integrated into an experienced team. Many of the engineers also hold professional licenses. JPL has had the responsibility for more than 20 facility projects with budgets of a million dollars or greater, including several over 10 million. JPL is currently involved in several projects, including a major upgrade and conversion project which will total more than 15 million dollars and is participating in the advanced planning and studies for a new large antenna project which will total more than 50 million dollars.

One of the studies being conducted as part of the large antenna project is the analysis and modeling of a wheel and track-type thrust bearing. While this study has been directed toward an antenna application, JPL has developed expertise which would be applicable in support of the currently proposed project.

RUSSELL BYERS

EDUCATION: Pasadena Junior College, AS in Aeronautical Engineering

CURRENT ASSIGNMENT: August 1969 to present, Jet Propulsion Laboratory, Manager Edwards Test Station, located on the Edwards Air Force Base, Kern County, California.

The duties include scheduling facilities, test operations and personnel. Implement active preventative maintenance program on all facilities and grounds. Prepare and administer fiscal budgets for facility operation. Initiate and administer the safety and health program as prescribed by Federal, State and local requirements. Administrator of all security and plant protection policies and procedures according to JPL, EAFB and other regulations. Maintain active liaison with the various branches of the EAFB concerning support to and operation of the ETS as these matters relate to the Edwards Air Force Base Use Agreement. Currently a member of the JPL Safety Committee.

EXPERIENCE: 1959 to August 1969, Senior Staff Assistant, Propulsion Division, Pasadena.

The duties included coordination of activities pertaining to personnel recruiting and advertising. Analyzed the long range facilities requirements for the Division, and collected input data for annual C of F submittals. Functioned as the Division Safety Coordinator and represented the Manager on all matters of safety. Represented Division Management in matters pertaining to technical services within the Division and technical services to other divisions. Initiated and administered specialized services contracts.

JAMES D. GLOMB

EDUCATION:	1942, 45, 46	San Mateo Junior College	A.A.
	1946	University of Calif. Berkeley	---
	1947-1948	Stanford University	BSME

CURRENT ASSIGNMENT: Member of Technical Staff, Solar Thermal Vacuum Testing Group.

EXPERIENCE: Engineer, Sr. Engineer. Design and Development work in wind tunnels, compressor plant engineer.

Group Supervisor. Compressor plant operations, modifications, maintenance and repair.

Group Supervisor. Space simulator and compressor plant operations, modifications, maintenance and repair.

Member of Technical Staff, Solar Thermal Vacuum Testing Group.

Numerous management courses, S.E.B. for technical support contract, work in coal, geothermal and solar energy fields. Designed and developed solar precursor concentrator for solar test program at JPL Edwards Test Station.

NORMAN R. MORGAN

EDUCATION: B.S.A.E., 1953, Ohio State University

EXPERIENCE: 1962 - Present: JPL/Caltech. Currently task leader on Wide Field and Planetary Camera for Space Telescope; this position entails responsibility for mechanical design and fabrication, thermal and structural analysis, materials, cabling and electronic packaging support. Past responsibilities include task manager of a study for the National Science Foundation on the feasibility and desirability of constructing a very large centrifuge for geotechnical studies, supervision of design efforts on large technical facilities, such as clean rooms and solar panel test facilities; supervision of design and construction of rocket engine test facilities and wind tunnel mounts; design and construction of electric arc shock tubes, free piston shock tubes, magnetometers for interplanetary missions, a zero-g liquid helium experiment to be rocket launched; design and supervision of modifications to the large 25 foot Space Simulator to permit testing at Mercury-orbit solar intensities; major test activities such as vibration test of the Viking Orbiter and Lander.
1959-1962: AiResearch Manufacturing Company, Phoenix, Arizona - Performed reliability studies of AiResearch produced valves, gas turbines, air turbine starters - These studies were both problem investigations and reliability predictions of prospective designs. Also performed stress analyses on high-speed rotating components, such as turbine wheels operating in the 30,000-65,000 rpm range.
1957-1959: Pratt & Whitney Aircraft, East Hartford, Connecticut - Performance Analysis of turbofans, turbojets, ramjets, rockets. Conducted studies of infrared suppression techniques for turbojets and turbofans. Interfaced with major airframe manufacturers as potential users of advanced Pratt & Whitney power plants.

ROBERT J. WALLACE

EDUCATION: BSEE - Fresno State 1957
Graduate School - Stanford 1957 to 1959
Professional Engineering Registration No. CS4565

CURRENT ASSIGNMENT: Technical Staff in Deep Space Net Engineering with a variety of duties, including filling in for Section Manager during his absences. Specific responsibilities include the coordination of activities for the Section. Additional duties include the review of Section budgets and support of the Advanced Development Programs.

EXPERIENCE: Previous assignment - Task Manager for the 100M Antenna Studies. This portion of the Large Antenna Array System Studies started with the Low Cost Antenna Studies in 1975 and evolved through in-house and Contracted Parametric Studies into the Light-weight 100M design and that was presented last year as part of the LAAS Life Cycle Cost Study.
January 1969 to May 1975: Was Supervisor of the Servo and Control Group within the DSN Engineering Section. Specific tasks included the design and fabrication of a central control unit for a large tracking station to reduce the number of station operators, the design of pure water coolant system for a megawatt transmitter, the fabrication and installation of antenna servo control systems at 2 overseas locations, the design, installation and testing of a servo control and drive system for a 30 foot transportable antenna. Also served as the Assistant Project Manager for the Fourth Large Antenna Project.
July 1966 to January 1969: Assignment was as a Member of the Technical Staff within the Servo and Control Group with primary responsibility for the analysis and design of servo and control systems used in the NASA/JPL Deep Space Network of Ground Based Tracking Antennas. Additional duties included that of Systems Engineer for the 210 foot diameter Tracking Antenna at Goldstone and the 64M antenna subsystem. Also responsible for developing the procurement package for the overseas 64M antennas.

JET PROPULSION LABORATORY *California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91103*

May 11, 1979

Refer to: 354-WAE:lc

Mr. David M. Dancer
Office of Rail Safety Research
Code RRD-33
The Federal Railroad Administration
U.S. Department of Transportation
2100 2nd Street, S.W.
Washington, D.C. 20590

Dear Mr. Dancer:

The Jet Propulsion Laboratory is pleased to provide three copies of a document entitled "JPL Capabilities for the Railroad Wheel Failure Mechanisms and Test Facility Project." The document contains a description of the JPL/Caltech capabilities relevant to a project on obtaining a better understanding of how and why railroad wheels fail.

We trust the document will be of assistance to you by answering some of your questions and fulfilling your previously expressed desire on our recent conference telephone call to have written information on JPL's capabilities.

JPL also is in the process of preparing a brief "Concept Paper" delineating the technical aspects of a railroad wheel project. We look forward to having this ready to discuss with you in the near future.

If you have any questions or desire additional information on the enclosed document, please call the undersigned Proposal Manager at (213) 354-4080 or (FTS) 792-4080; or Mr. Brad Houser, Manager for Transportation Systems Projects at (213) 577-9150 or (FTS) 792-9150.

JPL is very interested in performing this project for The Federal Railroad Administration and we look forward to discussing it with you at your earliest convenience.

Yours truly,

W.A. Edmiston

W. A. Edmiston
Proposal Manager

Enclosure

cc: Mr. Richard Barlow
Mr. Brad Houser

bcc Proposal Team
J. Chen
R. Daniel
E. Gregory
R. Purves
P. Tung
B. Zeldin

bcc JPL Management
M. Adams
R. Byers
H. Cotrill
D. Dipprey
M. Dowdy
T. Gindorf
R. Martin
C. Savage
B. Wada