NASA Technical Memorandum 81333

RESEARCH AND TECHNOLOGY

ANNUAL REPORT 1981

Ames Research Center
Moffett Field, California

Introduction

1981 was another year of significant accomplishments for the Ames Research Center. This annual report provides a clear indication of the breadth and quality of Ames' achievements during the past year in the sciences and technologies of aeronautics and space.

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C. A. Syvertson
Director

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Space Science

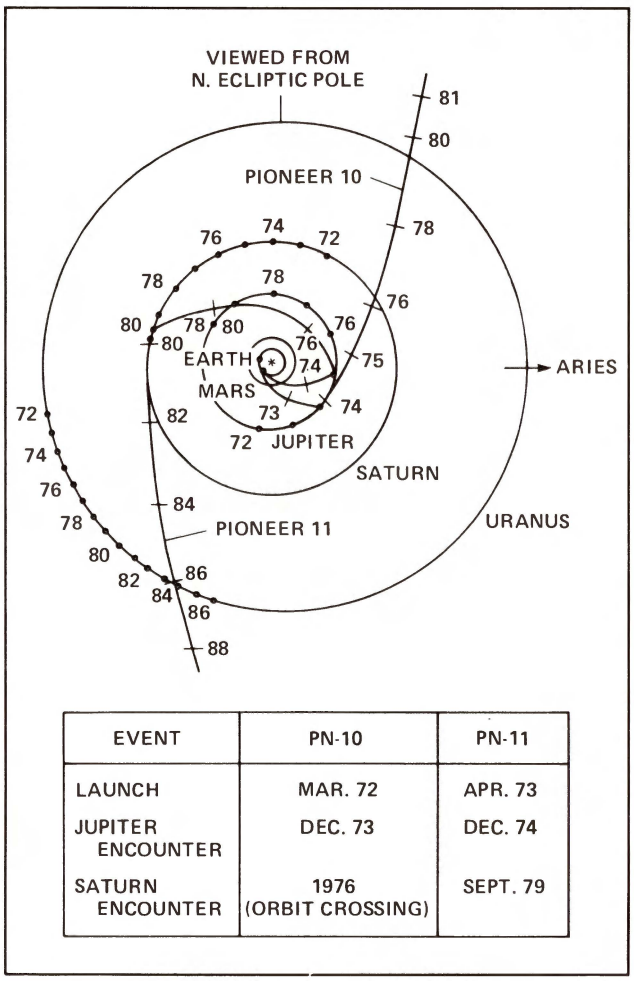
Pioneers 6, 10, and 11

On December 15, 1981, the Pioneer 6 spacecraft begins its seventeenth year of operation. The spacecraft continues to transmit useful solar-wind and cosmic-ray measurements.

The Pioneer 10 spacecraft continues its outbound journey from the Sun. It is the most distant man-made object in our Solar System and, in 1981, traversed the space between 23.3 to 26.2 AU. Data obtained from this spacecraft have totally changed our model of the solar wind developed in 1967. The heliopause boundary has not yet been reached; and the temperature of the solar wind does not fall off adiabatically as previously predicted. High-speed streams in the solar wind cease to exist beyond approximately 10 AU. Pioneer 10 will continue its escape from our Solar System in a direction opposite that of the Sun's motion through the Milky Way Galaxy.

Pioneer 11 is presently leaving the Solar System at a velocity of approximately 2.5 AU per year in a direction opposite that of Pioneer 10. These two spacecraft provide our first large-scale examination of the Sun as a star with its surrounding gas and dust. The spiral structure of solar-wind particles and fields is being measured as well as the incursion of interstellar particles into our Solar System. Data received from Pioneers 10 and 11 indicate that the presently available tracking systems will be able to measure properties of the heliosphere out to at least 40 AU.

(P. Dyal, Ext. 5523; R. Fimmel, Ext. 6456)



EVENT	PN-10	PN-11
LAUNCH	MAR. 72	APR. 73
JUPITER ENCOUNTER	DEC. 73	DEC. 74
SATURN ENCOUNTER	1976 (ORBIT CROSSING)	SEPT. 79

Position of Pioneers 10 and 11 since launch and the orbits of Earth, Mars, Jupiter, Saturn, and Uranus

Pioneer Venus

The nominal mission of the Orbiter was completed on August 4, 1979. During an extended mission with similar orbital characteristics, the Orbiter continued to send scientific data through the summer of 1980, until there was no longer sufficient fuel to maintain the orbit and it was allowed to change. The periapsis of the orbit is slowly rising and will reach 2300 km in 1986 when it will fall again. Eventually, the Orbiter will dip deep into the upper atmosphere of Venus where it will be destroyed – in 1992. All scientific instruments are expected to continue operating nominally.

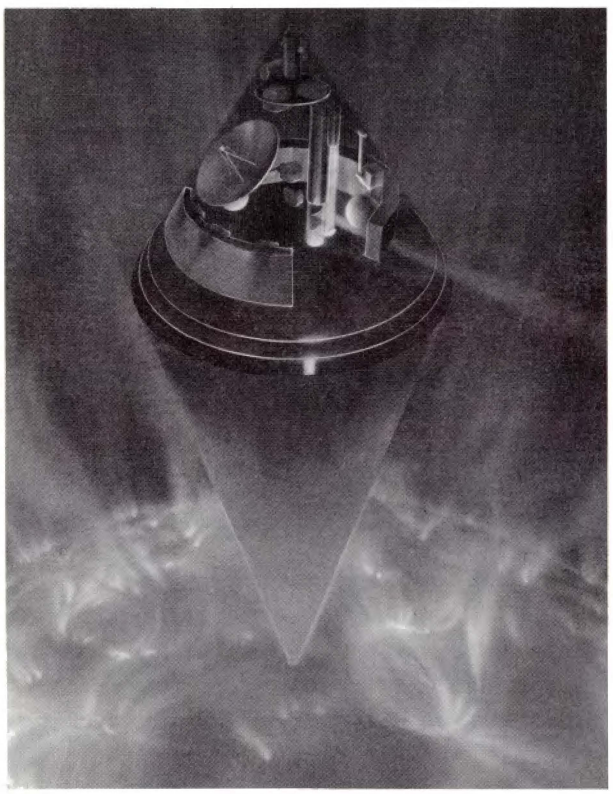
During the extended mission, the major focus will be on mapping the solar-wind/ionosphere interaction region, and on studying the chemical and thermal dynamics of the interaction. The influence of the 11-year solar cycle will also be investigated.

(L. Colin, Ext. 5519)

Mission to Sun Deemed Feasible

The proposed Star Probe mission will be man's closest venture to the Sun. It will approach within 3 solar radii of the Sun's surface. Because of the close proximity to the Sun, the probe will be subjected to radiation 2500 times greater than that felt on Earth. This environment will persist for several days before and after its closest approach to the Sun. A heat shield will remain pointed at the Sun's surface to provide shade for the spacecraft, thereby protecting the delicate instruments that constitute the payload.

The Star Probe mission will be managed by the Jet Propulsion Laboratory. Ames Research Center is responsible for the technical development of the heat shield. Currently, Science Applications Incorporated is under contract to Ames to develop and establish fabrication techniques for the heat-shield concept originated by the Entry Technology Branch at Ames.



Star Probe mission concept

The Ames concept consists of a conical carbon-carbon structure that will point toward the Sun and provide thermal protection for the payload located at the base. An in-house preliminary system study established the feasibility of the concept.

(H. K. Larson, Ext. 5369)

C-141 Kuiper Airborne Observatory

In FY 1981, the NASA C-141 Kuiper Airborne Observatory (KAO) flew 19 investigator teams for approximately 80 research flights in infrared astronomy. Studies continued on the galactic center, external galaxies, and interstellar gas and dust clouds. In the past year, higher resolution data were obtained in the middle and far-infrared regions because of improved instrumentation, particularly spectrometers and heterodyne receivers (for the submillimeter region). For the first time in the history of the KAO, solar observations out to 200 μ were made during the solar eclipse of July 31, 1981. This achievement extends the range of the KAO to the field of infrared solar astronomy.

(R. Cameron, Ext. 5338)

Far Infrared Studies of a Solar Eclipse

A series of solar studies, culminating with observations of the July 31, 1981 eclipse, have been carried out at far-infrared wavelengths from the Kuiper Airborne Observatory (KAO).

Scientists from the University of Hawaii, the United Kingdom Infrared Telescope, and the Ames Space Science Division collaborated with the KAO staff in modifying the 91-cm telescope of the KAO and the auxiliary tracking and guidance telescopes so that they could be safely used to directly view the Sun.

The solar observations were made in four separate spectral bands at wavelengths between 30 and 200 μm in the far infrared. The airborne observatory was required because this far-infrared radiation does not penetrate to the surface of Earth. Additionally, the mobility of the KAO made it possible to intercept the path of the eclipse off the coast of Japan. The observations were the first systematic study of the Sun at far-infrared wavelengths. This radiation comes from the "transition region" of the solar atmosphere — the region of the temperature minimum between the photosphere and the corona. This region is a particularly important one to study to improve our understanding of solar activity and of the transport of energy into the corona and the solar wind.

Scientific results were obtained during the solar eclipse; in the few moments just before and just after totality, it was possible to study the structure of the solar limb with an effective spatial resolution of $\leqslant$1 arcsec (corresponding to a linear scale of $\leqslant$750 km). This is a factor of 10 to 50 better spatial resolution than can ordinarily be obtained in the far infrared with existing telescopes. The preliminary analysis of the eclipse data suggests that, as the Sun emerges from totality, the solar limb is seen at 200 μm several seconds before it reappears at 30 μm; a similar effect is seen just before totality. These results indicate that the effective radius of the Sun observed at 200 μm is appreciably greater (by at least several hundred km) than observed at 30 μm. This result is qualitatively expected from the known opacity law in the solar atmosphere, but the precise quantitative information that will be extracted from the data obtained during the eclipse, and from numerous auxiliary observations, will provide important new constraints for models of the structure of the Sun and for our understanding of the general nature of stellar atmospheres. The physical quantities and questions to be investigated in the analysis include the mean density, pressure, and temperature as a function of height in the transition region, the nature and spatial scale of density inhomogeneities, and the influence of magnetic fields on the structure of the region.

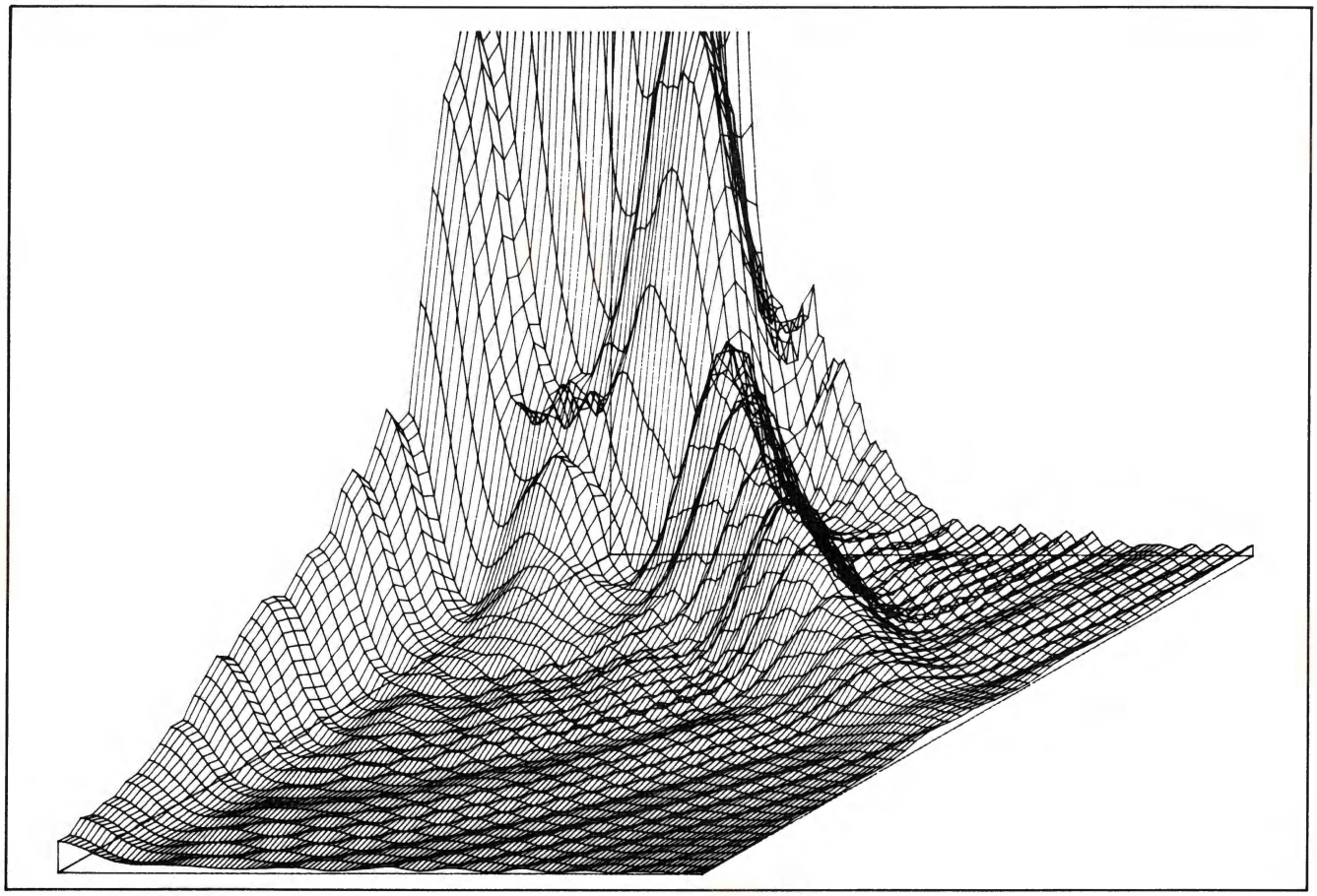
(M. Werner, Ext. 5101)

Infrared Astronomical Satellite (IRAS) Telescope Simulator

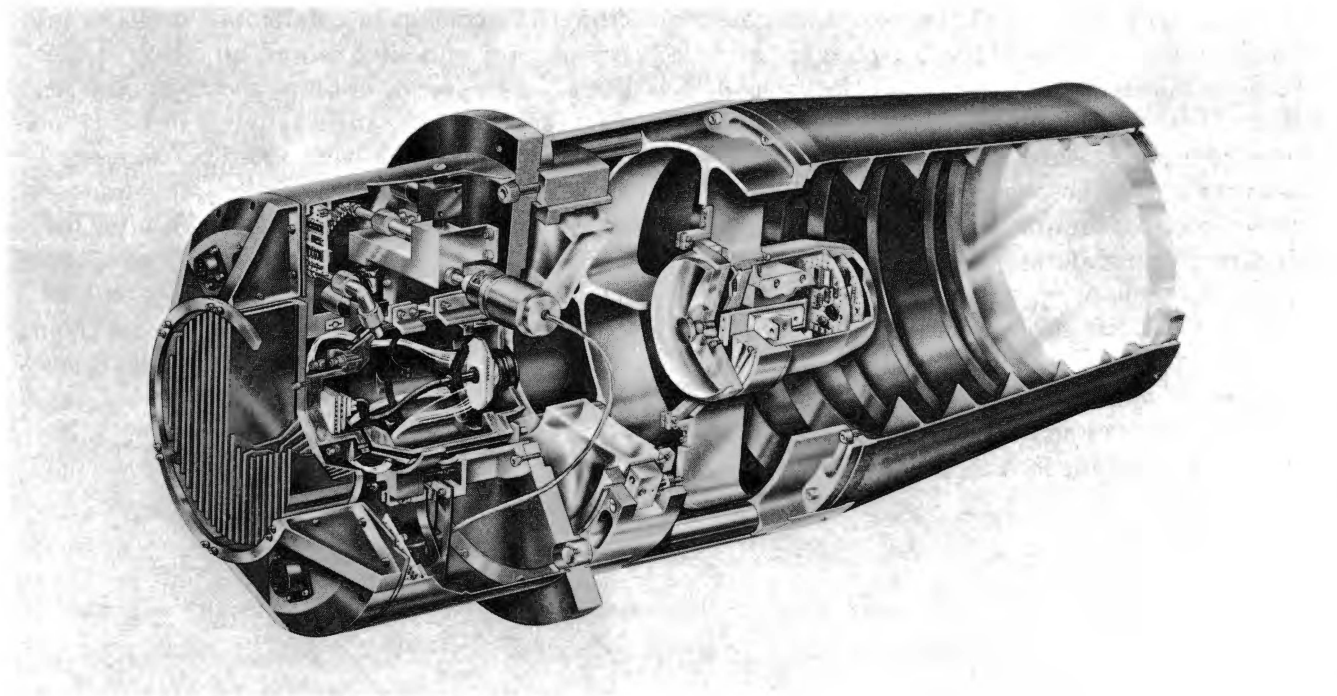
The IRAS telescope simulator (IRTS) developed by Ames is now operational and is being used by the Jet Propulsion Laboratory and the United Kingdom to develop and evaluate science data-processing algorithms for the IRAS telescope. IRTS is an interactive hardware/software analytical model of the telescope system and includes a simulated sky model of the infrared sources, both point sources and extended sources. The computer simulation consists of several input options such as type of noise desired, size and number of detectors in the focal plane, filter bandwidths, and sampling rates. The output from IRTS consists of data simulation tapes and analog plots of desired output functions such as optics, raw detector outputs, and filter outputs. An example of the optics output is shown below.

The IRTS modules are currently being reconfigured for other infrared system simulations such as the Shuttle Infrared Telescope Facility, the Small Helium Infrared Telescope System, and the Large Deployable Reflector. The simulator has proven to be a valuable tool in the design and development of infrared telescope systems and data-processing algorithms.

(H. Lum, Ext. 6544)



IRTS contour map showing an expanded infrared point source baseline



SIRTF prototype fine guidance sensor

SIRTF Prototype Fine Guidance Sensor

A prototype of the fine guidance sensor (FGS) that will be used on the Shuttle Infrared Telescope Facility (SIRTF) has been developed. The SIRTF prototype FGS incorporates several advanced technologies that will be crucial to the performance of the SIRTF pointing and control system. The new technology includes an advanced charge-coupled device (CCD) sensor controlled by a high-performance microcomputer. A computer-controlled secondary mirror, utilizing an Ames-developed algorithm to minimize energy dissipation, will provide both image motion compensation and precise space chopping. The system performed as intended; simultaneous image motion compensation and space chopping were demonstrated for the first time. Output from the prototype FGS will be presented on a digital color display which can be zoomed in or out, depending on the requirements for resolution and field of view.

Preliminary astronomical tests of the prototype FGS and display system will be carried out at the Lick Observatory during the early fall of 1981. Sensitivity, spectral response, resolution, and linearity will be measured to help understand the FGS performance under conditions not obtainable in the laboratory.

(H. Lum, Ext. 6544)

Astronomical Demonstration of Infrared CCD Array

To determine the usefulness of multielement infrared detector array technology in astronomical applications such as the Shuttle Infrared Telescope Facility (SIRTF), a demonstration on the 160-cm Mt. Lemmon, Arizona infrared telescope was performed. This was the first time an infrared charge-coupled device (CCD) had been used for astronomy. The detector array, a 20-element monolithic InSb CCD, was developed by Langley Research Center and loaned to Ames for evaluation. Following extensive laboratory tests at Ames during 1979-1980, the test system was modified for 2-μm observations on the telescope.

On the night of May 1, 1981, two stars, Alpha Hercules and Alpha Lyra, were successfully imaged on the array. The image size obtained was consistent with the computed diffraction disk, and it was found that crosstalk to adjacent detectors was small. The sensitivity of the array was within a factor of 3 of that measured in the laboratory, and the array was no more difficult to operate on the telescope than it was in the laboratory. These positive findings established that integrated infrared CCD arrays are very promising for astronomical applications, both on ground-based and orbiting telescope systems.

(H. Lum, Ext. 6544)



20-element infrared CCD array in operation on 160-cm Mt. Lemmon telescope

Search for Planet Formation Debris Near Stars 300 Million Years Old

Theories of planet formation involving accretion of the planets from smaller solid bodies require that collisional fragmentation take place

as well on a time scale of 10^8 years or longer. Such fragmentation would produce large clouds of debris around stars whose planets were still forming. The infrared luminosity of such clouds has been estimated on the basis of particle size distributions determined from the interplanetary particle size distribution of the Solar System. The spatial distribution of the particles was assumed to resemble that of the rocky mass in the solar planets. It was found that, if even 1% of the rocky mass of the planets were in such a debris cloud, it would cause a detectable infrared (8–13 μm) luminosity enhancement of a solar-type star.

Measurements of the 8–13 μm brightness of F, G, and K Main Sequence stars of the Ursa Major Stream were made with the NASA/University of Arizona 60-inch telescope. They showed no detectable enhancement in infrared luminosity. The measurements of six of the stars were sensitive enough to limit the debris cloud mass to 2×10^{-6} solar masses (1% of the rocky mass of the known planets). The upper limits on debris clouds around the other seven stars is 16×10^{-6} or less. This could mean that planet formation is not an extremely common phenomenon. It may mean, however, that planet formation occurs on a much shorter time scale than 300 million years, the age of the Ursa Major stream stars. It is hoped that this search can be extended to more Ursa Major stream stars and also to the solar-type stars of the Pleiades Cluster which are less than 100 million years old.

(F. Witteborn, Ext. 5520)

Stable Isotope Measurements of Geothermal Emanations

The composition of the atmosphere of early Earth strongly influenced the course of the origin and early evolution of life. Atmospheric scientists today use modern computational techniques to construct models for the early atmosphere. These investigators have concluded that emanations of gases such as methane and hydrogen from Earth's crust played a key role in controlling atmospheric compositions.

Our research has evaluated present-day crustal sources of methane as analogs to ancient crustal sources. Geothermal localities were studied because they are chemically very active and because geothermal activity was undoubtedly very intense on early Earth. Stable carbon isotopic measurements revealed that most of the hydrocarbons, including methane, found in geothermal emanations derive from the thermal decomposition of organic matter in sedimentary rocks. Such organic matter had been synthesized by preexisting living organisms whose organic debris had been deposited in ancient aquatic sediments. This observation indicates that most of the methane in present-day geothermal emanations required the preexistence of life. Therefore, before life existed to produce abundant sedimentary organic matter, the methane contributed to the prebiotic atmosphere by geothermal systems was probably considerably less than that observed today. Observations such as this provide atmospheric scientists with the numerical constraints necessary to improve their models of primitive atmospheric compositions.

(D. Des Marais, Ext. 6110)

Novel Luminescence Phenomena in Minerals and Organic Compounds

A detailed study has revealed novel luminescence (light emission) phenomena which accompany the interaction of inorganic and organic solids with aqueous solutions and organic solvents, as well as their vapors. The luminescence, which normally takes a matter of hours and sometimes days to decay, can be readily measured by a photomultiplier tube. Thus, it can be demonstrated and studied in almost any laboratory.

Even though the mechanisms of the luminescence remain to be elucidated, it is possible that

these phenomena can be used for detecting, monitoring, and characterizing a variety of physical-chemical processes, including ones that occur at extremely low rates. Notable examples are surface reactions of solids in the presence of liquids and gases, on a macroscopic as well as on a microscopic scale.

(S. Chang, Ext. 6206)

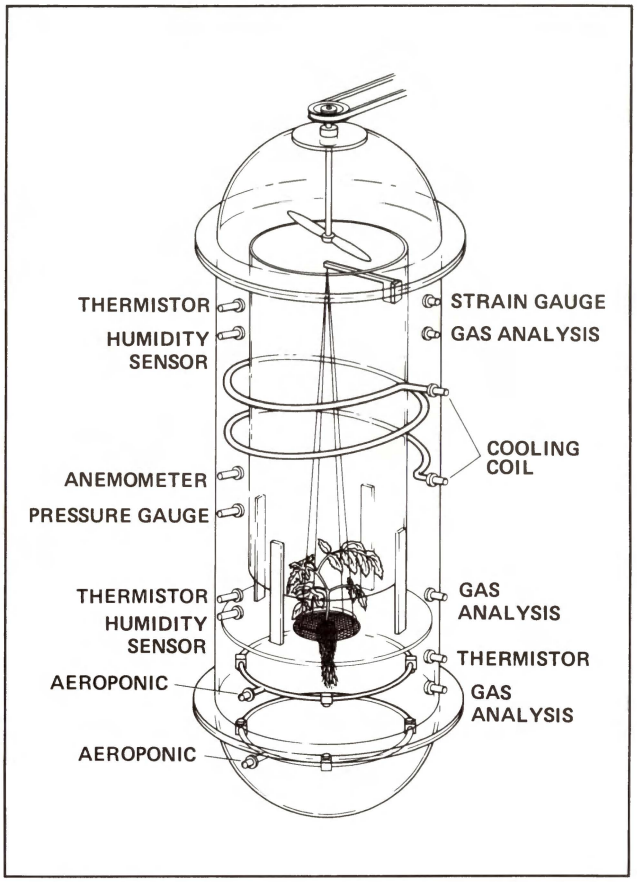
Lightweight Detector for Gas Analysis by Spacecraft

In past NASA missions, the surface of Mars was analyzed for volatiles and gases by the Viking landers and the atmosphere of Venus, by the Pioneer probes. The gas/vapor analyzers took samples, separated them into individual chemical components, and measured the amounts of each. The actual quantitative measurement was made by various types of detectors. A new version of detector for such applications has recently been designed and successfully tested. It is of the very sensitive ionization type and weighs 30 to 100 times less than its commercially available equivalent. Besides its utility on future solar system exploration missions, the new detector will also be useful for airborne missions in Earth's environment or for gas analysis aboard manned space vehicles.

(F. Woeller, Ext. 5769)

Autonomous Life-Support Systems

Long-duration spaceflight, involving many people, could be made more practical if the mass of the life-support equipment and materials could be reduced. One way to accomplish such a weight reduction is to recycle the materials usually stored for later consumption. Materials such as water, food, and breathable gases can be reused if preparations are made to recycle them and, when necessary, to regenerate the starting materials.



Plant growth chamber

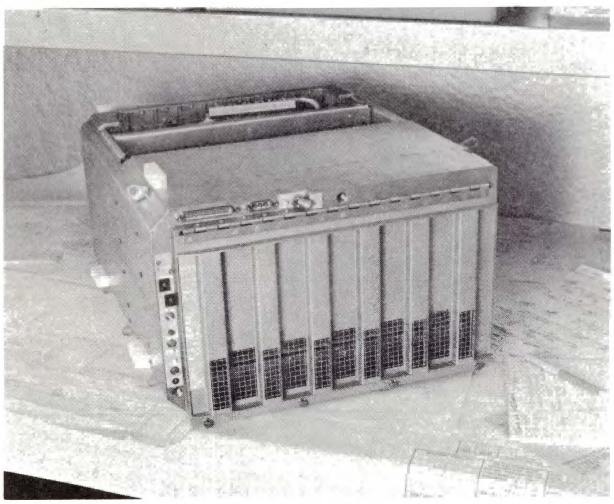
The most straightforward and, currently, the most reliable way to regenerate food is to use photosynthetic organisms to capture sunlight and use it to make food from waste minerals and gases. Such a system is under investigation and involves the development of an environment closely controlled by people and computers.

As part of this development, a chamber has been constructed that can maintain a constant internal environment, totally isolated from the external atmosphere. The function of the chamber is to investigate the growth, metabolism, and physiology of higher plants and to determine how these can be changed by manipulating their environment. It is necessary to monitor and control atmospheric gases, temperature, humidity, light intensity and quality, and the minerals in the hydroponic nutrient solution. The instruments that both monitor and control are operated by a computer. The information collected by the monitors provides a highly detailed record of the

needs and responses of the plants and permits an evaluation of attempts to control their growth and development. The chamber is a unique instrument and has excited much interest as a tool to evaluate newly developed agricultural strains as well as theoretical postulates of control theory.

(R. MacElroy, Ext. 5573)

Plant Growth Unit



Space Shuttle plant growth unit

The Space Shuttle plant growth unit (PGU) has been designed and built by Lockheed Missiles and Space Company and the Research Facilities and Instrumentation Division at Ames for the Life Sciences Flight Experiments Project Office to investigate the effect of zero gravity on the formation of plant lignin. Lignin, a product of metabolism in plants, forms the woody structure that stiffens the plant walls, aiding the plant in growing upright against gravity. Weightlessness affords a unique tool to further define the biochemical pathways vital to lignin synthesis.

The PGU is a self-contained, carry-on experiment designed to be loaded into the Shuttle late in the launch countdown and mounted in place of one of the storage lockers located in the Spacelab Orbiter middeck. The experiment is completely automatic, requiring no flight crew interaction; all data are stored within the experiment package. The hardware holds six plant growth chambers, each containing approximately 16 plant seedlings, a total of 96 plants. The experiment hardware also includes a thermal-control system, lighting, instrumentation, and a data-management system. NASA plans to first fly the experiment hardware on Space Transport System 3 (STS-3). This flight will involve species from three different plant classes. The outcome will provide basic data on lignin formation and will also help plant scientists to make a final selection of plant species to be used in a subsequent flight experiment, scheduled to fly on Spacelab 2.

(J. Tremor, Ext. 5731)

Cardiovascular Responses to Simulated Spaceflight

Studies of circulatory changes during weightlessness have required the development of appropriate instrumentation systems as well as the use of suitable animal models. Recently, advanced transducers have been developed to reliably measure pressure and flow in blood vessels as small as 2–4 mm in diameter. The system utilizes a cuff implanted around the vessel so that the vessel wall need not be penetrated. Pressure is sensed by a 4.5-mm strain gauge diaphragm transducer incorporated into the cuff so as to touch its external surface and reduce the normal vessel cross-sectional area by no more than 10%. Flow is registered by the Doppler principle using 8.5-MHz lead titanate crystals.

The system has now been used to study flow to the head (implanted about the carotid artery) in dogs and primates during conditions of simulated weightlessness which include changes in body position and water immersion to the neck. High-quality signals have been obtained for periods in excess of 8 months and provide assurance for long-term monitoring as will be needed during future Spacelab experiments.

(H. Sandler, Ext. 5745)

Physiological Responses of Older Women to Simulated Spaceflight

As part of a series of studies to develop passenger selection criteria for future Space Shuttle flights, eight healthy women, 55 to 65 years old, underwent 10 days of bedrest-simulated weightlessness. This group is the oldest group of women to participate in such a study and the results will contribute to an understanding of the physiological effect of weightlessness on aging astronauts and older scientists who may be chosen to conduct their experiments in space. Tests included response to exercise, tilt (using lower-body negative pressure, LBNP), and Shuttle reentry accelerations. All centrifuge runs were repeated with subjects wearing an inflated antigravity suit of the type worn by Air Force pilots. Expected degradations in physiologic function occurred after bedrest during all tests. Results revealed a 59% decrease in +3 G_z tolerance in this group, which was indistinguishable from the 56% decrease for the same stress in 45–55-year-old females and the 57% decrease seen in 35–45-year-old subjects. G-suits markedly improved tolerance in all cases. However, LBNP decrements were the largest seen to date (42% decrease compared to 8% decrease in 45–55 year olds, 19% decrease in 35–45 year olds). The reasons for these latter changes are presently unknown and are under study.

(D. Goldwater, Ext. 5749)



Test subject on centrifuge

Animal Model for Space Sickness Research

As part of a program to develop a suitable model for space motion sickness research, the motion sickness response of the squirrel monkey has been studied under a number of sickness-inducing conditions. In a sample of 15 animals, all became sick to the point of vomiting if they were rotated unrestrained at 25 rpm. However, if these same animals were rotated restrained (body restrained, head free), none became sick. These results are similar to those obtained with human subjects if the human subjects refrained from making head movements in the restrained condition. Also, the restrained squirrel monkeys were not susceptible to motion sickness under conditions of off-vertical rotation. Our results suggest that motion sickness may not be a problem in the fully restrained squirrel monkey.

(N. Daunton, Ext. 6245)

Bone Changes Under Simulated Zero Gravity

The pathophysiologic changes that occur in weightlessness are analogous to those that occur in man during immobilization. Skeletal losses occur with a resultant reduction of calcium and bone mass in the normally weight-bearing bones. Clinically, immobilization also results in increased gastric secretion due to altered serum calcium levels and an increased tendency to develop peptic ulcers. To evaluate the problem of bone loss and altered calcium homeostasis in depth, studies have been conducted with experimental monkeys in a simulated hypodynamic-hypogravic environment that minimizes normally occurring stresses in the pelvis, spine, and legs. After 6 months of simulated weightlessness, the animals lost approximately 25% of bone mineral in the tibiae and the bending stiffness that reflects strength of the tibiae declined 35%. A recovery period of approximately 9 months was required to restore normal bending properties. Histologically, a period of approximately 20 months was required to restore new osteonal systems in bone that are characteristic of the adult animal. The investigations show that cellular activity increases sufficiently to reverse the process of bone loss and to restore normal properties of bone. Additional measurements show that bone losses may be related to the effects of adrenal cortical hormones or parathyroid hormones. The monkey model is useful for studying bone mass loss, healing, new bone growth, and maturation of bone and is expected to be an important adjunct for studies of human problems of bone loss.

(D. Young, Ext. 5549)

Space and Terrestrial Applications

Aerosol Climate Effects

Additional data on the long-term effects of major volcanic eruptions on Earth's climate have been obtained by a series of U-2 flights performed in December 1980 and July 1981. The flights are a continuation of the series made in May-June 1980, soon after the May 18, 1980, eruption of Mt. St. Helens. The aircraft carries a group of aerosol and gas sampling instruments provided by scientists from NASA, National Oceanic and Atmospheric Administration, from the Universities of Maryland, Nevada, and Washington, and from Particle Measurements Corporation in Boulder, Colorado. The purpose of the flight series was to determine features of the global distribution of the volcanic debris, the rate at which volcanic gases that reach the stratosphere have converted to aerosols, and the properties of the maturing aerosol layer created by the volcanic eruption. The collections have also demonstrated that newer volcanic material has been added to the stratosphere since Mt. St. Helens. This newer material is believed to be due to the eruptions of Mt. Alaid at 51°N, 156°E on April 27, 1981, and Mt. Pagau at 18°N, 146°E on May 14, 1981. Results of the study are expected to lead to better assessments of the climate effects of past and future volcanic events.

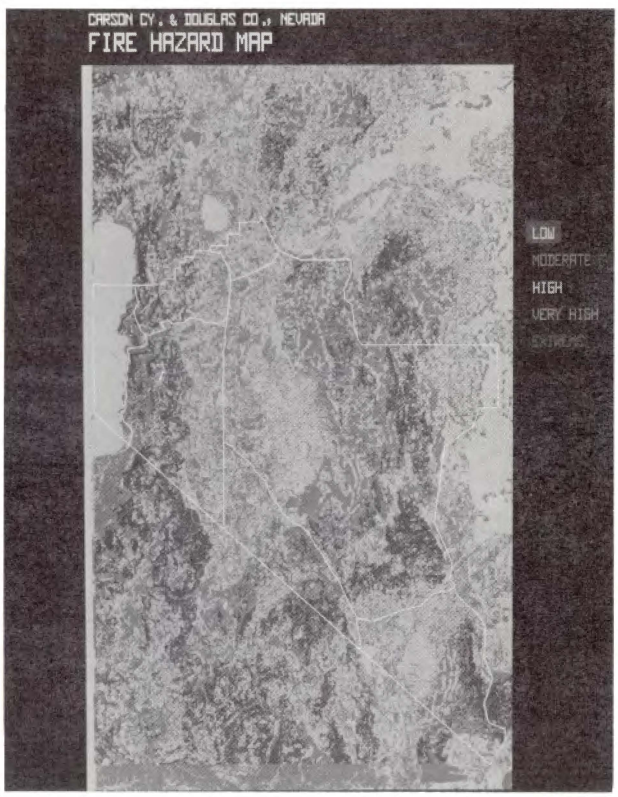
(J. Pollack, Ext. 5530)

Wildland Inventory and Resource Modeling Using Landsat and Digital Terrain Data

This Western Regional Applications Program (WRAP) pilot inventory project was a joint effort of NASA, Nevada's Division of Forestry, Division of State Lands, Governor's Planning Office, and the University of Nevada. The overall goal of the project was to demonstrate the potential usability of Landsat satellite imagery to map and inventory vegetative types in a demonstration area that included Douglas County and Carson City, Nevada. Specific maps and statistical products produced include land cover, mechanical operations capability, big game winter range habitat, fire hazard map, and forest harvestability.

As a result of this project, the Nevada Division of Forestry has determined that Landsat can produce reliable and low cost resource data. Added benefits become apparent when the data are linked to a geographical information system (GIS) containing existing ownership, planning, elevation, slope, and aspect information.

(D. Lumb, Ext. 5900)



Landsat mosaic of Nevada study area that classifies geographical fire hazard according to slope, steepness, land cover type, and fire-carrying capacity

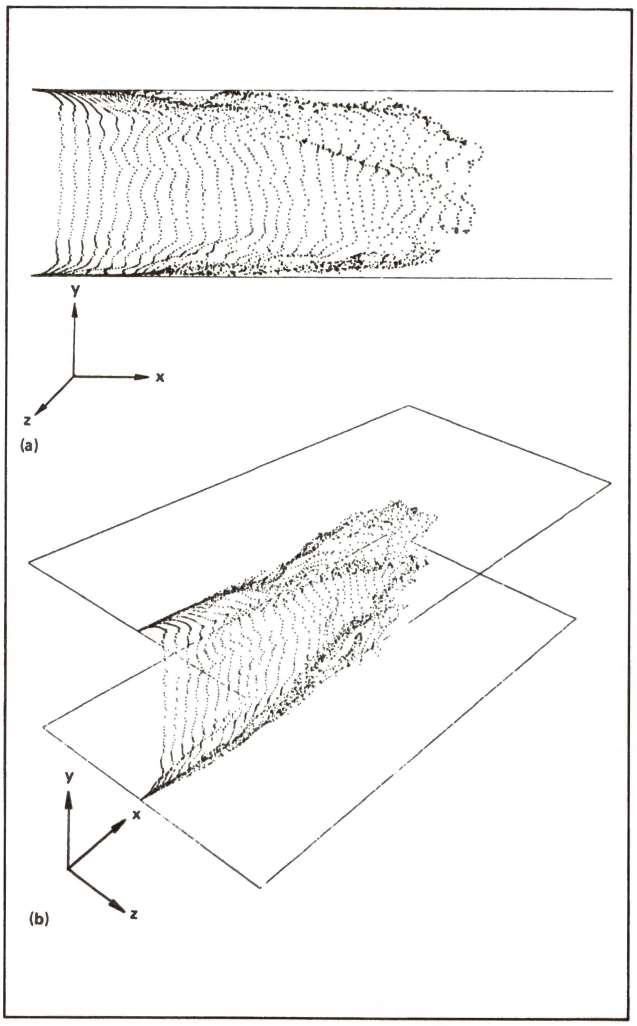
CV-990/Galileo II Activity

As part of the NASA/OSTA Severe Storms and Weather Research Programs, the Ames Airborne Laboratory, the CV-990/Galileo II, successfully completed tests of the Marshall Space Flight Center's new technique for measuring two-dimensional wind flow around storms. The Doppler Lidar System was proven during the NCAR/Department of Interior Cooperative Convective Precipitation Experiment (CCOPE) in Montana and Colorado.

(R. Cameron, Ext. 5338)

Aeronautics and Space Technology

Numerical Investigation of Turbulent Channel Flow



Particles generated from a vertical wire extended between the two channel walls; (a) two-dimensional view, (b) three-dimensional view

Fully developed turbulent channel flow has been simulated numerically at a Reynolds number of 13,800, based on centerline velocity and channel half-width. The large-scale flow field has been obtained by directly integrating the filtered, three-dimensional, time-dependent, Navier-Stokes equations. The small-scale field motions were simulated through an eddy viscosity model. The calculations were carried out on the ILLIAC IV computer with up to 516,096 grid points.

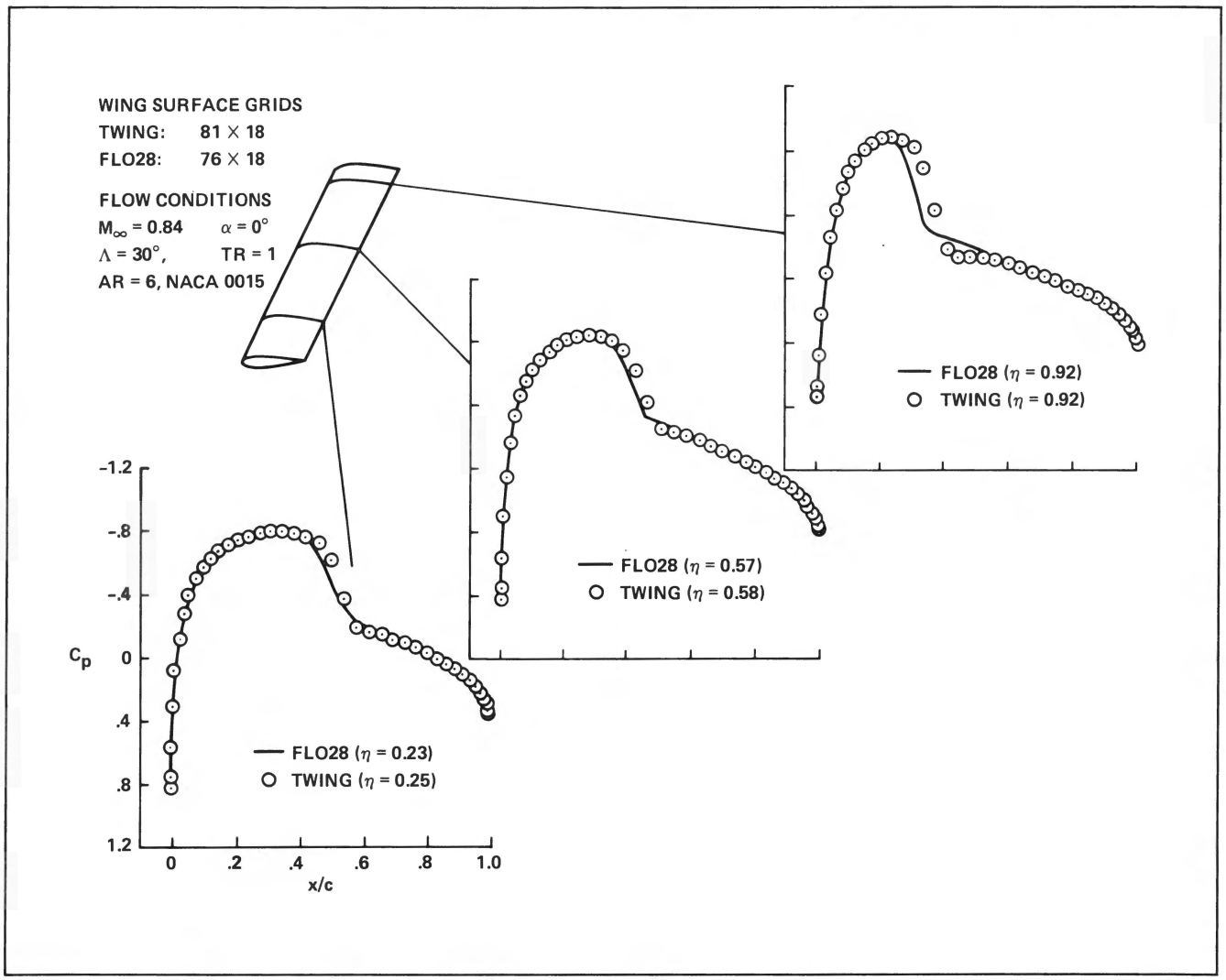
The computed flow field was used to study the statistical properties of the flow as well as its time-dependent features. The agreement of the computed mean velocity profile, turbulence statistics, and detailed flow structures with experimental data is good. The resolvable portion of the statistical correlations appearing in the Reynolds stress equations is calculated. Particular attention is given to the examination of the flow structure near the wall.

(H. Lomax, Ext. 5124)

Computational Aerodynamics

A highly efficient numerical algorithm, which has been used successfully to compute inviscid transonic flow about general two-dimensional aerodynamic configurations and three-dimensional flow about a swept wing supported by parallel walls, has been successfully modified to include the effect of lifting wings with finite free-standing tips. To compute such effects, two computer codes have been developed — GRGEN3 and TWING. The former generates a wing geometry of finite aspect ratio with spanwise variations of section shape, chord, thickness, and angle of attack, together with an efficient placement of neighboring computational field points. The latter code uses an implicit AF2 algorithm to find the flow field and various aerodynamic coefficients relative to the semispan wing. A typical case still takes less than 3 min of time on the CDC 7600 computer, which makes the code an inexpensive, efficient, and effective design tool for future aircraft configurations.

(P. Kutler, Ext. 6032)

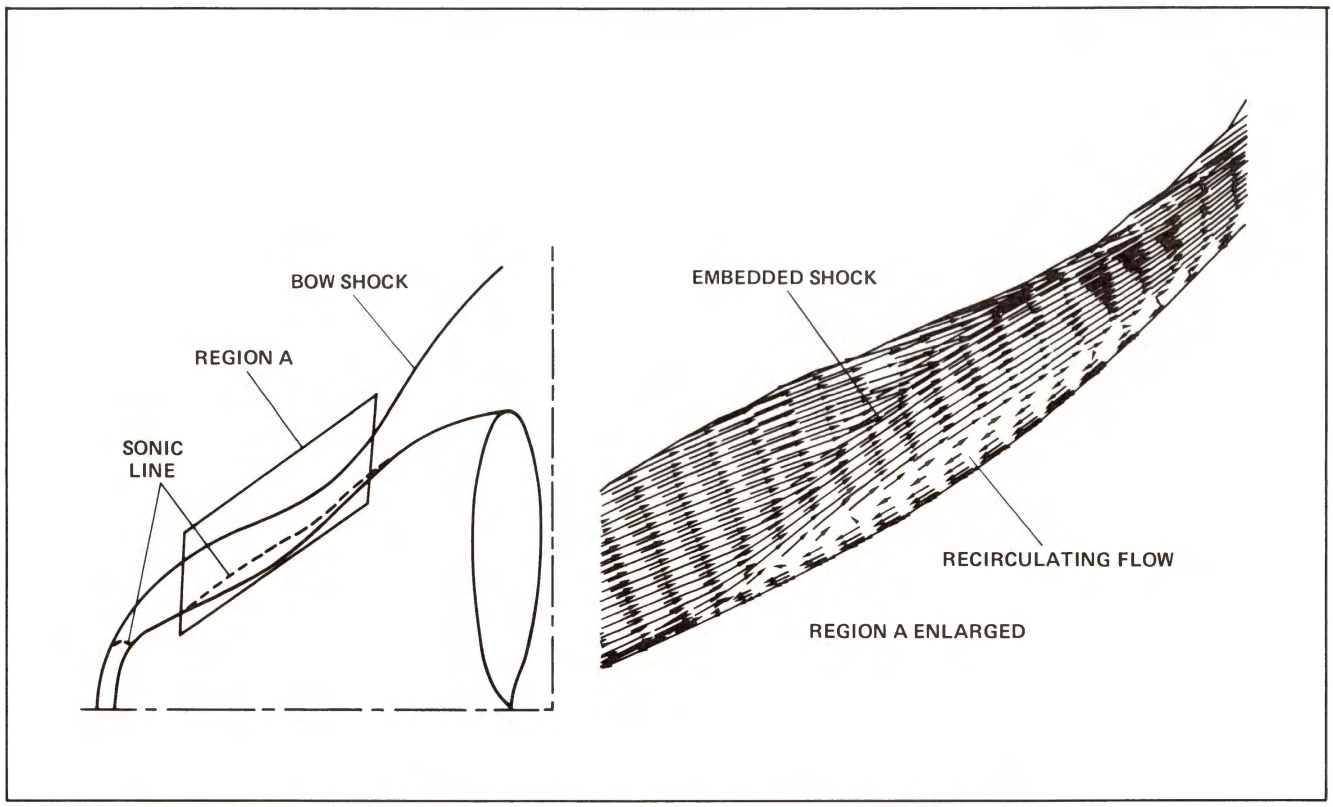


Surface pressure coefficient distribution at various spanwise stations compared with other data

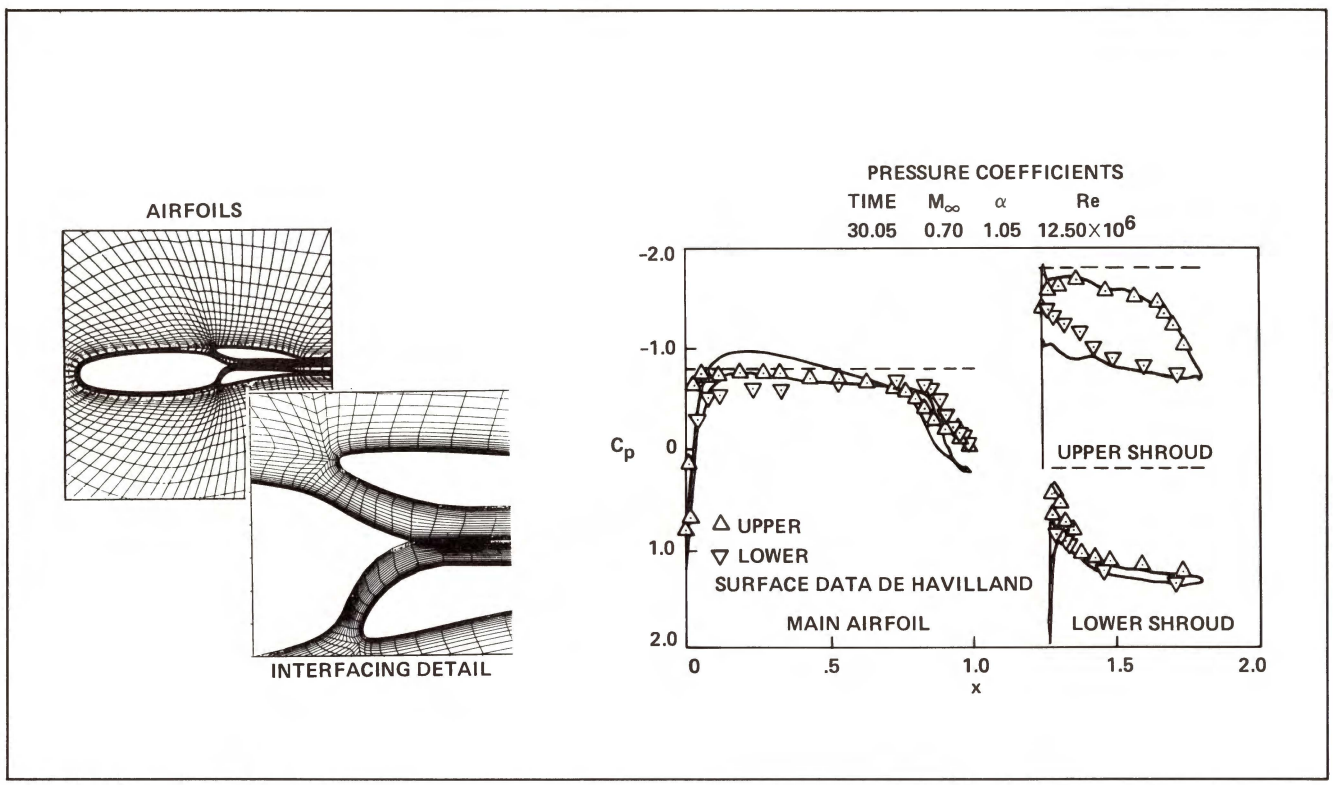
Viscous Simulation of Three-Dimensional Forebody Flows

A production computer program for determining the three-dimensional viscous flow about the blunt nose of configurations in a supersonic free stream such as the Space Shuttle or various missile configurations is now available. The code is capable of treating blunt-body flow fields containing embedded shock waves and streamwise separated-flow regions. The governing equations are the thin-layer Navier-Stokes cast in conservation-law form and are solved using a factored implicit algorithm. A generalized coordinate transformation is employed to map the disturbed flow region between the body and the bow shock into a cubical computational domain. The bow shock is treated as a sharp discontinuity and all internal discontinuities are captured. Steady-state or transient solutions for inviscid or laminar or turbulent flows are possible. The program is also used to provide starting solutions for inviscid or viscous marching codes for computing afterbody flows.

(P. Kutler, Ext. 6032)



Supersonic viscous flow about a mildly indented blunt body with embedded shock and streamwise separated flow region (M_∞ = 12, Re = 10^6/ft laminar)



Transonic viscous flow about augmentor wing section (no-blowing case)

Numerical Simulation of Viscous Flow About a Two-Dimensional Multielement Airfoil

New ideas as well as new applications of old ideas were required to tackle computation of the flow about the augmentor wing, a multielement airfoil designed and built by de Havilland Aircraft of Canada. A novel discretization procedure is used, consisting of multiple applications of an elliptic grid generator to produce body-oriented grids. The result is one continuous mesh composed of four C grids — one around each airfoil and one around the entire group. In the case where blowing out the main airfoil trailing edge is introduced, an additional grid is inserted between the shrouds. Adjacent grids are overlapped so that the boundaries of the inner grids lie along interior grid lines of neighboring grids, thereby avoiding interpolation and grid singularity problems. A two-dimensional, thin-layer, Navier-Stokes code is applied to each mesh region at every time step. Comparisons of numerical and experimental results for the no-blowing case are encouraging and lend confidence that this procedure will be useful in further understanding the improved aerodynamic efficiencies of the augmentor wing and will also serve as an important design tool to generate configurations capable of further enhanced performances.

(P. Kutler, Ext. 6032)

Turbulence Experiments

To develop computational techniques for simulating the flow fields about aircraft or reentry vehicles, turbulence models must be developed that capture the essential physics of turbulence. Therefore, a variety of experiments are being conducted to guide turbulence modeling and to verify the development of computational aerodynamics. Coordinated experimental studies, covering a variety of typical flow situations and a practical range of Mach and Reynolds numbers, are being performed at Ames and through grants to universities with unique facilities and expertise. Numerical and analytical studies are also being performed to develop and compare various proposed multiequation models with experimental results.

Both two- and three-dimensional steady and unsteady flows are being considered, and computations using the Reynolds-averaged, Navier-Stokes equations and the precise experimental geometry and boundary conditions are being made. Recently, completed experiments include transonic flow over an asymmetric trailing edge at high Reynolds number, a three-dimensional, shock-wave/boundary-layer interaction at supersonic speeds, and flow aft of a rearward-facing step. The data include surface pressures, skin friction, and mean and fluctuating velocity components throughout the flow field.

(J. Marvin, Ext. 5390)

High Reynolds Number Facility Improved

A second test leg for the High Reynolds Number Facility has been constructed and calibrated. This new leg allows the size of the test section to be increased by a factor of 2.3 and has the unique capability of operating over a wide range of Reynolds number at transonic speeds — from less than 1 million to 4 million. The first experiment is a study of supercritical airfoils at angle of attack to support the development of computational codes.

Comparisons of recent experimental results and computations show that employing two-equation eddy-viscosity turbulence models provides adequate predictions of attached two- and three-dimensional flows, symmetric trailing-edge flows, and flows with small zones of separation. However, for asymmetric trailing-edge flows where two dissimilar viscous shear layers are mixing or flows with large separation zones existing, turbulence models prove inadequate. Detailed analysis has shown that the length-scale equation used in these models must be improved.

(J. Marvin, Ext. 5390)

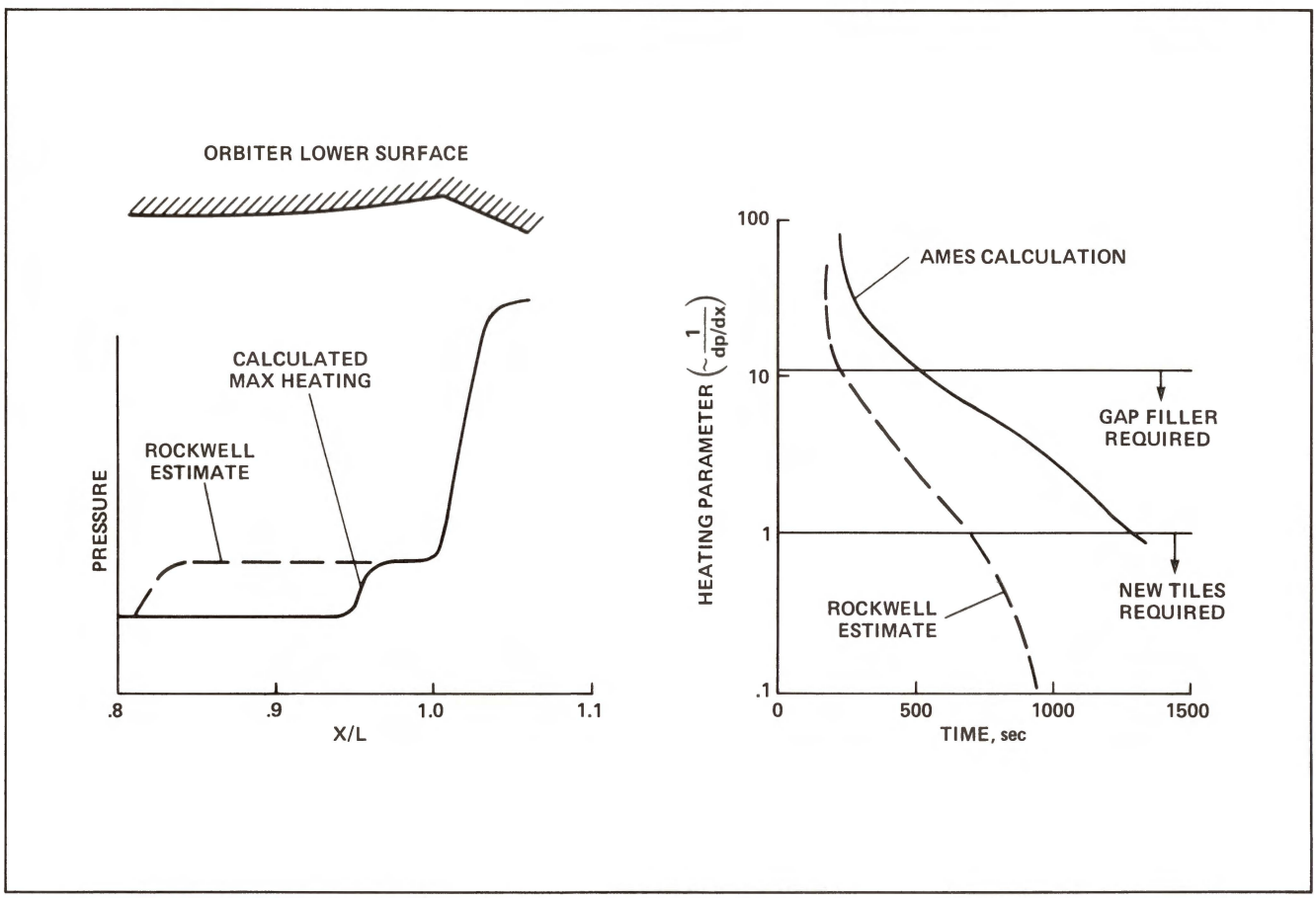
Space Shuttle Aerodynamics

Before the first Space Shuttle flight, Rockwell scientists were concerned that the separated boundary layer ahead of the deflected body flap would cause increased heating on the lower surface of the Oribiter. During their final design review, Rockwell estimated that the separation point could occur as far forward as X/L = 0.80; the increased heating caused by the large pressure gradient at separation would require new tiles and gap filler to protect the Orbiter during entry. The number of tiles affected would have caused a significant delay in the schedule for the first flight.

Using a computer code developed for turbulence modeling research at Ames, calculations were performed investigating this problem. Solutions to the full Navier-Stokes equations were made, varying body flap angle, time in trajectory, and real gas constants. The results showed that Rockwell's estimates were extremely conservative and that new tiles would not be required on the Orbiter. The maximum forward extent of separation was calculated to be at X/L = 0.96. Also, the addition of gap filler over only a small region would provide ample heat protection. Using Rockwell's estimate, new tiles would have been required over 20% of the lower surface.

The computer code was verified by comparisons with experimental data obtained on the Orbiter in the Ames and AEDC wind tunnels. The final design criteria used by Rockwell were based on Ames calculations.

(J. Marvin, Ext. 5390)



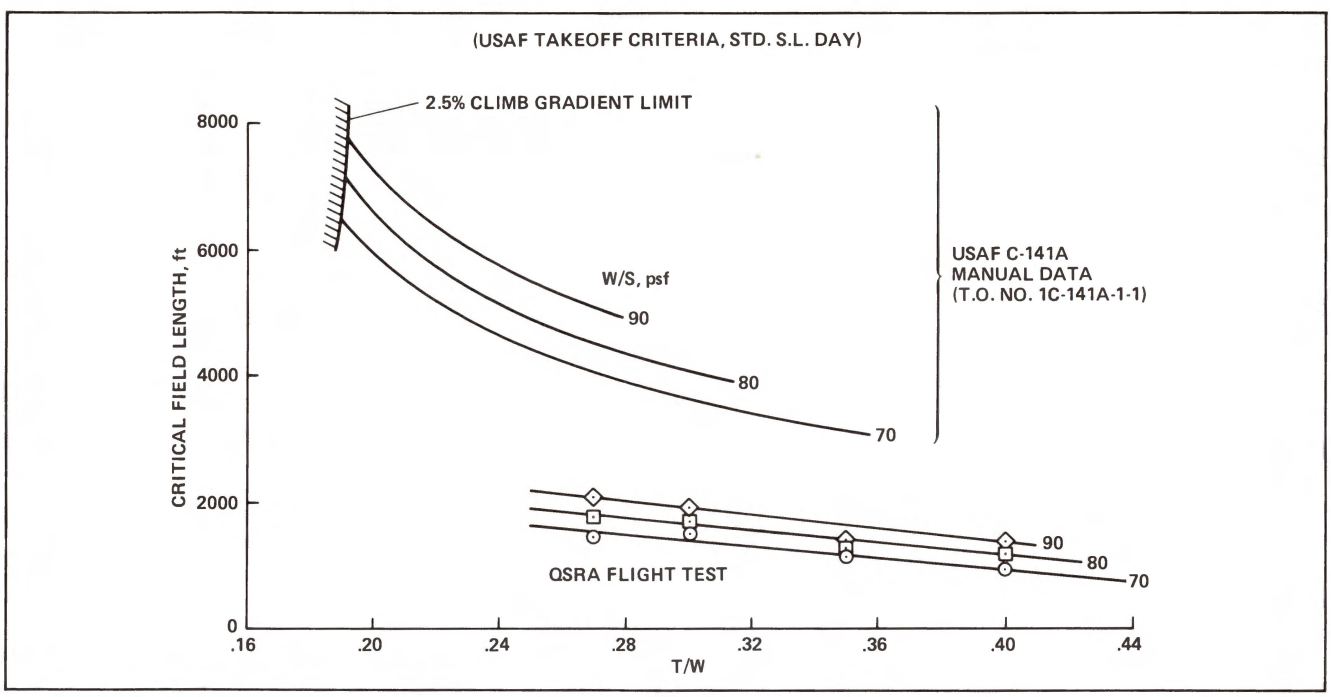
Heat protection requirements on Space Shuttle due to deflected body flap

Quiet Short-Haul Research Aircraft

In October 1980, a program was initiated to familiarize a broad cross section of aircraft pilots to QSRA technology. Twenty-three pilots representing 10 different organizations were exposed to comprehensive briefings and approximately 3 hr of flight in the QSRA. After the four-day program, each pilot was able to safely fly a steep STOL landing approach with one engine inoperative and with the stability augmentation system (SAS) turned off. This investigation showed that no unusual skills are required of a pilot to safely fly an aircraft with QSRA propulsive-lift technology.

Analytical studies indicated that upper surface blowing (USB), propulsive-lift technology could significantly reduce takeoff distance and/or increase payload even at the thrust-to-weight ratios and wing loadings of conventional aircraft. A reduced thrust experimental investigation was initiated to validate the analysis. Engine-out lift performance was measured over the thrust-to-weight range of interest, and minimum unstick takeoffs were performed to provide data for takeoff performance measurements. Takeoff performance was measured with all engines operating and with one engine inoperative (3 engines operating). Thrust-to-weight ratios investigated with all engines operating ranged from 0.20 to 0.44 and wing loadings ranged from 68 to 94 lb/ft^2. Three-engine and four-engine takeoff data were merged analytically to determine field lengths based on Federal Air Regulation Part 25 and also based on USAF Critical Field Length Criteria. These results were validated by takeoffs in which an engine was actually "chopped" at the takeoff decision speed (V_1). The measured takeoff performance of the QSRA was compared with that of the C-141 transport aircraft (as shown). The C-141 was used for comparison because Ames operates a C-141 and is intimately familiar with its performance. The data show that, at equal thrust-to-weight ratios and wing loadings, the QSRA can take off in less than half the distance required by the C-141. NASA pilots that fly the C-141 consider its performance excellent. Also, the reduced runway requirement can be traded for increased payload. These data indicate that upper-surface-blowing, propulsive-lift technology could be beneficial to most subsonic aircraft designs, including those operating at conventional thrust-to-weight ratios.

(J. Cochrane, Ext. 5662)



Critical field length comparison

XV-15 Tilt-Rotor Research Aircraft

There were several major accomplishments in the tilt rotor program in FY 81. Aircraft #2 was brought to flight status and was accepted by the Government after check flights and acceptance ceremonies at Dryden on October 28, 1980. This aircraft was used for flight tests aimed at verifying aeroelastic stability, evaluating fatigue loads reduction modifications, and expanding the maneuver envelope. Subsequently, this aircraft was ferried to Ames, where tests continued in the areas of handling qualities, SCAS and governor work, and expansion of the approach envelope.

Aircraft #1 was brought to flight status in the first quarter of FY 81 and initial work was done on the ground tiedown rig to verify the integrity of the vehicle in flight. This aircraft was used in a combined NASA/Army/Navy test, both in free flight and on the tiedown rig, to measure the downwash field under the aircraft in hover at various ground heights and at various rpm's and thrust levels. This test was also used to obtain noise measurements and to evaluate handling qualities and workload for the pilot in a precision hover task.

After some track and balance adjustments, aircraft #1 was ferried to Dryden and the wing and blades were removed from the aircraft before it was transported by USAF C5A to Farnborough, England. After reassembly and checkout flights at Farnborough and some practice flights for the aircrews, the aircraft was ferried to France for the 1981 Paris Air Show, June 4–14. The aircraft performed on schedule. After the Air Show, the XV-15 was transported back to England for a demonstration at Farnborough for RAE and invited guests. The aircraft was returned to Ames where it is now on flight status.

(J. Magee, Ext. 5020)

Helicopter Airborne Radar Approaches

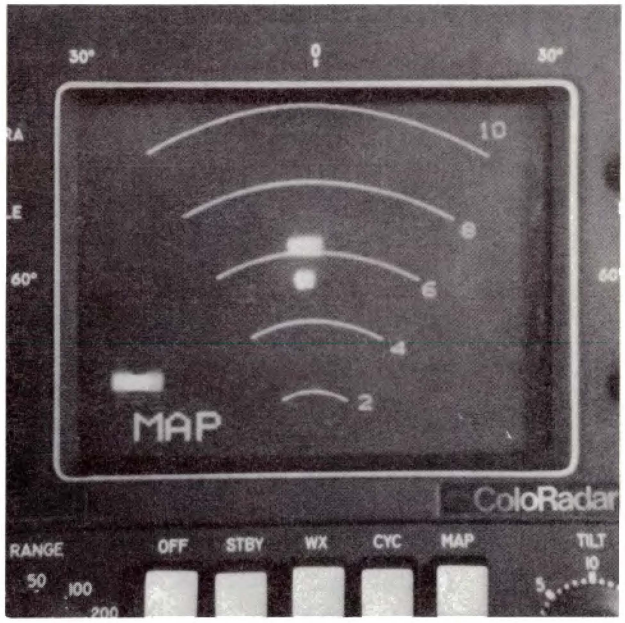
Civil weather/mapping radar can be used to provide approach guidance under instrument meteorological conditions to selected landing environments. Onboard radar systems are widely used by helicopter operators to provide approach guidance to offshore oil rigs without the need for electronic navigation aids at the landing site. For use over water, the radar provides guidance and ensures obstacle avoidance, but involves very high pilot workload and limited guidance accuracy. For use over land, the ground clutter return has made these approaches infeasible without more advanced radar systems.

Two programs at Ames have resulted in major advances in airborne radar approaches. One program involves the use of a video data processor in conjunction with the weather radar for overwater approaches to oil rigs and ships. This processor automatically tracks a designated radar target and displays a pilot-selected approach course. Other features of this system include automatic tilt and radar gain adjustment, display of course guidance information on the radar indicator, and the ability to provide guidance for offset approaches. This system is easily interfaced with existing weather/mapping radar systems, it reduces pilot workload, and it provides more accurate guidance information. The second radar program involved the development of an innovative approach to suppress ground clutter in order to locate simple low-cost radar reflectors near a landing site. This program, performed under a cooperative agreement with the University of Nevada, has progressed through a technology feasibility flight-test program (as shown — on the left, a typical overland radar return). After processing the radar video signal with pulse width discriminating and pulse paid decoding circuits, two sets of reflectors at the airport test site are clearly visible. This radar display could easily be used for an airborne radar approach.

(G. Clary and D. Anderson, Ext. 5452)



Radar display with clutter in airport vicinity

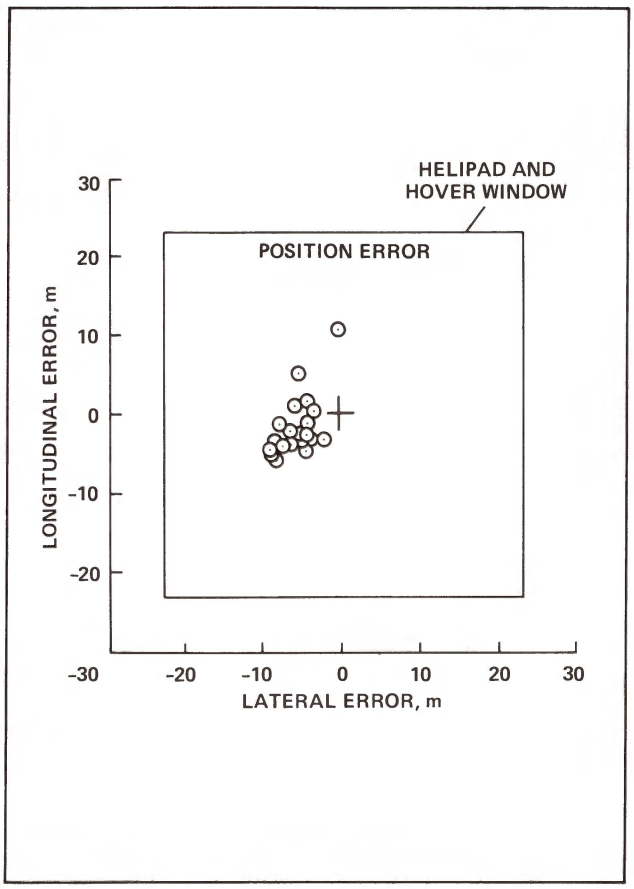


Radar display after declutter using pulse pair decoder system

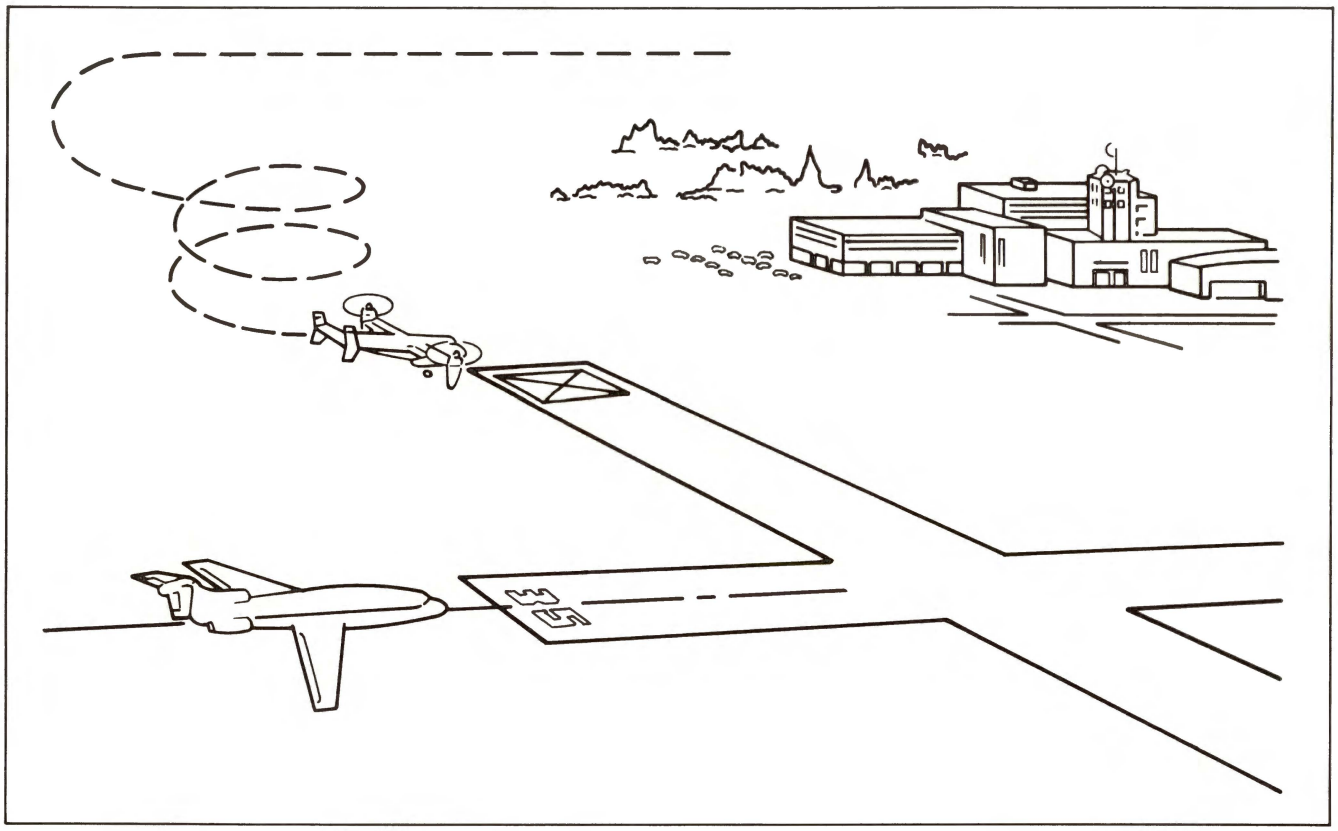
Helicopter Helical Approaches to Minimize Airspace Requirements

Initial flight tests to examine the feasibility of the helical approach as a concept for minimizing the use of airspace during landing in congested or confined areas have been completed. These tests were made using the NASA/Army UH-1H helicopter and the onboard V/STOLAND control and guidance research system. All approaches were made under autopilot control. The lateral and longitudinal error dispersions at the hover point above the landing pad were acceptable. In most cases, the pilots allowed the vehicle to continue to automatic touchdown from the hover point. The initial tests demonstrated the potential of the helical approach to minimize the airspace used so that simultaneous operation of high-speed CTOL aircraft and rotorcraft could be conducted using a single microwave landing system. The concept is applicable for both military and commercial operations.

(L. McGee, Ext. 5443)



Position error at hover point



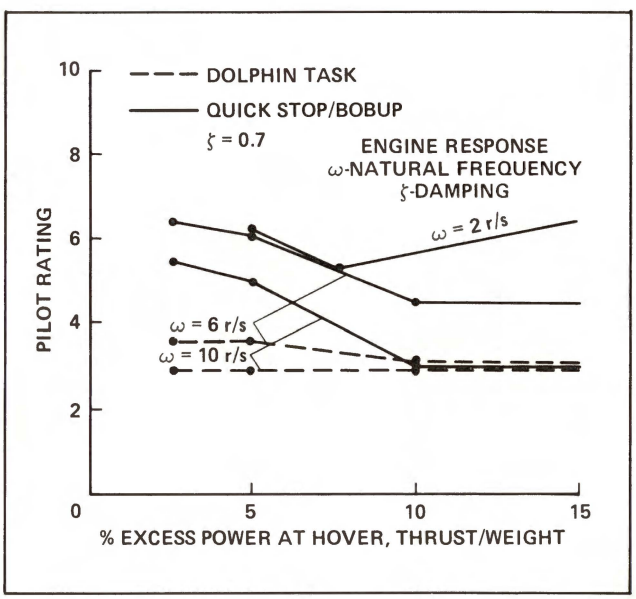
Automatic helical rotorcraft descent and landing using a microwave landing system

Effect of Engine Response Characteristics on Handling Qualities

The effects of engine fuel control/governor dynamics on helicopter handling qualities have been investigated. Such characteristics as engine time constants and rpm droop may have a significant effect on the agility and maneuverability of the vehicle during near terrain operation. Also in question is the excess power requirements for such maneuvering. A moving base simulation has been conducted to investigate, in a generic sense, such couplings and their effects.

This experiment considered a "dolphin" (oscillatory trajectory) and a quick stop/bob-up task. Preliminary results indicate that, over a wide range of engine frequency and damping characteristics, a significant degradation in handling qualities occurs when the engine response natural frequency is less than 8 rad/sec. When coupled with a pure time delay, little effect is noted for time delays of 0.15 sec or less. An evaluation of excess power requirements indicates that a minimum of 10% excess power is needed for the bob-up maneuver.

(L. Corliss, Ext. 6115)



Effects of excess power

Effect of Sideslip on Kinematics of the Helicopter in Steady Coordinated Turns

Unlike fixed wing aircraft, the helicopter in a steady coordinated turn will inherently sideslip. A set of exact kinematic equations describing this motion in steady helical turns has been developed, and a rational definition for the load factor that best characterizes a coordinated turn for a helicopter has been proposed. A steep coordinated helical turn at extreme angles of attack with inherent sideslip is of primary interest. The results show that the bank angle of the aircraft can differ markedly from the tilt angle of the normal load factor and that the normal load factor can also differ substantially from the accelerometer reading along the vertical body axis of the aircraft. Generally, sideslip has a strong influence on the pitch attitude and roll rate of the helicopter. The latter could have a significant impact on handling qualities because of the direct coupling of roll rate to the thrust of the main rotor.

An analysis has also been completed on the effects of sideslip on the kinematic relationships in a coordinated turn, which is based on new closed-form formulas that relate the aircraft angular rates and pitch and roll attitudes to the turn parameters, angle of attack, and sideslip. The results indicate that pitch rate is independent of angle of attack in a coordinated turn and that, in the absence of sideslip, angular rates about the stability axes are independent of the aerodynamic characteristics of the aircraft.

(R. Chen, Ext. 5008)

Longitudinal Static and Dynamic Stability Effects on Helicopter Flying Qualities for Instrument Approach

The fourth moving-base simulation experiment conducted as part of the joint NASA/FAA program concerning helicopter IFR airworthiness criteria was performed to investigate allowable longitudinal static and dynamic instabilities. Included were unstable static control gradients yielding dynamics with times-to-double-amplitude of 10 sec and 6 sec, as well as variations in short-term response characteristics, angle-of-attack stability, and pitch-speed coupling. Pilot evaluations were conducted on the Vertical Motion Simulator for a dual-pilot microwave landing system (MLS) approach task followed by a missed approach under instrument meteorological conditions (IMC) and for several levels of atmospheric turbulence.

The principal results of the simulation are as follows.

- The unstable gradient with a 10-sec time-to-double-amplitude was rated as clearly adequate in smooth air but marginally adequate at best in representative turbulence.
- With good static stability, configurations with a 0.3-sec pitch attitude response time constant were rated marginally adequate.
- The addition of artificial angle-of-attack stability had an insignificant effect on static control position stability and introduced undesirable coupling of pitch to rate of climb.
- In addition to artificial drag, damping had mixed effects: speed control with pitch attitude was improved, but speed-power coupling increased, which resulted in increased glideslope tracking workload.

(J. Lebacqz, Ext. 5272)

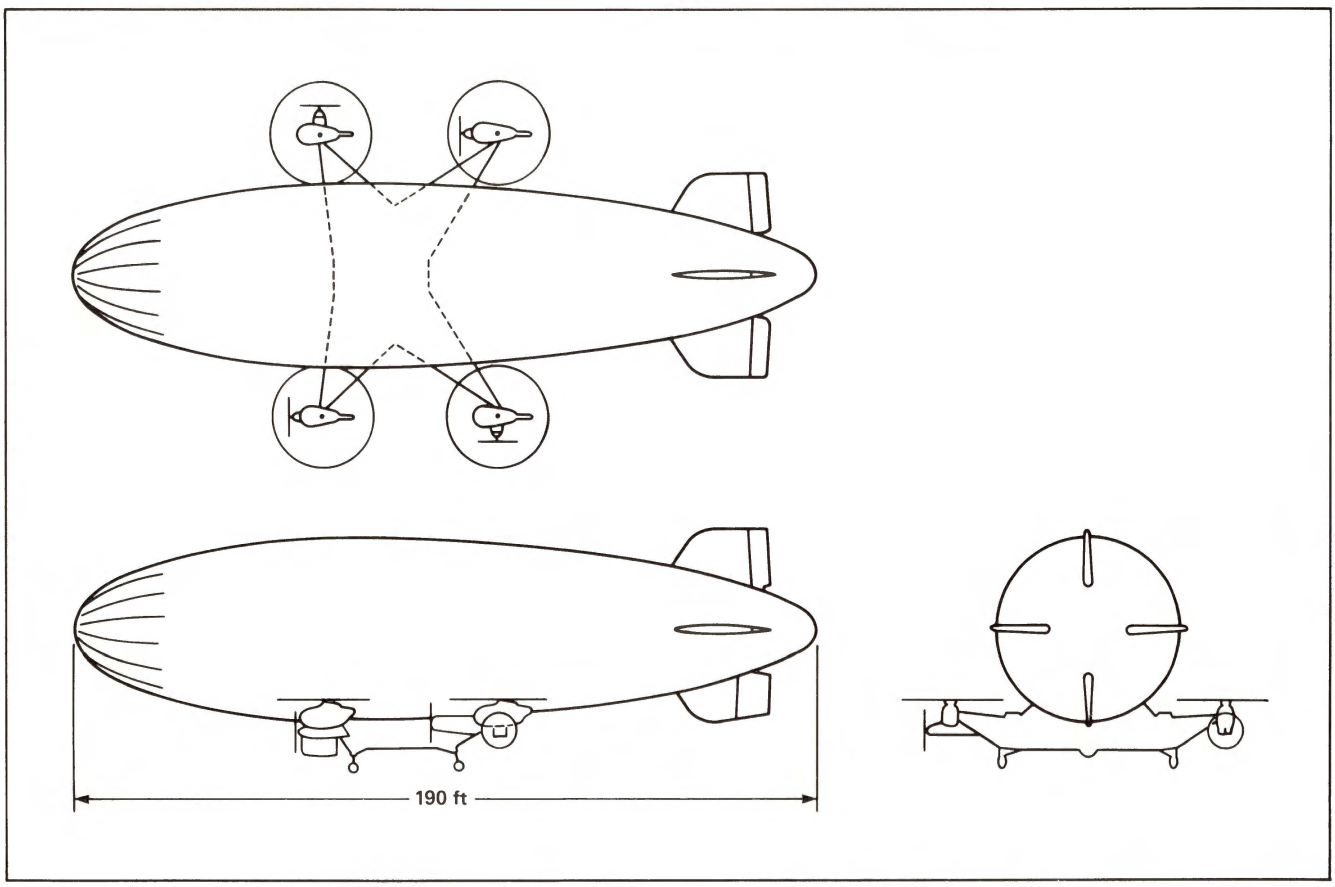
Piloted Simulation of a Buoyant Quad-Rotor Hybrid Airship Concept

The buoyant quad rotor (BQR) is a hybrid aircraft concept that combines aerostatic lift from a blimplike hull with propulsive lift from four helicopter rotors. The objective of a recent simulation was to investigate, for the first time, pilot-in-the-loop flying qualities.

Both NASA and Goodyear pilots found the aircraft to be adequately stable and maneuverable without stability augmentation, but the workload of the pilot was very high to achieve an acceptable level of performance. The objectionable characteristics were coupling of longitudinal maneuvering control inputs into pitch and roll, and the slow, acceleration-type responses to all inputs. These deficiencies are inherent in this type of design.

A great improvement resulted from providing increased attitude stability in pitch and roll, which effectively suppressed the coupling characteristics, and providing rate feedback to quicken the yaw and heave responses to the pilot's controls. The simulation also pointed to the relatively high maneuvering thrust demand by the pilots, which must be provided by auxiliary horizontal thrust units.

(P. Talbot, Ext. 5887)



BQR concept: simulated configuration

Blade/Vortex Interaction

A multiphase experimental program investigated the detailed characteristics of the wake and spanwise loading of a hovering rotor blade and the interaction between them. In the first phase, a semispan wing was used to simulate the rotor blade in the absence of the wake from the other blades. The second phase will obtain the spanwise loading and wake characteristics of a model hovering rotor. The third phase will use two semispan wings and the wake information from the model rotor test to simulate the blade/vortex interaction of the rotor.

During the first-phase test (recently completed), a computer-controlled laser Doppler velocimeter (LDV) was used to determine the spanwise load distribution and near-wake velocity distribution on a semispan wing designed to simulate a hovering model rotor blade in the absence of the wake of other blades.

The wing in this first test was a large-scale (3.6:1) model of the outboard third of the model rotor blade with a rectangular planform and square blunt tip. The large scale was selected to match the tip Reynolds number of the rotor blade and to facilitate a finer resolution of the velocity distributions. The wing twist distribution was selected to obtain a spanwise distribution of bound circulation, which would nominally match that of the hovering model rotor blade.

The spanwise distribution of loading was determined by the circulation-box method. The measurement detail was sufficient to detect the relative increase in the loading due to the tip vortex forming over the rectangular tip and also the presence of a low level of spanwise circulation beyond the tip for a distance of about one airfoil thickness. This latter effect is believed to result from the free vorticity in the separated region beyond the streamwise edge of the blunt square tip.

The wake was surveyed in planes normal to the free stream at 0.02, 0.8, 1.6, and 2.5 chords aft of the trailing edge. The measurement grid density was increased in the regions of the tip vortex and trailing vortex sheet to facilitate evaluation of the wake vorticity distribution, which is determined by the velocity gradients. Each spatial velocity measurement is the mean of 100 samples from which the standard deviations have been obtained.

(R. Piziali, Ext. 6668)

Dynamic Stall Apparatus

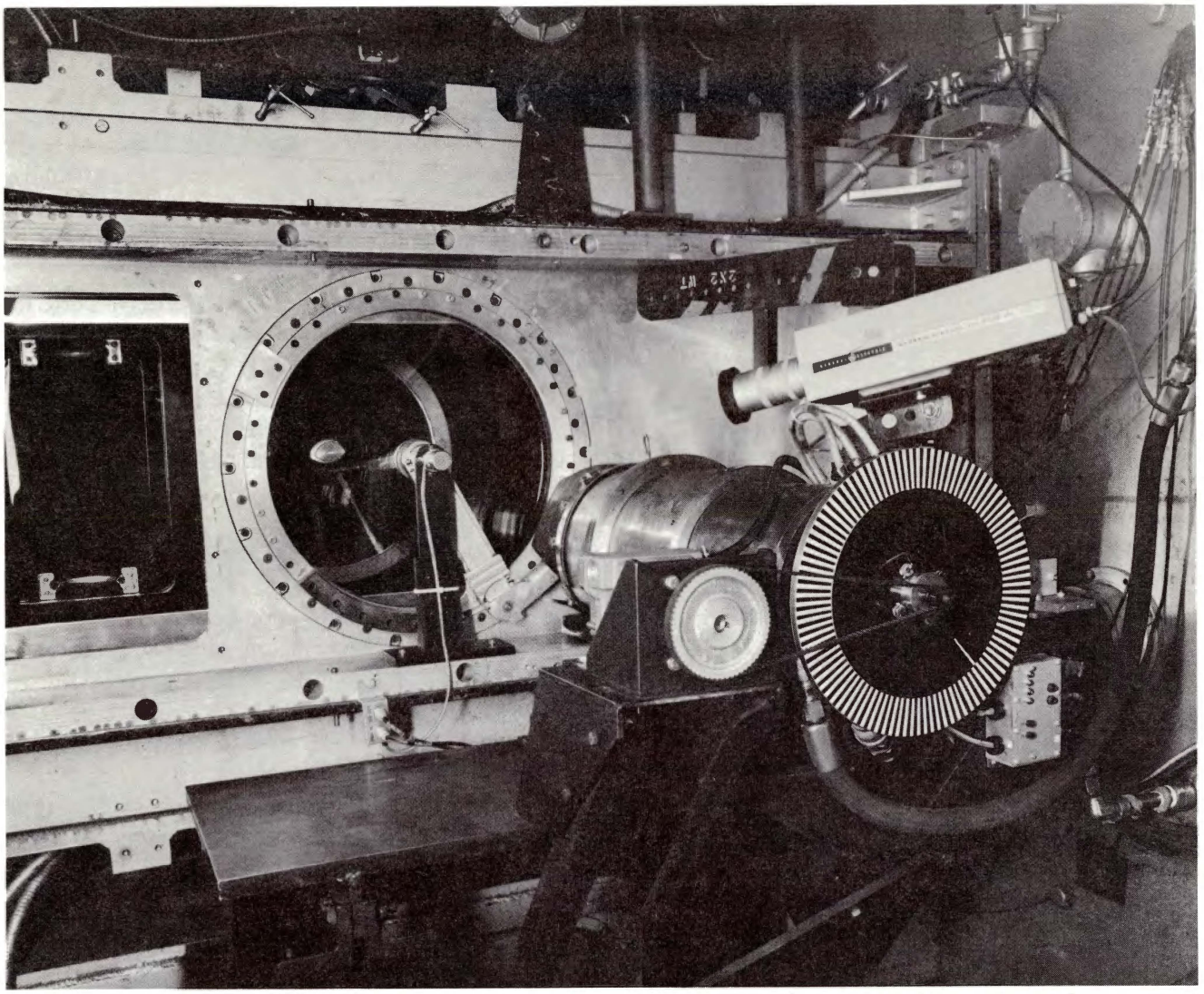
An oscillatory apparatus has been built to study the dynamic stall characteristics of helicopter blades. The unique feature of this apparatus is that the wing is mounted between glass windows of the Ames 2- by 2-Foot Transonic Wind Tunnel. This provides optical viewing by laser holographic interferometry, laser velocimetry, etc., to study the basic flow characteristics around the airfoil. The usual static and dynamic pressure measurements are also made on the wing.

A test of a NACA 0012 airfoil was successfully completed this summer. Mach numbers from 0.2 to 0.6, frequencies from 10 to 40 Hz, and Reynolds number up to 4×10^6 per foot were tested for this airfoil. Laser interferograms of the entire flow field and laser Doppler velocity profiles at several chordwise locations and the wake were taken for both increasing and decreasing angles of attack above and below stall. The dynamic stall characteristics of this airfoil were found to be influenced by the Mach number, Reynolds number, and oscillation frequency.

(D. Buell, Ext. 6265)

Acoustic Linings for Wind-Tunnel Test Sections

An experimental study was made of the sound absorption of several acoustic wall linings that are candidate designs for the Ames 40- by 80-Foot Wind Tunnel. The acoustic treatment will be used to reduce wall reflections from aircraft noise sources in the modified facility. The 152-mm-thick linings evaluated contained either fiberglass or polyurethane foam. Because the linings were designed to be permanently installed on the test

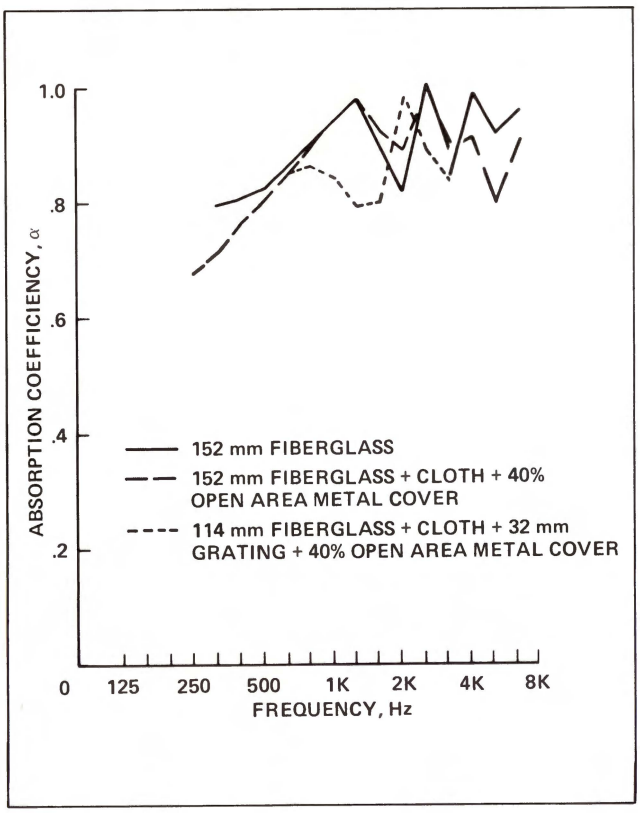


Dynamic stall apparatus

section walls, a variety of protective coverings were evaluated, including fiberglass cloth, perforated metal sheets, and metal gratings strong enough to support work crews and equipment. The experimental method used was the pulse reflection technique for in situ sound absorption measurement, a method that has become practical because of the development of microprocessors and digital analysis equipment. This technique allowed measurements of the absorption of several lining configurations in a wind tunnel, with and without flow, over a wide frequency range, and at four acoustic incidence angles, all in a relatively short time. Consequently, new information has been obtained on the sound absorption of protected linings with tangential airflow. This information should prove useful in designing an acoustic lining for a wind tunnel or duct; such acoustic data would be useful for a treatment that has a protective covering and structural members.

The design tradeoffs led to a 152-mm-thick fiberglass lining protected by a cloth membrane and a 40% open area perforated metal cover for the walls and ceiling. The floor requires a 38-mm-deep grating in place of 38 mm of fiberglass. The acoustic treatment will cover the full 24-m length of the 40- by 80-Foot Wind Tunnel test section.

(P. Soderman, Ext. 6675)



Measured sound absorption for zero wind speed and 15° acoustic incidence angle, with effects of wall and floor coverings

Design Study using Selected Powered Lift Propulsion Systems

A design study, utilizing the ACSYNT conceptual/preliminary aircraft design synthesis computer program, has been completed at Ames; it provides a comparative indication of the relative advantages of several propulsion systems proposed for use with powered lift aircraft. The results will be used to support decisions concerning which powered lift concepts will receive NASA technical assistance. Two baseline aircraft, the XV-15 tilt rotor research aircraft and the Navy S-3A, were used to evaluate the effectiveness of each propulsion concept in the research and antisubmarine warfare (ASW) missions, respectively. Since a powered lift research aircraft is not subjected to operational constraints as is a mission aircraft, design concerns, such as high-speed performance, payload fraction, and maintainability, can be traded for increased attitude control power, reduced cost, and versatility. The powered lift propulsion concepts investigated were Rockwell International's chin-nozzle system, McDonnell Aircraft's vented-D nozzle system, and Grumman's tilt-engine/nacelle system. A rotatable-nozzle system, used on the Rolls Royce Pegasus turbofan engine, was also used for comparison in the ASW mission design study. The designs within each mission category differed only in those respects necessary for integrating the particular propulsion concept with the baseline. This approach permitted an accurate assessment of the design integration and performance penalties associated with each concept.

A performance analysis of the research aircraft designs showed that a capable vehicle can be constructed using either of the three concepts, although the tilt-engine/nacelle design had better overall performance because its empty weight was 4% less. The ASW mission design study showed that, although the rotatable-nozzle design resulted in the lowest empty weight, its higher installation losses resulted in a 9% mission loiter time penalty compared to the vented-D design. The study also demonstrated the advantages of high-thrust/weight-ratio lift engines (necessary for balance in hover for the vented-D configuration) in a design for ASW missions, which require a low vehicle thrust/weight ratio for cruise and loiter.

(G. Kidwell, Ext. 5886)

Vented-D Nozzle

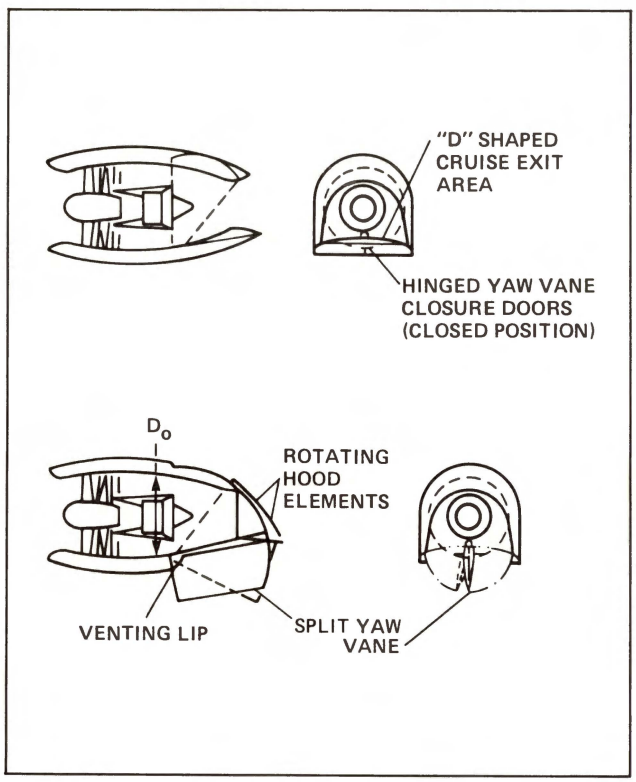
A project is underway to demonstrate the capabilities of a vented-D thrust deflecting system coupled with a high-bypass-ratio turbofan engine. Specific objectives are to (1) obtain nozzle performance characteristics, (2) demonstrate the compatibility of the nozzle with a turbofan engine, (3) obtain pressure and temperature distributions on the surface of the vented-D nozzle, and (4) establish a correlation of the nozzle performance between small-scale and large-scale models.

The test phase of the program was completed on August 25, 1981. The test program, a joint NASA/McDonnell-Douglas research effort, was very successful. Significant results include the following.

- A VTO nozzle efficiency of 95% was achieved, which is comparable to small-scale predictions and is sufficient for additional considerations in V/STOL aircraft design.
- No adverse effect due to ground proximity was measured.
- The inner walls of the vented-D nozzle remained cool (≤120 F) during all test conditions.

This finding means that neither high-temperature materials nor cooling air will be required for a production vented-D nozzle. Therefore, the potential weight and cost of a production nozzle can be reduced.

(R. Christiansen, Ext. 6669)



Vented-D nozzle geometry

Top Inlet Technology

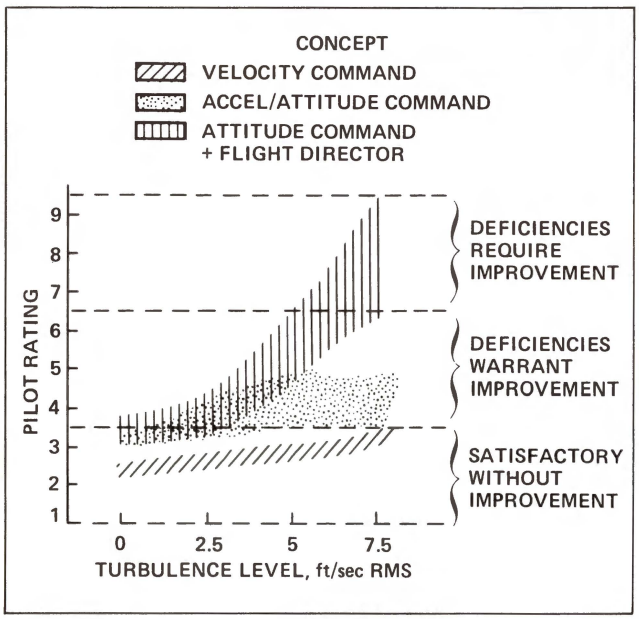
Advanced fighter/attack aircraft configurations with top-mounted inlets are being studied in a joint NASA/Navy/industry research program. The program is focusing on aircraft and inlet aerodynamics of top-inlet configurations. Example research areas include the effect of inlet spillage on aircraft minimum drag and the effect of airframe caused flow distortion on inlet performance.

During 1980 and 1981, aerodynamic and inlet performance tests were conducted in the Ames 12-Foot, 11-Foot, and 9X7-Foot Wind Tunnels (M = 0.2 to 2.0) using a 9.5% scale model. Data were obtained at angles of attack and sideslip from -2° to +28° and 0° to 12°, respectively. The effects of inlet location, wing leading edge extensions, variable incidence canards, and wing leading- and trailing-edge flap deflections on aircraft aerodynamics and inlet performance were determined. Results indicate good inlet and airframe performance for most of the configurations investigated. However, in some cases, improvement in one area was accompanied by losses in the other. For example, the canard configuration improved aerodynamic performance but decreased inlet performance.

(D. Smeltzer, Ext. 6010)

VTOL Control/Display Concepts

Four control/display system concepts suitable for landing a VTOL vehicle on small ships under low visibility conditions have been investigated during fixed-base and moving-base simulation. The concepts ranged from attitude command to fully decoupled velocity command, where the variants included horizontal velocity command through either pitch or roll attitude or through thrust deflection. A head-up display (HUD) presentation was used and provided flight director commands for the simpler control concepts and velocity situation and command information for the decoupled velocity concepts.



Pilot rating of VTOL control/display concepts for decelerating curved-path approaches to station-keeping point

The flight task involved a decelerating transition from 120 knots along a curved approach (pursuit) path to an initial station-keeping point to the starboard side of the ship's landing pad. Horizontal translation to the pad for a vertical landing was conducted from the station-keeping point.

The decoupled velocity command system and associated HUD was the only system that provided fully satisfactory flying qualities for the transition and vertical landing task over a wide range of wind, turbulence, and sea conditions. The attitude command system with the HUD and flight director was found to provide adequate flying qualities over much of the operational envelope. Specifically, the attitude command system was given pilot ratings from 3.5 to 5 for rms turbulence levels up to 7 ft/sec for the transition phase and pilot ratings from 4 to 6 for sea states up to 4 for hover and landing aboard a DD 963 type ship. A continuous tradeoff of flying qualities with control concepts is evident in the results.

From these results, it appears that, even for such a challenging landing task as investigated here (and with the restrictions of a narrow field-of-view visual simulation), flying qualities requirements do not provide sufficient justification for the complication of a decoupled velocity command system that closes control loops through the engines' fuel control and thrust deflection control. Further study of these concepts is planned.

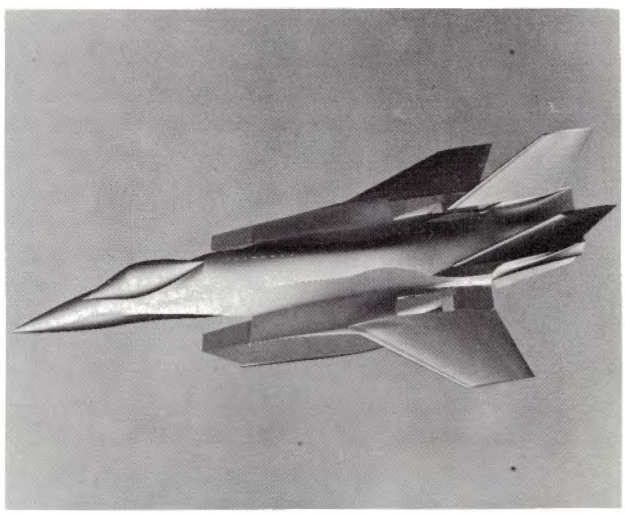
(V. Merrick, Ext. 6194)

Aircraft Geometry Definition and Verification using Enhanced Computer Graphics

A vital part of the aerodynamic analysis of aircraft configurations is the accurate representation of the aircraft geometry. Verification of mathematical models of aircraft geometry has proven to be a vital and difficult problem.

A new method developed to deal with this problem is the generation of color-shaded surface images of the mathematical model using enhanced computer graphics. Flaws in the mathematical model will be much more apparent using this new technique.

(J. Cozzolongo, Ext. 5855)



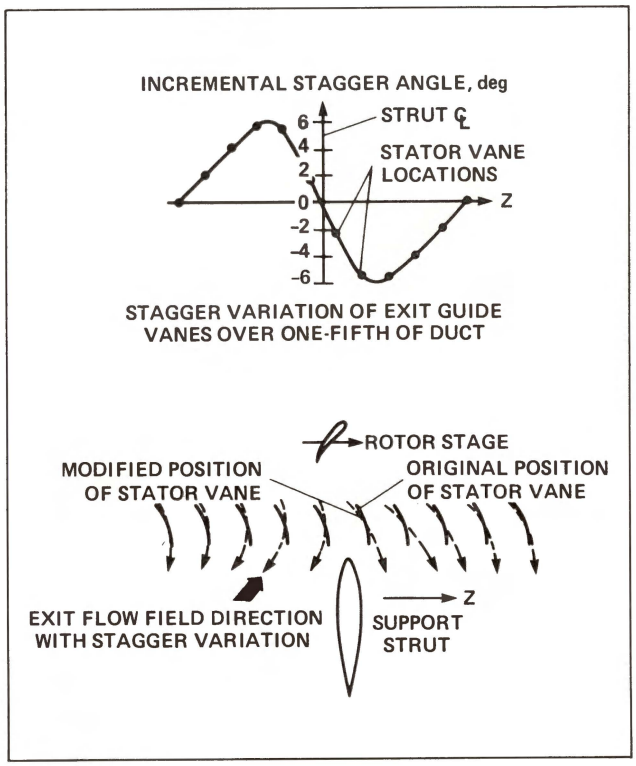
Color-shaded surface display for a V/STOL fighter configuration

Reduction of Dynamic Bending Stress in Wind-Tunnel Compressor

Since its completion in 1956, the three-stage compressor of the Ames 11-Foot Transonic Wind Tunnel has experienced high rotor blade dynamic stresses. Recent efforts have successfully reduced the stresses to well below acceptable levels. The dynamic stresses were caused by first mode bending oscillation of the rotor blades induced by flow disturbances around the five equally spaced struts supporting the streamlined afterbody of the compressor centerbody. Because the frequency of this five-per-revolution excitation approached the first mode natural frequency of the rotor blades with increasing compressor speed, the dynamic stress level increased with compressor speed. A maximum compressor speed and strict rotor blade inspection and replacement procedures were imposed to minimize the risk of rotor blade failure. These restrictions limited the operation of the facility and represent a heavy and expensive maintenance burden.

The recent efforts to reduce these dynamic stresses involved varying the stagger angle of the 60 exit guide vanes (the final stage of stationary blades just upstream of the five support struts) in a five-per-revolution pattern to aerodynamically cancel the pressure disturbance propogated upstream from the struts. This process was patterned after an analytical technique developed by the Boeing Company to eliminate cyclic pressure disturbances generated by the single pylon strut supporting Boeing 747 engine nacelles. A final configuration of stagger angle distribution was selected on the basis of data from test runs of earlier configurations, with the result that the first mode bending dynamic stress level was reduced to approximately 15% of its original value. This simple and very inexpensive change in the aerodynamic design of the compressor precluded the implementation of major structural changes that would be very costly and would also result in the facility being offline for an extended period of time.

(L. Guist, Ext. 6258)



Optimized stagger angle distribution of exit guide vanes

Propfan Installation Aerodynamics

Tests on a propeller-powered semispan model of an advanced swept wing transport are being conducted as part of the NASA advanced turboprop program. These tests are being conducted to assess the interference drag penalties of the nacelle and propeller slipstream, to understand the flows causing the interference, and to determine configurations that minimize the interference drag.

The 0.12 scale wing/body/powerplant half-model was tested in the Ames 14-Foot Wind Tunnel to measure the effects of the propeller and nacelle on the airframe drag. The propfan is powered by a 730-hp compressed-air-driven turbine. The supercritical wing has an aspect ratio of 7 and a maximum thickness ratio varying from 17.5% at the root to 12% at the tip. Propeller forces are measured by a six-component rotating strain-gauge balance located in the propeller hub.



Advanced turboprop semispan model in 14-Foot Wind Tunnel

Total model forces are measured by a five-component force-moment balance located beneath the tunnel floor.

The propeller is an 8-blade propfan configuration made of a carbon-epoxy composite. Several blades were instrumented to measure their bending and torsion characteristics. The model was instrumented with 350 pressure taps on the wing and nacelle to aid in locating the source of adverse slipstream effects on the wing. Data were obtained over the range of Mach numbers from 0.6 to 0.82 at angles of attack from -3° to +5°. Propeller rpm was varied from windmill speed to 9000 rpm at several blade pitch angles. Future tests are planned to investigate configuration changes such as wing leading-edge extensions and a new contoured nacelle.

(A. Levin, Ext. 6010)

Smoothing of Flight Test and Accident Data

Unique work is being performed in support of flight research programs at Ames and as part of a joint program with the National Transportation Safety Board (NTSB) to assist in accident investigations. A procedure for analyzing flight-test data and aircraft accident data has been developed at Ames as a digital-computer program called "SMoothing for AirCraft Kinematics" (SMACK). The program utilizes a novel information processing technique with a six-degree-of-freedom kinematic model of the aircraft to define the relations between the aircraft response and the forces acting on the aircraft. Inputs to the program are data that are measured during a flight test or are available from NTSB following an accident. The program provides estimates of bias and scale-factor errors in the data and trajectories of measured and unmeasured states and forcing functions.

As applied to flight-test data processing, it performs a check of data consistency and provides smoothed, error-free estimates of all time histories needed for subsequent studies, such as the identification of aerodynamic derivatives. For accident analysis, it optimally combines and processes data from onboard foil or digital flight recorders, and air traffic control radar systems to provide accurate reconstruction of aircraft position, velocity, and attitude during the critical moments of the accident.

(R. Bach, Ext. 5429)

Air-Data Measurements in Ground Effect

An analysis technique has been developed at Ames to assist the National Transportation Safety Board in their investigation of accidents or incidents. In analyzing flight data recorded during aircraft operations near the ground, it is important to recognize the influence of ground proximity on the measurements of airspeed and altitude. To account for the effect of ground proximity on these measurements, three sources of errors have been studied using potential flow theory. From these studies, it was found that the primary error results from ground constraint of the wing lifting pattern. Smaller errors result from constraint of the flow over the fuselage and of the engine exhaust.

Equations have been derived to provide corrections for the three error contributions. The equations are general and can be applied to airplanes of different geometries operating in different conditions. The accuracy of these analytical methods was investigated using data recorded onboard the Ames CV-990 research aircraft during operations in ground effect (takeoff, go-around, and landings). The results from this evaluation are encouraging and indicate that the theory provides a practical way of correcting the measured air data for effects of ground proximity. This technique is now being used to assist the National Transportation Safety Board.

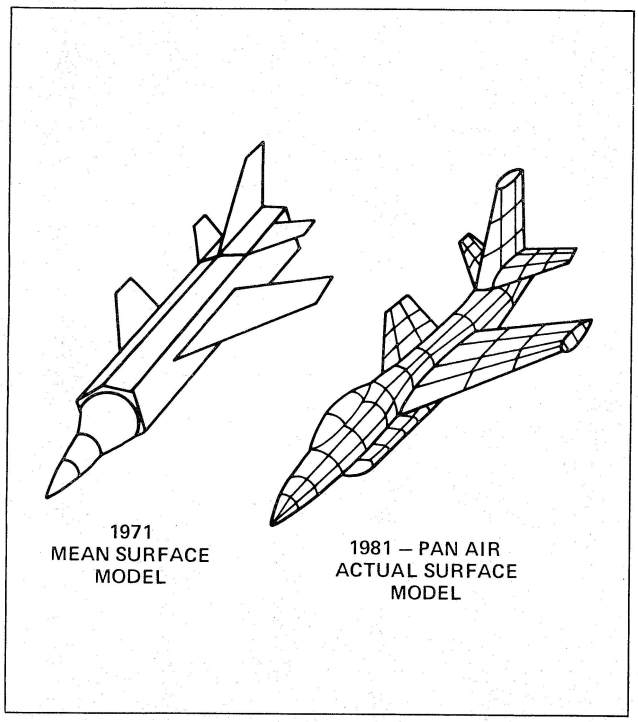
(R. Wingrove, Ext. 5429)

PAN AIR — Panel Method for Predicting Subsonic or Supersonic Linear Potential Flows About Realistic Aircraft Geometries

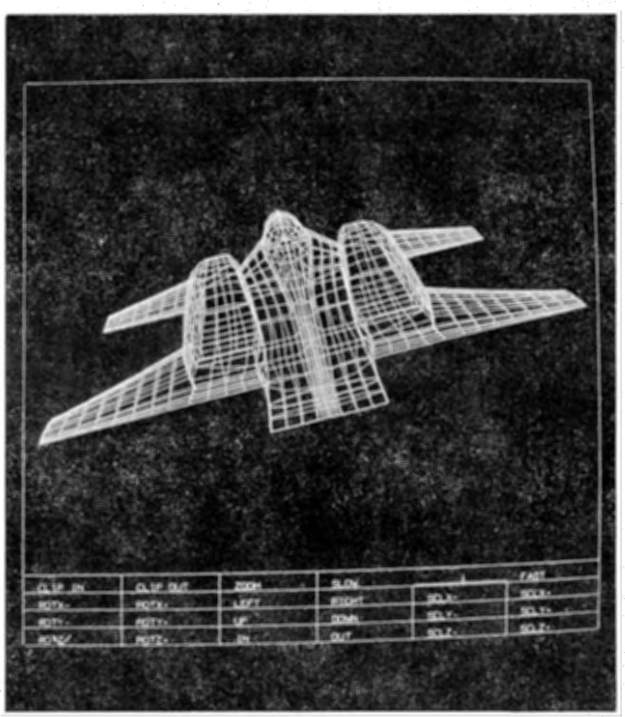
The PAN AIR computer program can now predict the supersonic flow about nearly arbitrary three-dimensional surface geometries, a problem that has defied solution for many years. The code implements linear source and quadratic doublet distributions in a manner that greatly reduces numerical stability problems that have plagued earlier attempts to make surface paneling methods work successfully for supersonic flow. With PAN AIR, the actual surface geometry of an aircraft can be modeled, as opposed to an approximate mean surface geometry. Panel layouts are not restricted to geometries that are winglike or fuselagelike in appearance. This independence from any specific geometry allows blended wing bodies, canopies, and other real surface shapes to be modeled.

PAN AIR was developed by the Boeing Military Airplane Company under the joint sponsorship of NASA's Ames and Langley Research Centers, the Air Force's Aeronautical Systems Division and Wright Aeronautical Laboratories, and The Naval Coastal Systems Center. The code is well documented and was designed with ease of use a primary consideration. PAN AIR has been made available to the aerospace community through MOSMIC. Users' classes attended by over 100 participants from industry were held in 1981.

(L. Erickson, Ext. 6216)

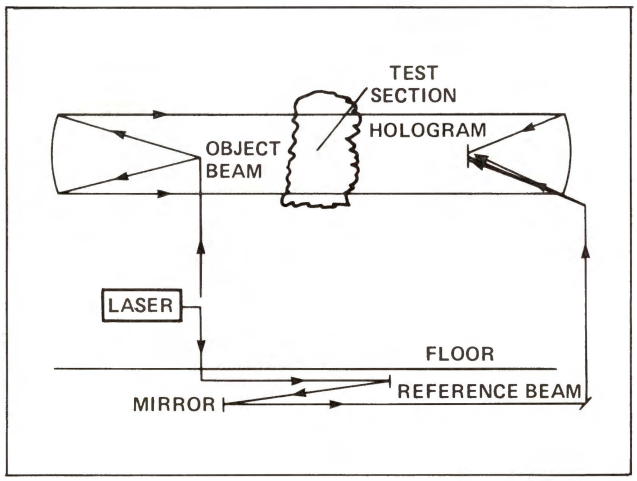


Panel method models



PAN AIR model of a V/STOL fighter

Laser Holographic Interferometry



Sketch of 2X2-ft interferometer



Interferogram of a two-dimensional airfoil in transonic flow

A permanent laser holographic interferometer has recently become operational in the Ames 2- by 2-Foot Transonic Wind Tunnel. This system will provide the capability for nonintrusive quantitative measurement of the density fields around wind-tunnel models. The design criteria required the system to be compact, easy and fast to set up, and requiring little or no realignment or adjustments during a wind-tunnel shift. A very stable Nd:YAG laser was used for this purpose. All optical components were specially mounted to reduce vibration. Interlocks were installed to several components and the laser beam was shielded to protect personnel.

A typical interferogram of a two-dimensional airfoil is shown. The light and dark fringes are lines of constant density. Other features such as shock waves, boundary layer, and wake can be seen. Pressure deduced from such interferograms are within 1% of those measured with pressure orifices on the wing.

(G. Lee, Ext. 5861)

A Technique for Predicting Pilot-Induced-Oscillation Tendencies and Pilot Opinion Ratings

Application of modern digital stability and control augmentation systems has created a renewed interest in the study of aircraft handling qualities. This is attributable to two factors. First, the higher order nature of the dynamics often associated with digital control law implementation makes analytical prediction of handling qualities difficult. Second, the shortcomings of existing predictive techniques are made even more critical by the fact that severe handling qualities deficiencies often arise in practice which are directly attributable to the higher order nature of the control law implementation. An example of this is the ability of high-frequency phase lags or time delays in the control system to sharply degrade aircraft handling qualities and to be a contributing factor to so-called pilot-induced oscillations.

To help alleviate these analytical difficulties, a mathematical modeling technique was developed based on an optimal control model of pilot response. The technique provides a unified approach to pilot/vehicle analysis for modeling

the pilot in situations where aircraft dynamics are of higher order than those normally encountered; predicting the susceptibility of aircraft to pilot-induced oscillations; and predicting relative numerical pilot opinion ratings of vehicle handling qualities.

(R. Hess, Ext. 5443)

Application of Nonlinear Inverse-System Theory to Automatic Flight Control for Helicopters

The analysis and experimental evaluation of automatic-flight-control systems for helicopters has been undertaken as part of a program to develop methodology for the design of flight-control systems that have the capability of integrating a wide variety of active control functions. Nonlinear inverse system techniques are being used in this effort. Recent progress has been made in the development of theory for strongly nonlinear systems, including the complex helicopter system. The approach has the advantage that the system looks linear and decoupled when viewed through the inverse, thus greatly simplifying control system design. A full-envelope, automatic-flight-control system has been synthesized for evaluation on the UH-1H research helicopter. The system has been successfully checked out on a ground-based simulator and flight experiments with the system are in progress.

(G. Meyer, Ext. 5444)

Aviation Safety Reporting System

The Aviation Safety Reporting System (ASRS) serves the aviation community, the Federal Aviation Administration, and the Department of Defense by providing a central focus for collecting, analyzing, and disseminating safety information derived from confidential reports of incidents and situations in the national aviation system. Designed and implemented to improve the current aviation system and to provide data for enhancing future aviation systems, the ASRS has processed and analyzed more than 30,000 reports since April 1976. In addition to the regular quarterly reports and a monthly publication, "Callback," issued by the ASRS program, more than 700 alert bulletins have been issued and more than 270 research studies have been conducted. Many alert bulletins and research studies have resulted in modifications and improvements to aviation procedures, operations, facilities, and equipment. An example of ASRS output — the "Distractions" study that appeared in the program's Ninth Quarterly Report — was instrumental in the creation of federal aviation regulations mandating the implementation of the "sterile cockpit" concept in certain air carrier operations. Other ongoing research activities examine such safety issues as controlled flight toward terrain, fatigue in air transport operations, in-flight emergencies, general aviation and weather encounters, and information transfer problems in the aviation system.

(W. Reynard, Ext. 6467)

Flight Crew Coordination

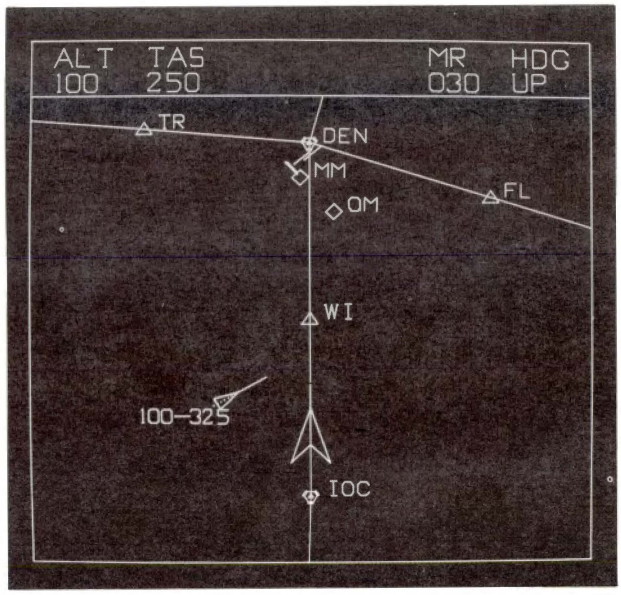
The lack of adequate crew coordination and faulty information transfer have been factors in many aircraft accidents. As part of a continuing effort to identify and propose solutions to these problems, a study was conducted in which the cockpit voice recordings of a full-mission simulation were analyzed and in-flight errors were recorded. This study revealed that the relationship between the communication patterns of the cockpit crew and their performance is significant. Generally, crews who communicated less made more errors, but the type and quality of communication also was important. In response to this work, the National Transportation Safety Board (NTSB) has recommended to the Federal Aviation Administration (FAA) that steps be taken to ensure that adequate communications is maintained between crew members, particularly in noisy cockpits.

Studies in this series have also shown that full-mission simulation can be beneficial to pilot training. Traditional recurrent pilot training has largely been to practice certain maneuvers. While beneficial, this type of training provides little experience in areas related to crew coordination and the effective management of resources. Line-oriented flight training (LOFT) allows a realistic simulation of an actual flight from one point to another with a full crew. During these simulated flights, operational problems are sometimes introduced that require the coordinated action of the flight crew in real time. LOFT was the subject of a recent NASA/industry workshop, and guidelines for the conduct of LOFT were drafted. These guidelines stimulated a change in FAA regulations to promote the more widespread use of LOFT as a tool for training in crew coordination and resource management. Several airlines have also found LOFT to be useful in identifying problems with procedures or new equipment before they occur in flight.

(J. Lauber, Ext. 5717)

Cockpit Traffic Displays

A series of experiments examined the types of maneuvers pilots make while viewing different "conflict" situations on a cockpit traffic display. The display shows the relative position of nearby air traffic on an electronic moving map. The objective was to compare the maneuver decisions pilots intuitively make when exposed to an aircraft encounter presented on the display with the decisions that would be made by proposed automatic collision avoidance systems. Results show that pilots often maneuver to avoid conflicting air traffic in a manner different from that which current collision avoidance algorithms would have commanded. In situations judged to be of lower threat, pilots tend to maneuver so as to reduce the time to resolve the conflict, even if their maneuver requires a turn through a collision course. In contrast, automatic decision logics generally select maneuvers that will maximize the minimum miss distance between aircraft. This difference in criteria for selecting avoidance



Cockpit display of traffic information

maneuvers often manifests itself by the pilot choosing to turn toward the conflicting traffic in situations in which an automatic logic would have the pilot turn away from the other aircraft. The potential for pilot errors is enhanced by these conflicting decision patterns.

(S. Ellis and E. Palmer, Ext. 6147)

Properties of Molecules

The theoretical determination of the physical and chemical properties of molecules and atomic clusters from first principles continues to produce important results. Extensive calculations have been completed for the first row transition metal atoms. Analysis of these data has led to a much improved prescription for computing potential energy curves and spectroscopic properties for diatomic metal hydrides and metal dimers. Using this approach, the properties of NiH, ScH, and Cu_2 have been determined. The results for NiH and Cu_2 are among the most accurate achieved to date and demonstrate that calculations for larger transition metal molecules and clusters are practical. For ScH, the calculations predict an unexpected and novel ground state configuration

owing to a d-electron bonding. This research will have a major impact on other efforts to compute the physical properties of inorganic molecules and metal clusters.

Using recently developed computational methods, accurate third-order susceptibilities of H_2 and O_2 have been determined on the basis of quantum mechanical calculations. These results have been used to determine absolute cross sections and spectra for a variety of nonlinear spectroscopic processes such as two photon absorption and coherent antistokes Raman scattering (CARS). Both the resonant and nonresonant contributions to the susceptibility have been determined. These quantities are required for the analysis of data from nonintrusive diagnostics measurements of temperature profiles in fluid dynamics and combustion experiments.

(J. Arnold, Ext. 6209)

Atomistic Simulation of Materials

The structure of small clusters, both isolated and supported on substrates, has been investigated by minimizing the total energy using two-body and three-body interaction forces. Clusters containing as many as 13 atoms were investigated. The results obtained showed that the effect of three-body interactions on the structure of small clusters is significant. Furthermore, these calculations show that the energetically preferred structure of a small cluster varies from a compact three-dimensional configuration to a two- and even a one-dimensional structure as the strength of the three-body interaction increases. Calculations on clusters supported on substrates showed that, when three-body interactions were neglected, the cluster was deformed and spread over the substrate surface. As the three-body interaction strength was increased, the clusters remained erect and deformed only negligibly. This research on cluster geometry and structure is contributing to the understanding of both surface and thin-film processes.

A new atomistic model that simulates the initiation and propagation of cracks in metals has been developed. Each of the 414 atoms presently included in the model is treated discretely and allowed to interact with the other atoms via both two- and three-body interaction forces. This model has accurately predicted that the increase in length in a single metal crystal under tension occurs through a series of slips. This information is providing assistance in understanding the fundamentals of material strength.

(J. Arnold, Ext. 6209)

Localized Depth Analysis of Corrosion Scales

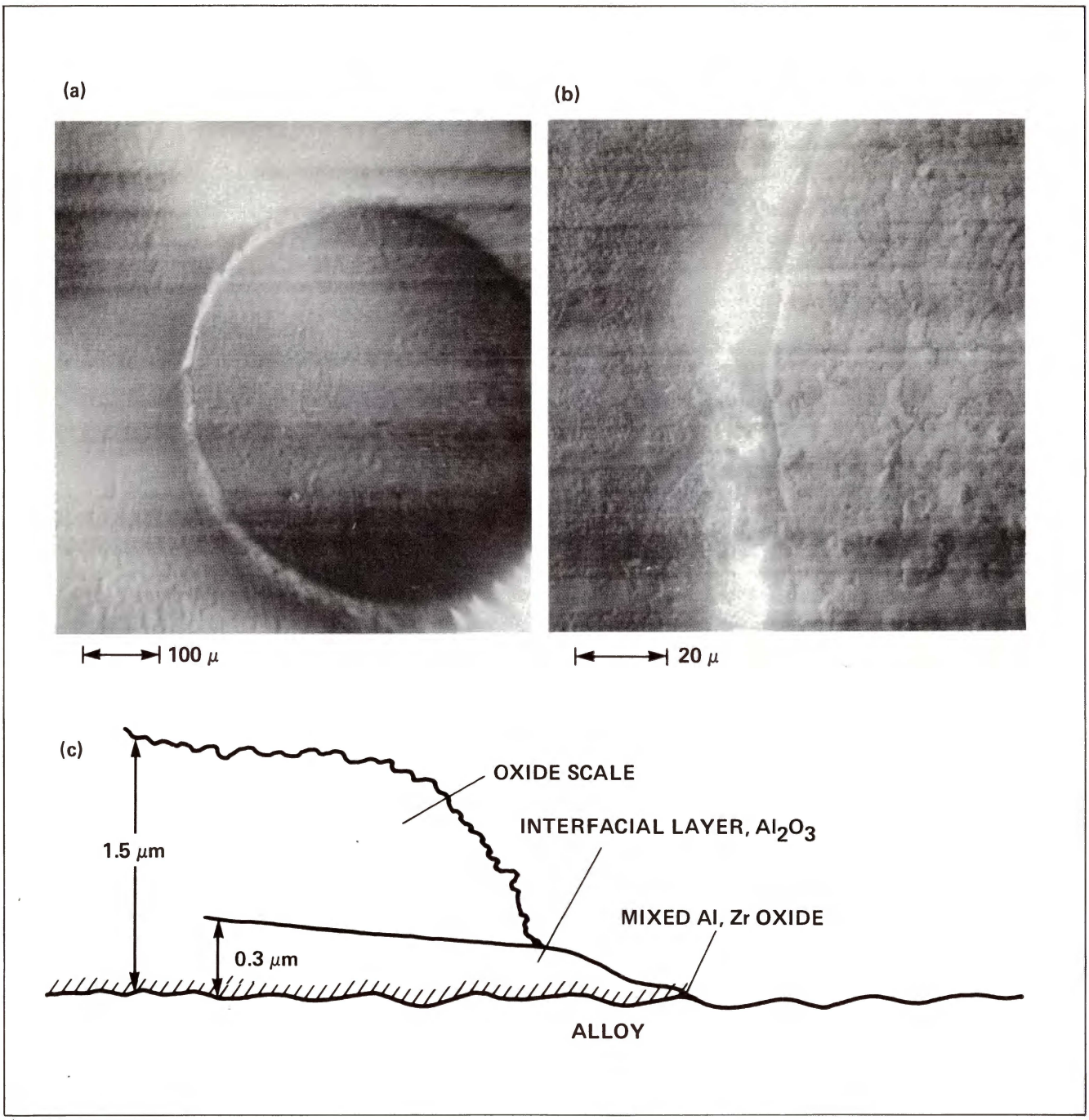
The adherence of protective corrosion scales to high-temperature, oxidation-resistant metal-chromium-aluminum alloys is an area of critical importance for the development of advanced turbine blade materials. The role played by small additions of oxygen active trace elements to these alloys is of particular interest. A recently developed new surface analytical instrument, a micro-area scanning auger microprobe, has been successfully applied to studying the elemental depth composition of a NiCrAl-0.5 (wt.%) Zr alloy oxidized in air for 1 hr at 1180°C. A small spot size (300 Å = 3×10^{-6} cm) electron beam is scanned along the wall of a crater ion beam etched through the corrosion scale into the base metal, and characteristic electron emission is used to chemically analyze the corrosion scale with very high spatial and depth resolution.

The salient features of the present results are as shown: (a) scanning electron microscopy (SEM) image of the crater, (b) enlarged view of crater wall, and (c) sketch of crater wall compositional (depth) profile. The external oxide was rough, about 2 to 3 μm thick, and contained Ni, Cr, Al, and O. It was discovered that stoichiometric Al_2O_3 was restricted to a homogeneous layer about 300 nm thick between the oxide and the base metal. The metal immediately beneath this Al_2O_3 was found to be depleted in Al and roughly 10 times richer in Zr than the bulk alloy. The observation of the scale/alloy interface layers is significant because these layers are conceivably important to any mechanism of the adhesion or

growth of oxide layers. It is hypothesized that the diffusion of Al outward to form the Al_2O_3 scale is reduced by the Zr-containing interfacial layer.

An understanding of such mechanisms is important in the development of advanced aerospace materials.

(J. Arnold, Ext. 6209)

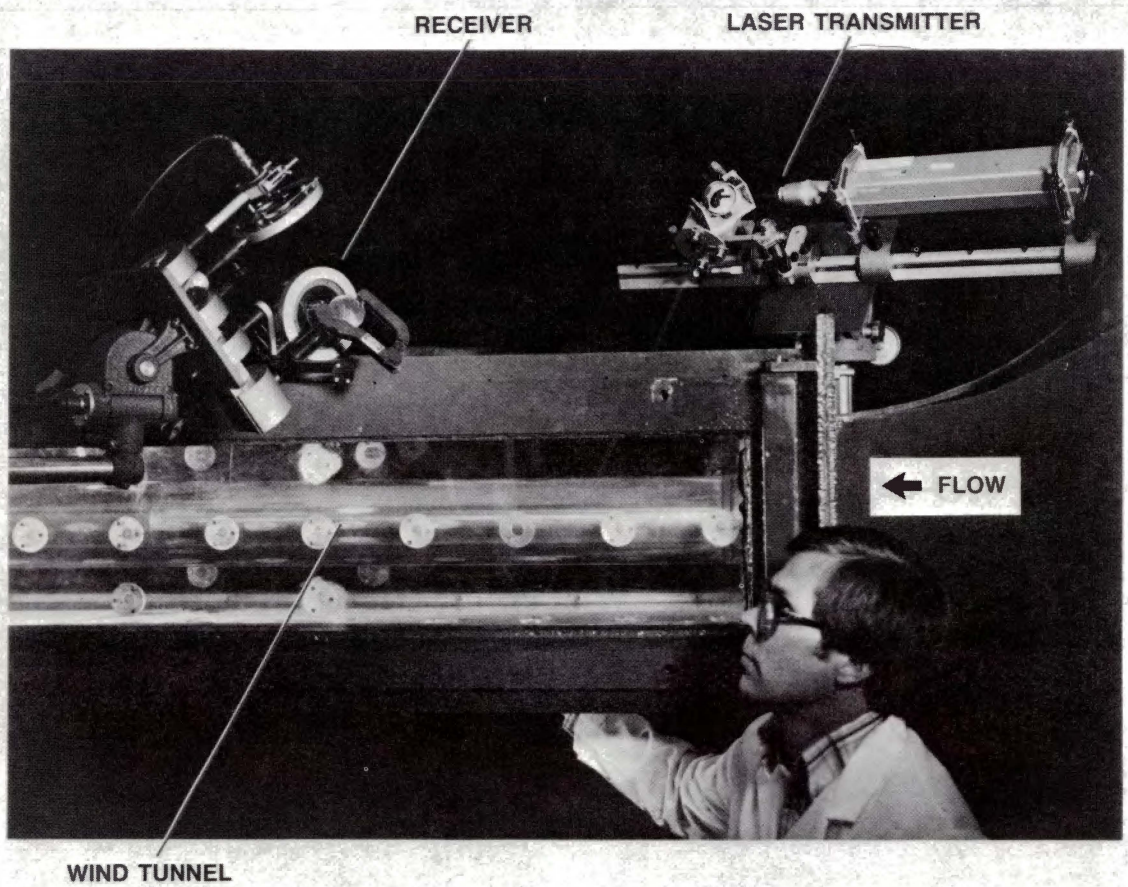


Composition of turbine blade coatings by scanning auger microscopy

Photophysics Instrumentation

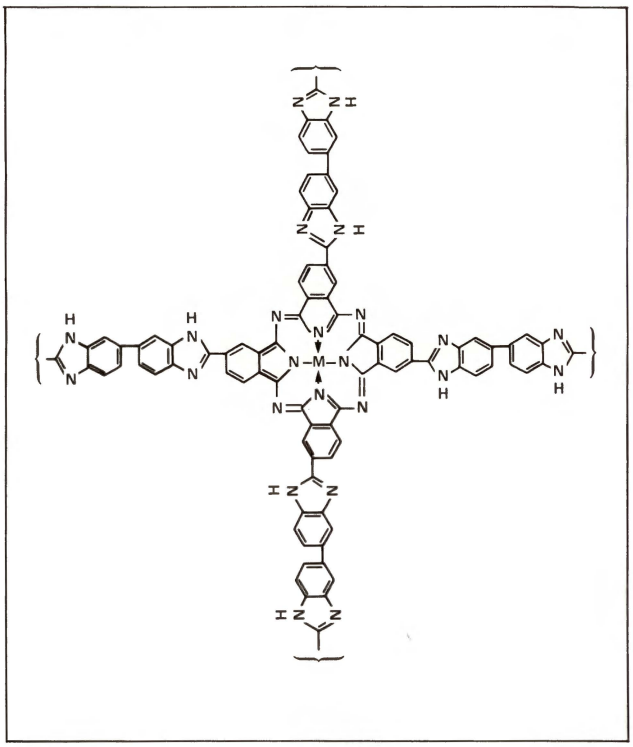
A nonintrusive, laser-interferometer, skin-friction meter has been successfully developed and demonstrated in several complex wind-tunnel flows. The meter uses interference fringes produced by coherent laser light to precisely measure the rate of change of thickness of an oil film placed on an airfoil. This information is then used to compute the skin friction, which is the aerodynamic shearing stress on the wall causing the oil to flow. The instrument works well in subsonic separated flow, supersonic high Reynolds number flow, and supersonic three-dimensional flow over a delta wing at angle of attack. These results show that the instrument could provide an accurate, inexpensive, and convenient method for measuring skin friction in a wide variety of wind-tunnel flows. It can provide data in cases where conventional instruments such as hot wire gages cannot.

(J. Arnold, Ext. 6209)



Dual-laser beam skin friction interferometer being installed in wind tunnel

New Polymers for Advanced Aeronautical Materials



Molecular structure of phthalocyanine-based polybisimidazole polymer

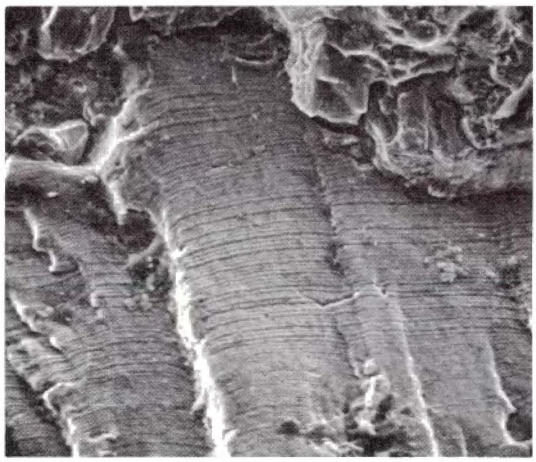
Work is in progress to develop fire-resistant seats, carpets, and other interior materials for use in advanced aircraft. In the past year, novel polymers of two classes have been made which represent an advancement in fire resistance and high-temperature capability. In the first class are phosphorus based polybismaleimide polymers, of which several modifications are possible. Graphite composites prepared from this class of polymers do not burn in pure oxygen, even when heated to 300°C. In the second class, several polymers based on the stable phthalocyanine structure have been made. In one version, amine substituted phthalocyanine was used to cure epoxidized novolacs to give a material having a char yield of 75% in N_2 at 800°C. Previously made epoxies have char yields of less than 45%. Polyimides have been made with char yields of 80% at 800°C, higher than any previously reported imide. In another type, polybisimidazoles were prepared incorporating the phthalocyanine group. These materials had char yields of 90% at 800°C in N_2. Composites made with these materials have a use temperature approaching 500°C. The molecular structure of such a polymer is shown. These materials can serve in environments where composites were not feasible before. It is expected that applications will be found in commercial aircraft and other aerospace vehicles.

(G. Fohlen, Ext. 5936)

Application of Fracture Mechanics to Failure Analysis

Over several years, fundamental studies have been conducted to better understand the fracture behavior of both graphite/epoxy composite and metallic aerospace structural materials. Recently, an effort was made to apply this knowledge through the use of fracture mechanics to help solve existing materials problems, to develop life-prediction procedures for improved component reliability, and to perform more meaningful analyses of component failures. A good example of such an effort was the analysis of compressor blade failure in the Ames 14-Foot Wind Tunnel. Through a complete characterization of the fracture surface, comparison with fracture surfaces created under controlled conditions in our laboratory, and the application of fracture mechanics, a near-complete stress and time history for blade failure was constructed. This analysis, together with a modal analysis of the aluminum blade, suggests blade failure was the combined result of minor surface damage (~0.005-in.-deep scratch on the blade shank) and a high alternating stress from a resonant vibration in a previously unidentified mode. The tunnel operating condition capable of producing this detrimental vibrational mode is being established.

(H. Nelson, Ext. 6137; R. Hampton, Ext. 6223)



5.0×10^{-4} in.

Fatigue striations on the fracture surface indicating a high alternating stress (~19 ksi), yielding a fast fatigue crack growth rate (3.2×10^{-5} in./cycle)

Advanced Heat-Shield Materials for Space Shuttle

Thermal conductivity problems delaying the implementation of Ames-developed fibrous refractory composite insulation (FRCI) were solved. Initial delivery of FRCI-20-12 production units by Lockheed Missiles and Space Co. for Orbiter OV 103 will begin in January 1982. The estimated weight savings for each Orbiter is over 1000 lb.

Ames-developed advanced flexible reusable surface insulation (AFRSI) was installed in the elevon cove on the Orbiter Columbia after the first Shuttle test flight (STS-1) to solve an overtemperature problem. Implementation has recently been accelerated by Rockwell International based on successful aeroacoustic tests in the Ames 2- by 2-Foot, 11-Foot Transonic, and 9- by 7-Foot Supersonic Wind Tunnels. As a result, some AFRSI will probably be installed on Orbiter OV 99's orbital maneuvering system pods. The reaction cured glass (RCG) coating, LI-2200 silica reusable surface insulation and Ames gap fillers performed successfully on STS-1. Several hundred more Ames gap fillers are being installed for the second test flight of Columbia, STS-2, in addition to the approximately 4000 used on STS-STS-1. Arc plasma tests to certify Columbia's thermal protection system for its first and second flights were successfully performed. All tests were completed well in advance of the flight dates.

New materials for the advanced space transportation system are being developed. A tailorable advanced blanket insulation (TABI) concept (defined in 1981) is being developed under contract at Woven Structures, Inc. Hughes Aircraft is under contract to develop a new strain isolation pad concept. A contract to pilot plant the newest member of the FRCI family of insulation materials will be awarded in January 1982.

(H. Larson, Ext. 5369)

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16. Abstract

This report describes various research and technology activities at Ames Research Center. Highlights of these accomplishments indicate the Center's varied and highly productive research efforts for 1981.

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