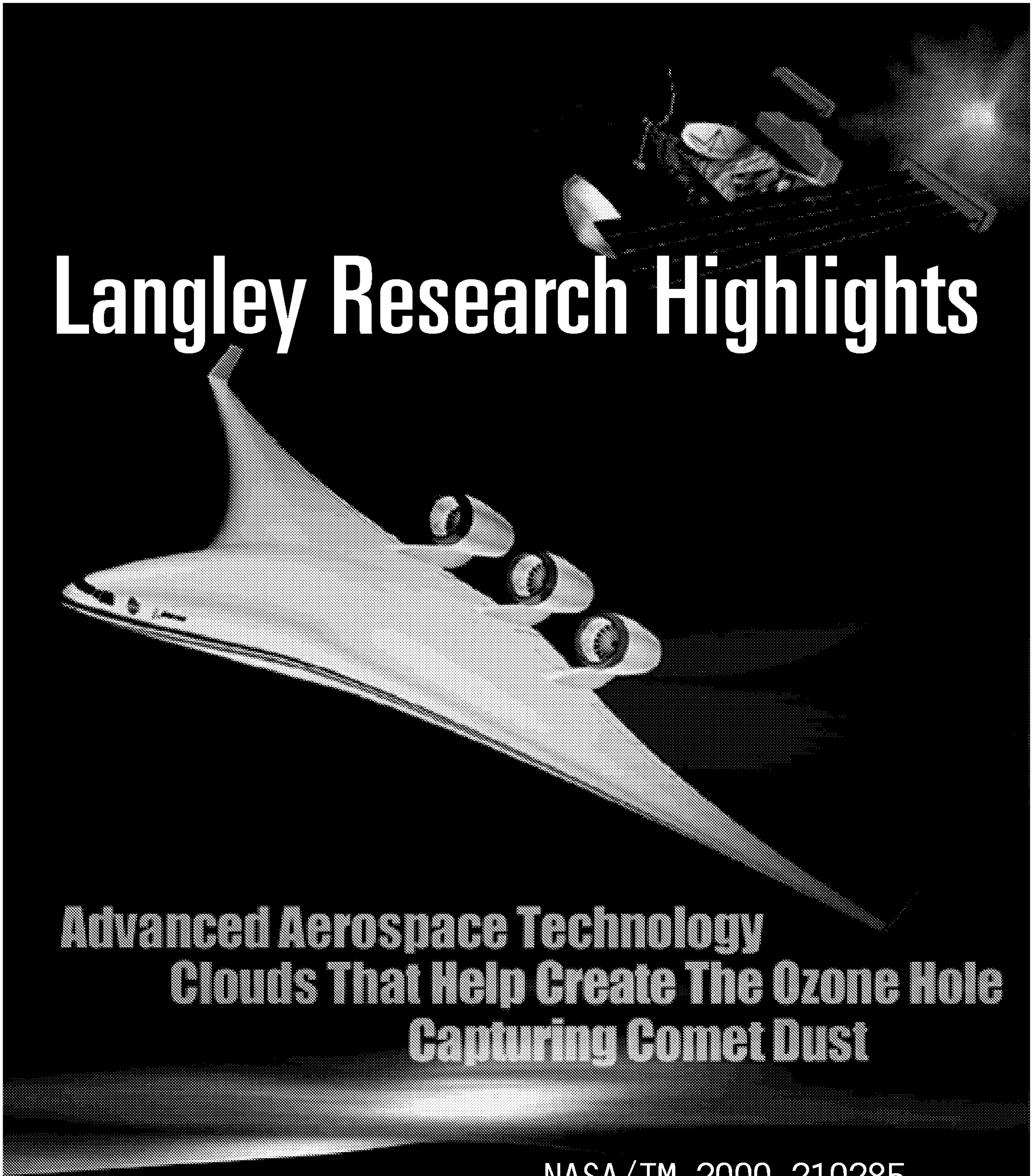
Langley Research Highlights



Advanced Aerospace Technology
Clouds That Help Create The Ozone Hole
Capturing Comet Dust

NASA/TM-2000-210285
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23681-2199

At the top of the cover is the Stardust spacecraft, the fourth Discovery class mission and the first mission that will return samples from a comet (Wild-2). Langley played a major role in the definition of the entry, descent, and landing sequence of the Stardust sample return capsule. The spacecraft successfully deployed the aerogel particle collector, which will extend one side into open space to capture microscopic bits of interstellar dust. JPL will return the collector in 2006. (For more information, contact P. N. Desai at p.n.desai@larc.nasa.gov on page 51).

In the middle of the cover is the Blended Wing Body (BWB) aircraft, which represents an advanced unconventional subsonic transport concept that addresses long-range NASA goals for safety, emissions, noise, capacity, and cost of travel. The BWB concept minimizes the required aircraft surface area per passenger by combining a rigid, wide airfoil-shaped fuselage with high aspect ratio wings that incorporate engines into the upper wing surface aft of the passenger compartment. This concept works well for balance and improves safety because the engine turbines and compressors are completely clear of the main structural elements, pressurized compartments, and fuel storage. The fan intakes on the three high-bypass ratio engines are shielded from the ground by the centerbody. This arrangement is expected to virtually eliminate fan inlet noise radiation to the ground. An experimental program was undertaken to validate the noise reduction benefits of the BWB design. (For more information, contact C. H. Gerhold at c.h.gerhold@larc.nasa.gov on page 19).

Shown on the bottom of the cover are Polar Stratospheric Clouds (PSCs) observed from the NASA DC-8 aircraft over Greenland during the SAGE III Ozone Loss and Validation Experiment (SOLVE) in January 2000. (The mission was conducted during three phases from November 1999 through March 2000.) PSCs were discovered in the early 1980's by Dr. Pat McCormick and Dr. William Chu of Langley in their analysis of data from the Langley Stratospheric Aerosol Measurement II (SAM II) satellite instrument. PSCs were later shown to be a primary factor in the formation of the ozone hole over the Antarctic. Photo courtesy of Dr. Lamont Poole of Langley. (For more information, contact C. R. Trepte at c.r.trepte@larc.nasa.gov on page 42).

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1999

NASA/TM-2000-210285

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Foreword

In 1915, twelve years after the Wright brothers flew over the dunes of Kitty Hawk on the Outer Banks of North Carolina, Congress established the National Advisory Committee for Aeronautics (NACA) and located its first facility at what is now the Langley Research Center in Hampton, Virginia. Orville Wright served on the NACA and was involved with Langley research from 1918 until his death in 1948. In 1958, Langley became part of the new National Aeronautics and Space Administration (NASA). Virtually every American aircraft and a number of spacecraft in operation today incorporate some technology that developed from research originating at NASA Langley. Today, the Center continues its historic national leadership role in Aerospace Technology research, plays a major role in Earth Science research, and partners closely with the other NASA Centers and the Jet Propulsion Laboratory in Space Science and the Human Exploration and Development of Space.

The Aerospace Vehicle Systems Technology program assigned to NASA Langley includes research that will help keep American aircraft safer, more maneuverable, quieter, and more energy efficient than those of our competitors. The research will also help to make our aircraft cheaper to manufacture, maintain, and fly, as well as to assure the continuing preeminence of U. S. military aircraft. Other Langley programs include Intelligent Synthesis Environment, which will revolutionize our national engineering culture and its design tools, and a Technology Commercialization program that provides the benefits of research breakthroughs to the commercial sector, for which Langley received the 1999 Award from the Federal Laboratory Consortium for Technology Transfer. One very important program is Aviation Safety, which assures that travel on American aircraft will always be the safest in the world. In 1999, Langley became the first federal worksite to be awarded the Voluntary Protection Plan (VPP) Star certification by the Occupational Safety and Health Administration for providing “an outstanding safety program” for our employees. Last year, Langley also received its ISO-9001 certification.

Langley's Atmospheric Sciences program began in the 1970's to study potential changes to the atmospheric environment associated with operating advanced aircraft. The program has become a world-class producer of innovative research and technology to advance knowledge of atmospheric radiation, chemistry, and dynamics for understanding global change. In close collaboration with the NASA Earth Science Enterprise and partnerships with academia, Langley scientists identify critical atmospheric science issues for research and provide key contributions to national and international assessments of the environment. The resulting advanced technology, remote sensing techniques, atmospheric data sets, and scientific information are widely used by the scientific, policy-making, and educational communities.

Langley is designated as the Agency's Center of Excellence for Structures and Materials in recognition of its long history of research into innovative composites, polymers, metallics, and structures for aircraft and spacecraft. The Center also serves as the Agency’s focal point for wind tunnels and test facilities and has a major role in the development of safer and cheaper new space transportation technology for the future.

This report contains highlights of some of the major accomplishments and applications that have been made by Langley researchers and our university partners and industry colleagues during 1999. The highlights illustrate the broad range of research and technology activities carried out by NASA Langley Research Center and the contributions of this work toward maintaining leadership of the United States in aeronautics and space research. A color version is available at URL http://larcpubs.larc.nasa.gov/randt/1999/. For further information, contact Dennis Bushnell, Senior Scientist, at Mail Stop 110, NASA Langley Research Center, Hampton, Virginia 23681-2199; at (757)-864-8987; or at e-mail address: d.m.bushnell@larc.nasa.gov.

J. F. Creedon

Dr. Jeremiah F. Creedon
Director

Availability Information

The accomplishments in this report are grouped into four categories based on NASA's Strategic Enterprises: Aerospace Technology; Earth Science; Space Science; and Human Exploration and Development of Space. The Aerospace Technology Enterprise is further divided into three “Pillars”: Global Civil Aviation; Revolutionary Technology Leaps; and Access to Space. The descriptions of the Enterprises are all taken from the NASA website (http://www.nasa.gov/).

The contributions have been carefully screened to avoid disclosure of any export-controlled information, any company-proprietary information, or any other “enabling” data from joint NASA-industry programs such as those under Space Act Agreements, focused programs, or any potentially patentable inventions for which patents have not already been granted.

For additional information about the research or any papers referenced in the Highlights, call or e-mail the point-of-contact (POC) that is identified with each Highlight. Only a limited number of black and white paper copies of this report have been printed because the full report is available in color on the Internet and can be downloaded from the Langley Research Highlights web page at http://larcpubs.larc.nasa.gov/randt/1999/.

Table of Contents

Aerospace Technology Enterprise

Pillar One: Global Civil Aviation

Pillar Two: Revolutionary Technology Leaps

Pillar Three: Access to Space

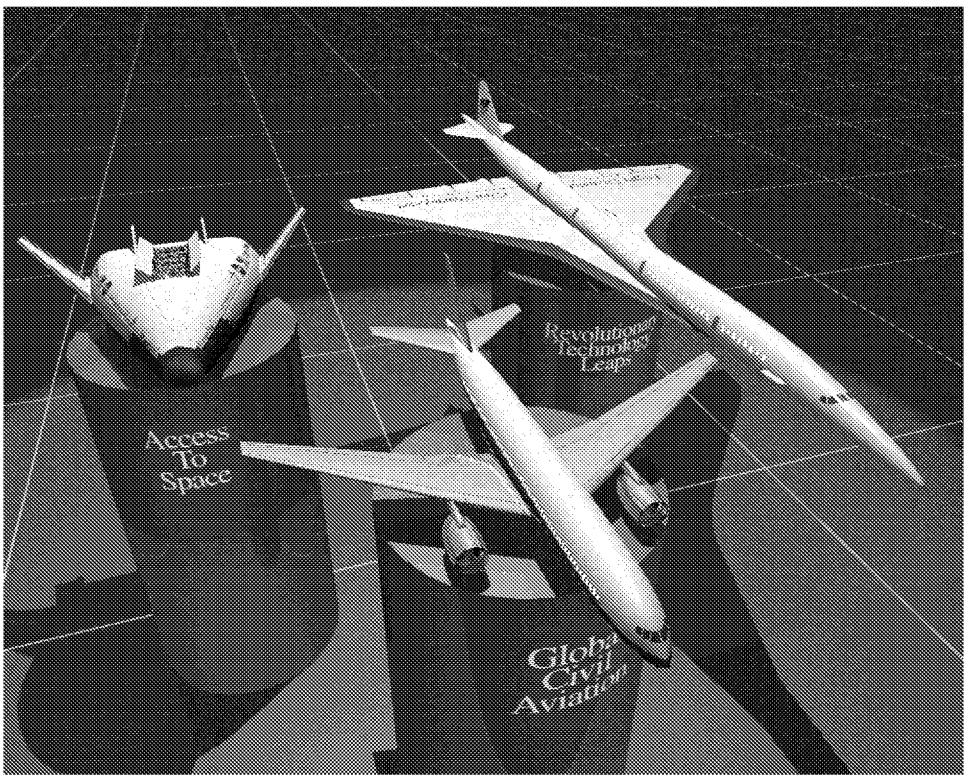
Earth Science Enterprise

Human Exploration and Development of Space Enterprise

Space Science Enterprise

Technology Partnerships

Aerospace Technology Enterprise



During 1999, the Aerospace Technology Enterprise had 3 Pillar Goals and 10 Technology Objectives that aggressively addressed the critical aerospace needs of our Nation, most notably aviation safety, productivity, environmental stewardship, and cost effective access to space.

NASA's Global Civil Aviation Goal 1 is to enable the development of an environmentally friendly global air transportation system for the next century of unquestioned safety that improves the Nation's mobility.

This Nation's economic growth has been fueled by technology-driven productivity improvements. Information technology and high-speed digital communications are expanding our economy in new ways. While this digital revolution is leading the way, communications and transportation remain integrally linked.

Today, aviation enables the high-speed movement of people and goods over long distances--a requirement in today's fast-paced economy. Unfortunately, the growth in air traffic is beginning to push the aviation system to its limits. Constraints threaten to halt the growth that is required to support our economy. Therefore, our effort in Global Civil Aviation is focused on developing technology solutions that eliminate barriers to growth for the global civil aviation system.

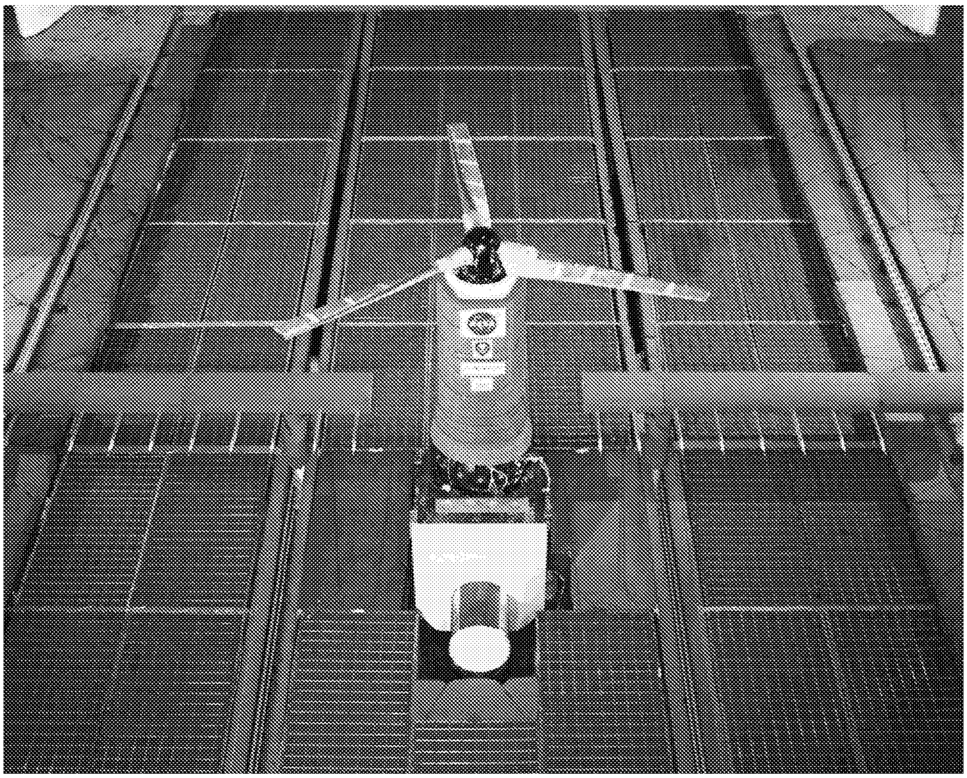
NASA's Revolutionary Technology Leaps Goal 2 is to revolutionize air travel and the way in which air and space vehicles are designed, built, and operated.

NASA envisions the expansion of our air transportation system along the dimension of much faster doorstep-to-destination speeds--whether those doorsteps and destinations are half a world away, or in a neighboring community--whether you are starting from or traveling to a small rural community or a major city. High-speed, supersonic transports will eventually cut in half the time required for long-distance, transoceanic travel. New, safe and efficient small aircraft and smart small airports will create a new air transportation network that will connect small suburban and rural communities with each other and with major cities and airports. These innovations and the resulting major expansion in personal mobility will be a hallmark of the new millennium.

NASA's Advanced Space Transportation Goal 3 is to achieve the full potential of space for all human endeavor through safe, affordable and reliable space transportation.

Space is the next frontier for our evolving transportation system. As we move out from the planet, we open up new territory for exploration and development. We envision that technology will enable us to do two things. First, technology will extend our reach, enabling us to explore further into space. Second, as NASA stays at the leading edge of space exploration, technological advances will allow commercial ventures to establish space operations and develop the commercial potential of space--starting first with safe, reliable, low-cost access to space. This will require developing technologies that enable new launch and in-space transportation systems with orders of magnitude improvement in safety, cost and reliability.

Pillar One:
Global Civil Aviation



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Rotorcraft Noise Model Prediction Comparison with XV-15 Measured Footprint

The development of a transportation infrastructure based on rotorcraft would reduce congestion at major airports by transporting passengers without requiring direct access to main runways at major airports and by diverting short-haul commuter traffic to smaller, more conveniently located vertiports. While it is possible to build civil aviation rotorcraft and tiltrotors of various sizes and capacities, the aviation industry and U.S. government officials are concerned with the impact of noise on land use surrounding the transportation facilities. The concern includes possible curtailment or even termination of rotorcraft operations during certain hours in the day. The cost for curtailing operations would significantly impact the economics of an operator, which may prevent the successful introduction of civil transport rotorcraft vehicles.

In response to these concerns NASA Langley Research Center has sponsored the development of a new a Rotorcraft Noise Model (RNM) that will be provided to government agencies, airframe manufacturers, airport operators, environmental planners, and acoustical consultants who have a requirement to make rotorcraft noise predictions. The model would be used for two purposes: first to develop approach and departure noise abatement procedures; and second, to quantify the community noise level from rotorcraft operations in the vicinity of an airport or vertiport.

The Rotorcraft Noise Model is an aircraft noise modeling computer program developed for NASA Langley Research Center, which calculates the sound levels at receiver positions on a uniform grid or at specific defined locations. The basic computational module calculates a variety of metrics. For example, shown in figure 1 is the noise footprint in decibels (dBA) of the Sound Exposure Level (SEL), which is an integration of the overall sound pressure level over the duration of the flyover.

Measured XV-15 noise footprints have been compared to noise footprints predicted by the RNM. The example comparison shown in figure 1 was for a complex, multi-segmented decelerating approach, including nacelle angle changes. The example comparison shows good agreement between the measured and predicted footprints. Similar results were found for several other XV-15 and V-22 tiltrotor comparisons. RNM will be further validated for additional flight conditions and other vehicles using both multiple data bases and aeroacoustic predictions. Enhancements to RNM are planned to account for propagation effects in an inner-

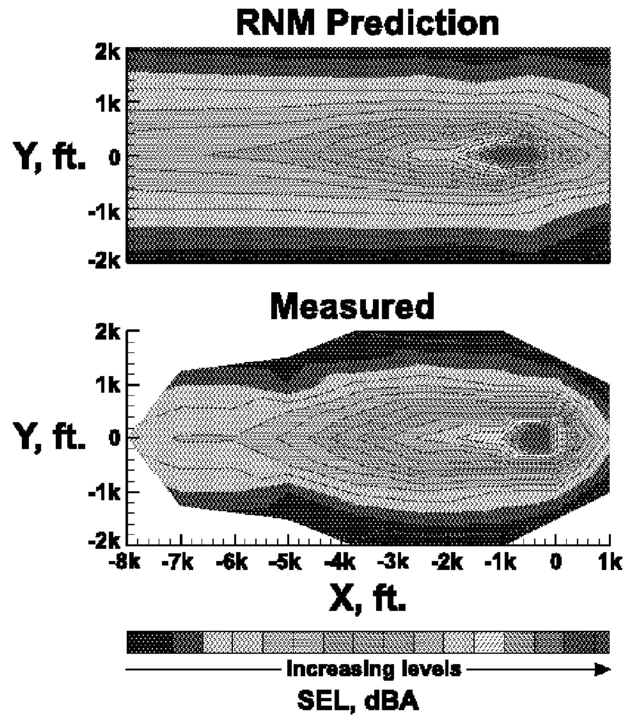


Figure 1. Noise Footprints. The numerical scale of the noise footprints is not shown. (Color version is on report website.)

city setting where reflections off of buildings can significantly alter the noise footprints, thus providing a more robust prediction capability.

(David A. Conner, d.a.conner@larc.nasa.gov, 757-864-5276)

Tiltrotor Aeroacoustic Analysis and System Validation

The Short Haul Civil Tiltrotor (SHCT) Project under the Aviation Systems Capacity (ASC) Program (previously under the Advanced Subsonic Transport initiative) was tasked to address the critical issues that would enable the acceptance of the civil tiltrotor aircraft. Under this project a number of tests, both flight and wind tunnel, have been conducted along with analyses to investigate and demonstrate advanced civil tiltrotor technologies. The deliverables, as well as Level 1 milestones, include the isolated-TRAM (TiltRotor Aeroacoustic Model) database for low noise proprotors and the validated Tiltrotor Aeroacoustic Code (TRAC). The TiltRotor Aeroacoustic Code (TRAC) is being developed as a cooperative effort between NASA, academia, and the U.S. helicopter industry to provide analysis for the design and evaluation of efficient low-noise tiltrotors as well as support for the development of safe, low-noise flight profiles. The isolated-TRAM (TiltRotor Aeroacoustic Model) database, which includes tiltrotor noise, airloads, rotor wake, and aero performance data for a 25% scale V-22 rotor, was obtained to validate TRAC. The first TRAC/TRAM aeroacoustic correlations were performed this year as partial completion of the SHCT Project Level 1 milestone 7.

In order to predict rotor noise, it is first necessary to predict the aerodynamics of the rotor blades as they rotate. Rotor blades can be considered as rotating wings that provide both the lift and the forward movement for a helicopter. Because they rotate, the blades see fluctuations in lift. It is the fluctuations that produce the noise. Hence, TRAC couples a comprehensive rotorcraft code with either a high resolution sectional loads code or a full potential CFD rotor code to predict unsteady blade loads which are input to a noise prediction program. One of the most dominant and annoying noise sources for tiltrotors operating in and near airports is due to blade vortex interactions (BVI). For tiltrotors, BVI noise has been found to occur over a much larger range of operating conditions, (i.e. rotor angles) than seen for helicopters. BVI noise, since it requires very accurate modeling of the rotor wake and rotor blade airloads, is very difficult to accurately predict. Figure 2 shows the comparison of measured and predicted maximum BVI noise levels for a large range of rotor angles, which correspond to different flight conditions ranging from descent (positive angles) to ascent (negative angles). Since the blade characteristics and dynamics of the TRAM were not currently known, several options for blade descriptions were examined with regard to sensitivity to noise prediction. The variation of TRAC predictions demonstrates the great care that must be taken in defining the blade motion, because of the sensitivity of wake formation and subsequent BVI. This sensitivity is accentuated for the tiltrotor compared to helicopters because of the significant inboard loading and its resultant multiple vortices. However, even with this variability, the predictions using the different blade modeling clearly and successfully bracket the measured acoustic data and demonstrate the proper acoustic data trends for conditions ranging from descent to ascent. TRAC will provide industry, for the first time, with a "design for noise" capability that should facilitate development of low noise rotor designs that would provide an increased community acceptance of rotorcraft.

(Casey L. Burley, c.l.burley@larc.nasa.gov, 757-864-3659)

Low Noise Tiltrotor Test Program

A model rotor acoustic test in the NASA Langley Research Center 14- by 22- Foot Subsonic Tunnel has demonstrated that a future large civil tiltrotor can be at least 6 dB quieter than a current generation large tiltrotor. Noise levels are assessed using so-called

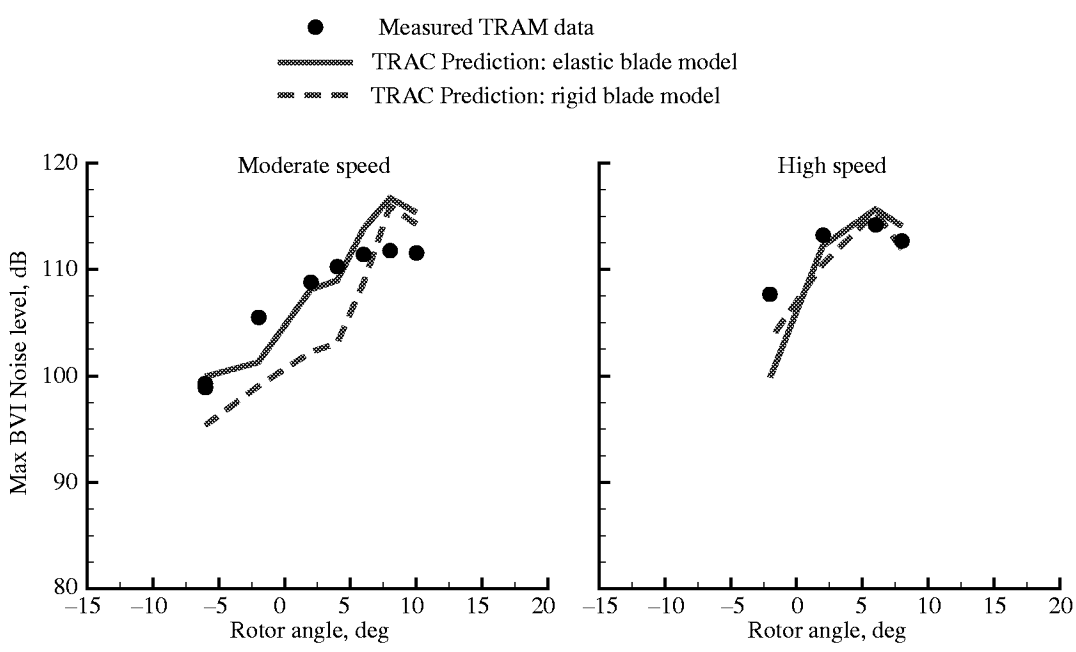


Figure 2. TRAC Predictions and Measured Tiltrotor (TRAM) Noise.

"A-weighted" noise levels, which tends to more highly rate the portion of the noise that humans are sensitive to, rather than those frequencies to which humans are less sensitive. Demonstration of a 6 dB A-weighted reduction in noise relative to current technology for a large passenger tiltrotor accomplished through rotor design is a major goal of NASA's Aviation Systems Capacity Program, Short Haul (Civil Tiltrotor) [SH(CT)] project. The SH(CT) program has encouraged the development of low-noise efficient proprotors as well as low-noise operating procedures through the funding of analytical studies, small-scale and large-scale model tests, and full-scale tests. Industry has responded in kind by funding the design and building of model-scale low-noise efficient rotors for application to tiltrotors. A Low Noise Tiltrotor test program was conducted in the NASA Langley 14- by 22- Foot Subsonic Tunnel in 1998 to evaluate industry low noise tiltrotor designs compared to a baseline model rotor representative of a large current technology tiltrotor. The isolated rotor test, employing rotor models representative of right hand side rotors for tiltrotor aircraft, was conducted as a cooperative effort by NASA, U.S. Army, Boeing, and Sikorksy. During the nine-week test, four industry-developed low-noise concepts including two versions of the Sikorsky Variable Diameter TiltRotor (VDTR) and two Boeing 5-bladed advanced rotor configurations were compared to the baseline rotor at several operating conditions representative of a typical level fuselage approach (see figure 3). Noise measurements of the baseline model were then used to evaluate the potential noise reduction benefits of the industry rotor designs. In spite of the extreme technical complexity involved in using three different rotor hubs and five different blade sets, the test was successfully completed on schedule. Initial evaluation of the results indicate that the Boeing 5-blade rotors substantially reduced noise for some conditions, and the Sikorsky VDTR configurations met or exceeded the SHCT goal of a 6 dB A-weighted noise reduction for most conditions tested. The data acquired during the Low Noise Tiltrotor test program will be useful in the further refinement and development of rotor designs to reduce noise and will allow validation of analytical prediction codes.

(Earl R. Booth, Jr., e.r.booth@larc.nasa.gov, 757-864-3627)

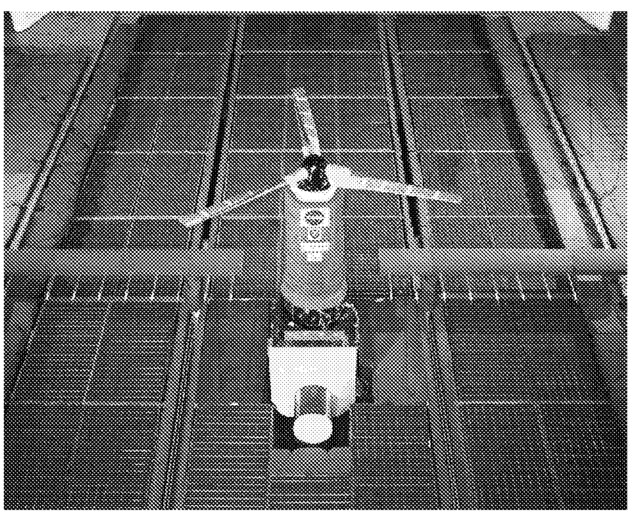


Figure 3. Baseline isolated rotor tiltrotor model shown installed in NASA Langley Research Center 14- by 22- Foot Subsonic Tunnel for acoustic measurements to determine noise reduction potential of industry concepts for a low noise tiltrotor aircraft.

Weather Channel in the Sky

President Clinton announced in February 1997 a national goal to reduce the fatal accident rate for aviation by 80% within ten years. This national aviation safety goal is an ambitious and clear challenge to the aviation community and is reflected in the Pillar 1 Global Civil Aviation safety objectives of NASA's Aerospace Enterprise. Weather-related accidents comprise 33% of the commercial air carrier accidents and 27% of general aviation accidents. Using the inputs of industry and government, the NASA Aviation Safety Investment Strategy Team and the National Aviation Weather Program Council have identified and prioritized research that should be addressed for reduction of weather-related accidents. NASA has established an Aviation Weather Information (AWIN) project at the Langley Research Center and a Weather Information Communication (WINCOMM) project at the Glenn Research Center to develop technologies that will provide accurate, timely and intuitive information to pilots, dispatchers, and air traffic controllers to enable the detection and avoidance of atmospheric hazards. NASA's objectives and plans reflect close coordination with related industry, Federal Aviation Administration (FAA), and Department of Defense (DOD) efforts. To accelerate research, development, prototyping, and implementation of aviation weather information systems, NASA has initiated nine cooperative efforts with industry teams in which NASA and the industry participants share in funding the proposed research. Collectively, these teams include over forty different industry, university and government organizations.

A team led by Honeywell is developing a national and worldwide "Weather Information Network (WINN)" including strategic and tactical airborne displays,

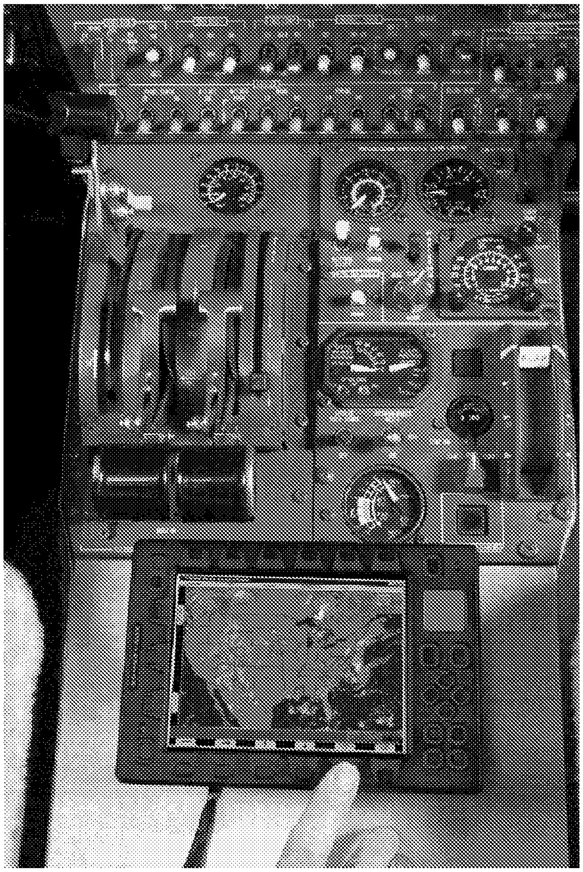


Figure 4. Honeywell Weather Information Network (WINN) display in the cockpit of a business jet.

airborne and ground based servers, and multiple providers of weather products and data link services. A prototype of this system was installed on a business jet and demonstrated to airlines during the summer of 1999 (see figure 4). The Boeing Company is leading an "Aviation Weather Information (AWIN)" implementation team that is using both a Federal Express MD-11 and an Air Force C-135C transport to evaluate a complete weather information system with weather sources, terrestrial networks, and ground to air satellite communications. The graphic display of current and advanced weather products to the flight crew is being evaluated during normal transport operations.

Weather information systems for general aviation are being developed by teams led by ARNAV Systems and AlliedSignal (formerly NavRadio). During 1999, the ARNAV team conducted in-flight evaluations of four advanced weather products being developed by the National Center for Atmospheric Research (NCAR). Additionally, the ARNAV team initiated evaluation of electronic reporting of humidity, temperature and icing conditions from short haul aircraft being operated by Federal Express. The AlliedSignal team is developing an affordable, open architecture Flight Information Services (FIS) system for general aviation. Another team led by AlliedSignal has developed a prototype low-cost sensor package for in-flight measurement and transmission of automated weather observations from small airplanes that fly "down in the weather." In July 1999, both ARNAV and AlliedSignal were selected by the FAA to implement nationwide weather-in-the-cockpit information systems. Both of these systems utilize technologies that were developed with support from the NASA Advanced General Aviation Transport Experiment (AGATE) program and the Aviation Weather Information (AWIN) project.

During 1999, Rockwell Science Center completed a prototype of a web-based system to improve general aviation preflight weather briefing and en route situational awareness. Text and graphical weather information sources are integrated, and information is filtered, to display to the user only that which is route and/or time relevant (based on mission, equipment, flight rules, and pilot risk threshold). Rockwell Science Center is also developing a system that will integrate on-board, in-situ, radar information with up-linked ground radar information. Honeywell Technology Center has developed a prototype route optimization tool that integrates both weather data and perception of weather hazards. The National Center for Atmospheric Research (NCAR) leads a team undertaking the development and phased evaluation of an operational weather hazard dissemination system for aviation operations in oceanic and remote areas. The intent is to provide a timely summary of potential weather hazards to airline dispatch centers, air traffic control centers, and flight crews of en-route aircraft. Information transmission systems are currently being verified prior to initiation of tests on transports flying across the south pacific.

Results of these cooperative efforts will be commercialized by industry and will be used by NASA as the basis for development of enhancements to improve the coverage, affordability and ease of use of weather information systems.

(Paul Stough, h.p.stough@larc.nasa.gov, 757-864-3860)

New Mechanism for Rotation of a Supercell Storm

A supercell storm is a tall, rotating thunderstorm that can cause tornadoes, hail, and turbulence. An understanding of these storms is required to develop technologies for reducing the number of civil aviation accidents that are weather related. Of primary importance is an understanding of the mechanism of rotation.

For many years, it was believed that the rotation of a supercell storm was not due to the Earth's rotation. The Coriolis force, which results from the Earth's rotation, was believed to be too weak to spin up a supercell storm in the observed time of a couple of hours. Another mechanism for rotation was developed and incorporated into the mathematical models of supercell storms. A recent article, however, presents a new Coriolis mechanism for rotation that is very strong: "Pulsing inertial oscillation, supercell storms, and surface mesonetwork data," by Robert C. Costen and L. Jay Miller, *J. Engr. Math* . 34, 277-299, (1998). (The co-author, L. Jay Miller, is with the National Center for Atmospheric Research (NCAR), which is sponsored by the National Science Foundation.) This new mechanism, called the pulsing inertial oscillation (PIO), is shown in figures 5 and 6.

Figure 5 shows the movement of an air parcel on a horizontal plane above the friction layer in the absence of any pressure disturbance. The trajectory is a circle because the Earth is rotating beneath it; i.e., the parcel moves so that the centrifugal force is balanced by the Coriolis force. The time for one cycle depends on the latitude and is typically 18 hours. Figure 6 shows how the movement shown in figure 5 can be organized to produce contraction and cyclonic spin-up. Each parcel in the contracting core is being compressed. This compression is achieved by the parcels' descending in a downdraft to levels of higher pressure. The downdraft is driven by evaporative cooling of the descending air. Practical limitations on evaporative cooling allow rotation rates of up to 100 times the rotation rate of the Earth. Spin-up from zero occurs in as little as 30 minutes. A mathematical model based on this mechanism compares well with data from a supercell hailstorm, as shown in the article cited above. The data, however, are not conclusive.

The significance of the new mechanism is that now there are *two* mechanisms that can account for the rotation of a supercell storm: the conventional and the PIO. In the conventional mechanism, spin-up occurs in an updraft; in the PIO mechanism, spin-up occurs in a downdraft. Conclusive data are needed to determine which mechanism is actually operating in a supercell storm. The possibility exists that both operate under different circumstances. Only when this determination is made can complete and accurate models be developed for predicting the updraft/downdraft structure that is essential for civil aviation safety.

The author presented the new mechanism in seminars at the University of Oklahoma, School of Meteorology; National Oceanic and Atmospheric Administration, National Severe Storms Laboratory; and the NCAR Mesoscale and Microscale Meteorology Division.

(Robert C. Costen, r.c.costen@larc.nasa.gov, 757-864-1413)

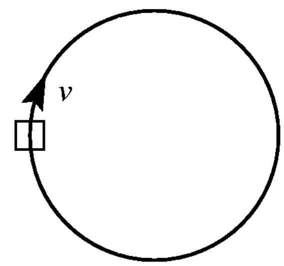


Figure 5. Frictionless movement (velocity *v*) of an air parcel on a horizontal plane in the absence of any pressure disturbance.

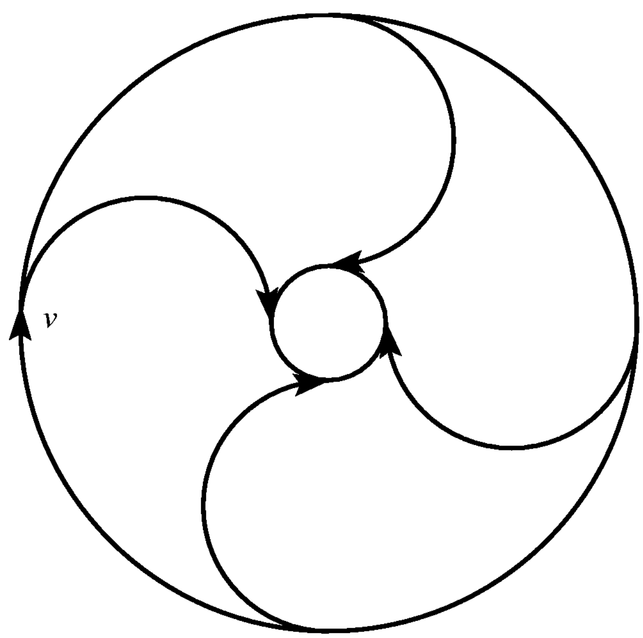


Figure 6. Contraction and cyclonic spin-up of a compressible, cylindrical downdraft.

Low-Cost, Light-Weight Composite Wing Structure Technology

Composites offer the potential for lower weight, more aerodynamically efficient, and lower cost airframe structures that lead to reduced airframe production and operation costs. These factors contribute significantly to airline Direct Operating Cost (DOC), which in turn is a major factor in the overall cost of air travel. Historically, the biggest barriers to the use of composites in commercial jet transports have been the issues of high cost and low damage tolerance associated with composite primary airframe structure. Starting in the late 1980's, a joint NASA/Industry endeavor was embarked upon to develop textile composites technology approaches that would provide a paradigm shift in cost and damage tolerance to overcome these barrier issues. In 1995, building on the results of this earlier work at the subcomponent level, the Airframe Materials & Structures (AFMS) element of NASA's former Advanced Subsonic Technology (AST) Program was initiated, in a partnership with Boeing, to design, fabricate and test a full-scale wing box structure. The overall goal of the AFMS element was to demonstrate a 25% weight and 20% cost reduction in wing box primary structure compared to today's best aluminum wing box technology, while meeting airline and FAA requirements for structural performance, damage tolerance, maintainability and repairability. The cost and weight reduction goals of this program directly support the Reduced Cost of Air Travel Goal under the Global Civil Aviation Pillar.

The technology development to date has focused on extremely innovative and cost-effective techniques for stitching dry textile fabric preforms and then curing them with a resin film infusion (RFI) process. This will make it possible to significantly reduce the cost of fabricating composite primary wing structure, and also provide greatly improved damage tolerance, due to the through the thickness stitching of very large components in an automated process. This development effort is scheduled for completion during year 2000 with the testing of a full-scale (40-ft. long), semi-span wing box to validate the structural performance and weight goal. The semi-span test article has been fabricated and delivered to Langley, where testing is underway in the Structures and Materials Laboratory. The cost reduction goal has been verified through the fabrication of multiple, full-scale wing cover panels, simulating a production type environment. Cost data from seven full-scale wing cover panels is shown in figure 7, demonstrating that the cost goal of a 20% reduction has been achieved.

(David E. Bowles, d.e.bowles@larc.nasa.gov, 757-864-3095)

Prediction and Minimization Methodology for Community Noise Impact

Advanced community noise impact prediction methods and operational procedures to reduce community noise will be required in meeting the 10-year and 25-year Enterprise noise reduction goals. Optimized flight trajectories were developed which are made possible by advanced flight guidance and flight management systems. A community noise impact model referred to as the AirCraft Noise Impact Model (ACNIM) has been developed which incorporates airport noise prediction, census data, and satellite

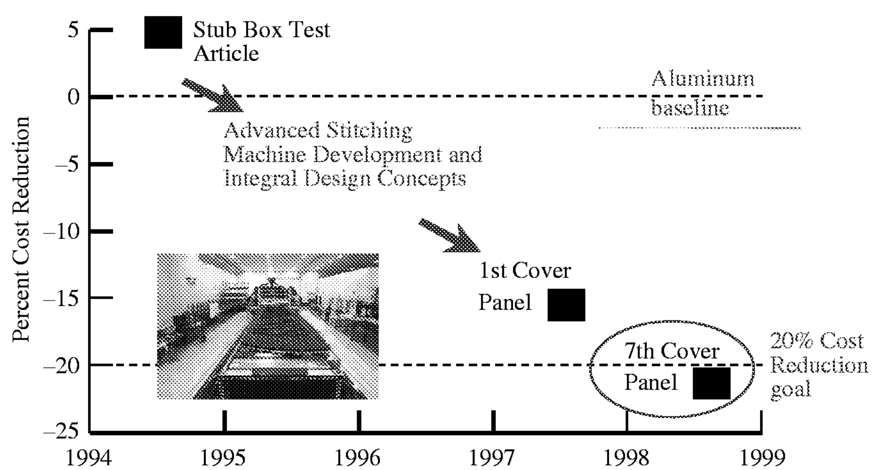


Figure 7. Fabrication of multiple, full-scale wing panels demonstrated a 20% reduction in cost.

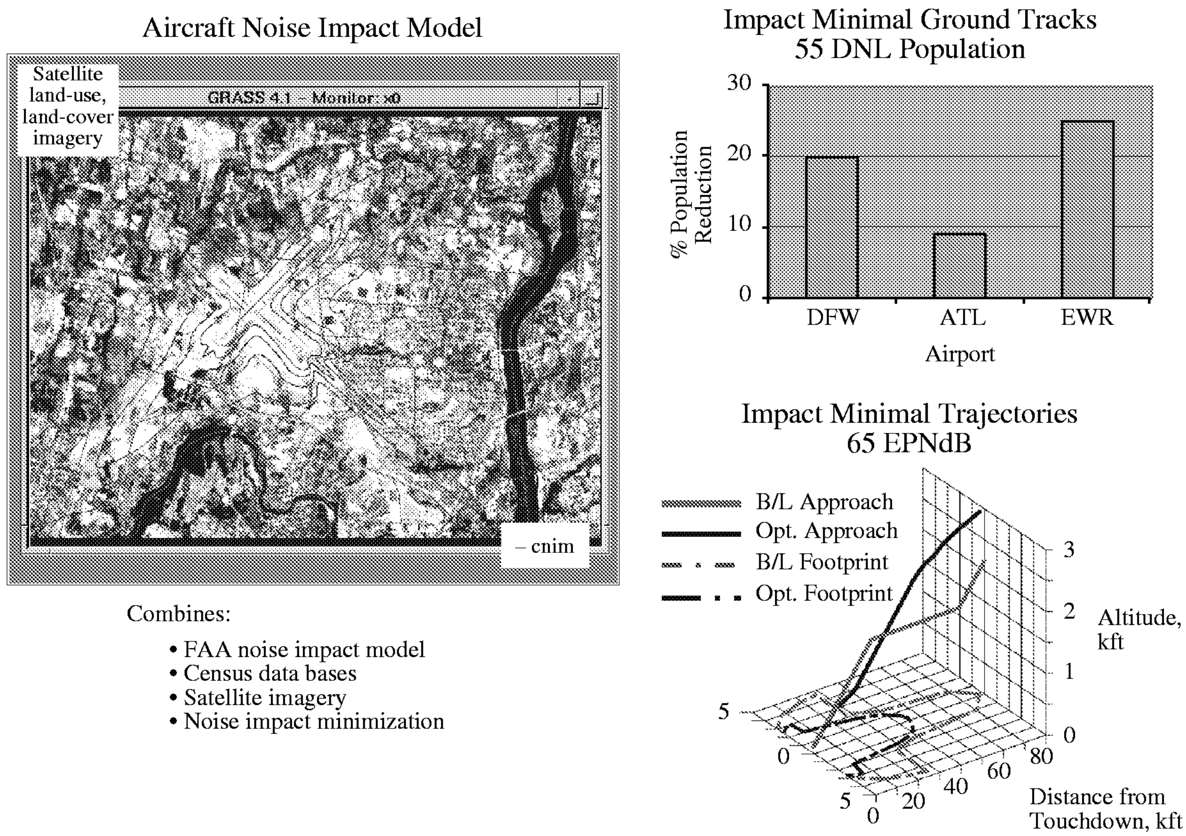


Figure 8. Prediction and Minimization Methodology for Community Noise Impact. (Color version is on report website.)

imagery, into a user friendly Geographical Information System (GIS) computer program. The airport noise prediction is performed using the FAA's Integrated Noise Model, which is the standard airport noise prediction tool used around the world. Incorporation of census data, which includes population data and population characteristics, allows the prediction of community impact. Satellite imagery is used in combination with the census data to determine more accurate land use and population locations. ACNIM also incorporates the capability to determine optimized aircraft ground tracks for minimal community noise impact. Results of studies with the developed models indicate that improved high-lift systems, in combination with advanced operational procedures have potential to reduce community impact by the equivalent of 2-4 dB source noise reduction.

An example airport noise impact graphic showing noise contours and census tracts superimposed on satellite image is shown in figure 8. Examples of potential benefits of impact-minimal ground tracks and optimized approach trajectories are also given. The Baseline (B/L) is a standard approach procedure (3 deg glide slope, fixed throttle and flap settings for the final approach). The optimized approach allows throttle and flap settings to be continuously varied (still at 3 deg glide slope). It was concluded that noise contour areas can be reduced by this method, although the gains are fairly small.

(Dr. Kevin Shepherd, K.P.Shepherd@larc.nasa.gov, 757-864-3583)

Active Structural Acoustic Control of Interior Noise

This technical accomplishment validates the application of Active Structural Acoustic Control (ASAC) to reduce aircraft interior noise by applying time varying force inputs to the primary structure of a Beech 1900D. This is a 19 passenger, turboprop powered commuter aircraft of conventional rib stiffened aluminum construction. Initial ground trials of 82 candidate force locations, all on ring frames, were made and from these an optimized subset of 21 actuator locations were chosen to apply control forces in flight. A control strategy based on a principal component, least mean squares (PC-LMS) approach was implemented on a dual chip digital signal processor system with 32 microphone inputs and the 21 actuator outputs. A sample rate of 1238 samples/sec was used to control the first three propeller tones at 103 Hz, 206 Hz and 309 Hz individually and simultaneously. Reductions of 15dB were obtained at the blade passage frequency during single frequency tests and reductions of 10dB, 2.5dB and 3dB were obtained for simultaneous control for the first three propeller tones. These reductions were achieved with 21 pairs of cigarette pack sized, miniature shakers each using 7 watts or less of electrical. The PC-LMS based controller is a new and unique approach to control system design providing an orthogonalized set of control inputs that adaptively converged in an extremely stable manner. The optimization procedure for choosing the actuator locations also proved unique and robust. However, additional performance would be expected by optimizing locations from a set of trial locations taken under pressured flight conditions, as this has been shown to have appreciable effect on the structural response. Interior noise reduction research is related to the Three Pillar noise goal in that public expectations are for lower aircraft noise levels, outside and inside the aircraft fuselages. In addition, as weight is taken out of aircraft structure to meet performance or cost objectives it becomes increasingly more difficult to maintain interior noise levels without such innovative approaches.

Results of a cooperative flight test on the Raytheon/ Beech 1900D shown are illustrated in the top left of figure 9. The propeller blade-passage-frequency tones were reduced by the active structural acoustic control system by an average 15 dB in the front seats of this commuter aircraft where the propeller tones are the loudest. The size of an actuator mounted to a ring frame is indicated in the picture in the lower right corner of the chart as compared to the size of rivet heads.

(Dan Palumbo, D.L.Palumbo@larc.nasa.gov, 757-864-6185)

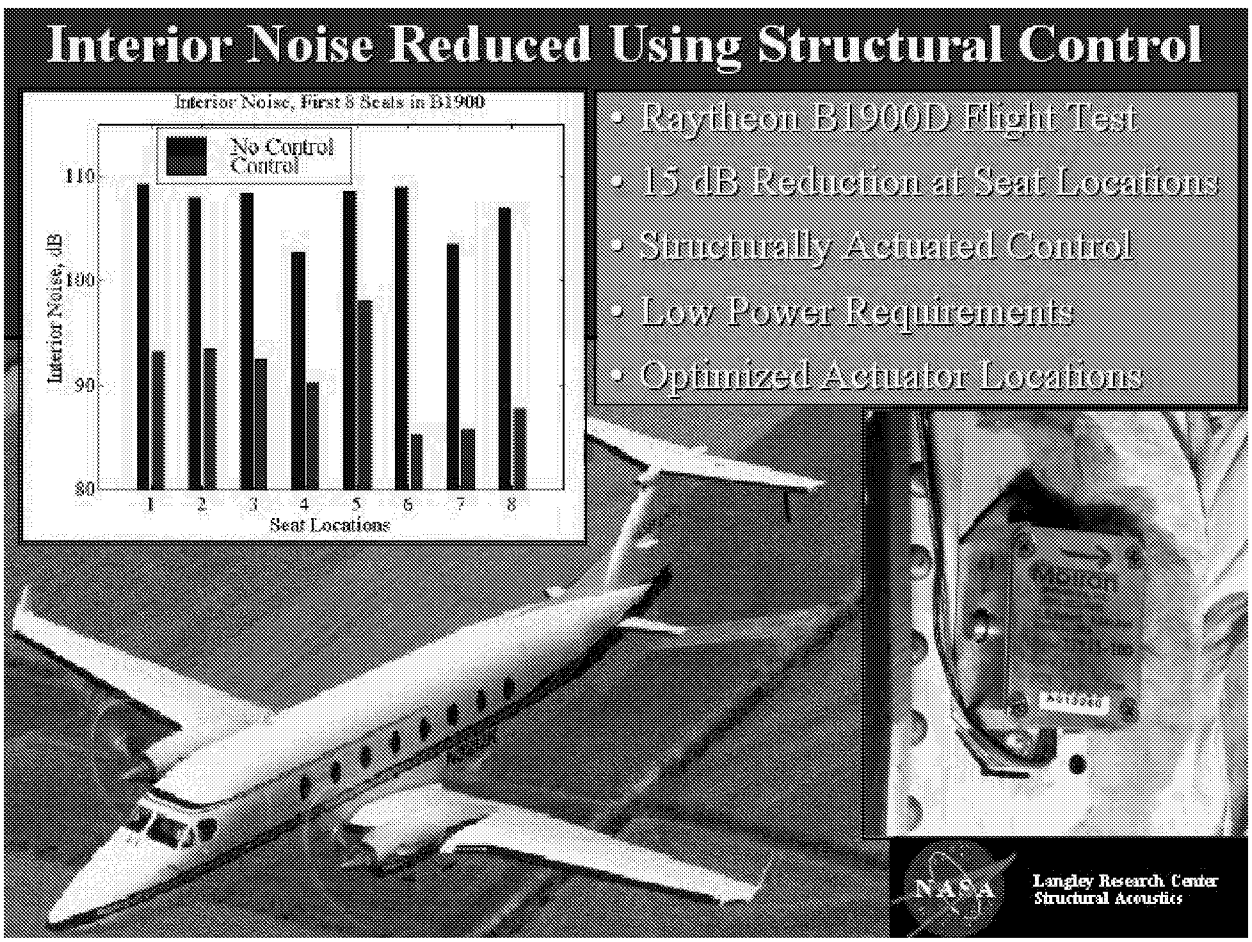


Figure 9. Interior Noise Reduced Using Structural Control. (Color version is on report website.)

Active Control of Turbulent Boundary Layer Induced Interior Noise

This technical accomplishment validates the application of Active Structural Acoustic Control (ASAC) to reduce sound radiation (and thus aircraft interior noise) by applying time varying force inputs to an aircraft-like structure subject to turbulent boundary layer (TBL) excitation. In this test, a panel was constructed similar to the sidewall of an aircraft fuselage; however, the panel was flat to allow a simple incorporation into a wind tunnel wall. The static in-plane stress normally associated with aircraft cabin pressurization (at 40,000 ft) was provided via a tensioning fixture. Thus the smooth "exterior" side was subjected to TBL flow inside the tunnel, and the other (interior) side radiated sound. Accelerometers were mounted on the interior side of the panel, and microphones were positioned to monitor sound radiation.

The control method employed an ASAC strategy in a feedback control topology. The system utilizes structurally mounted piezoceramic control actuators, accelerometers with sound radiation filters, and a Generalized Predictive Control (GPC) technique to minimize the total sound power radiating from the structure.

Experiments were conducted in Langley facilities at both Mach 0.8 and Mach 2.5 flow conditions, and active control was performed on a single bay and two bays. The results (see figure 10) demonstrate reductions in total radiated sound power of approximately 10–15 dB at resonances, and 5–10 dB integrated over the bandwidth of 150–800 Hz. Although the goal was to reduce sound radiation, the vibration levels were also reduced. This work represents the first known demonstration of ASAC of aircraft style panels subjected to both subsonic and supersonic flows.

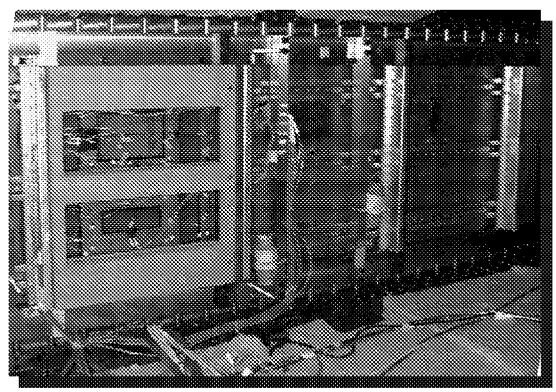
(Gary P. Gibbs, g.p.gibbs@larc.nasa.gov, 757-864-8977)

Features

- Piezoelectric surface mounted actuators
- Structural sensors predict total radiated energy (cost)
- Generalized Predictive Control feedback controller
- 10 - 15 dB reduction of resonances
- 9 dB reduction over bandwidth of 150 - 800 Hz

Structural Acoustics Branch
NASA Langley Research Center

Test Panel Photo



Reduction of Radiated Sound Energy

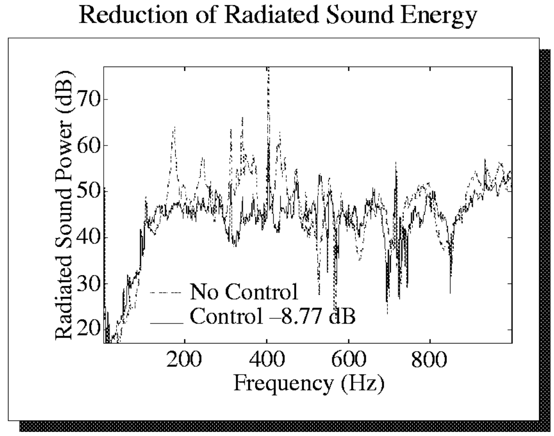


Figure 10. Active Control of Turbulent Boundary Layer Induced Sound Radiation from Aircraft Style Panels. (Color version is on report website.)

Injury Mechanisms and Injury-Mitigating Technologies

Unfortunately, there are fatalities each year in airplane accidents that could be survivable. As part of its safety effort, the NASA Langley Research Center is conducting research to improve human survivability in airplane accidents of transport, rotorcraft, and general aviation class aircraft through a systems approach for improved crashworthiness design.

In order to categorize injury mechanisms and limits of human survivability in aircraft crashes with survivors, a detailed study of 11 transport accidents was conducted. Under a contract with Simula Technologies, records available through NTSB (National Transportation and Safety Board), FAA, and foreign aircraft accident investigations were studied. Technologies that could prevent serious injury and fatality in potentially survivable aircraft accidents were identified and prioritized.

In 24 potentially survivable accidents between 1983 and 1999, there were 1219 fatalities and 378 serious injuries. The study for transport aircraft revealed the following areas that lead to an increase in the potential for survivability:

(1) improve egress and evacuation by better and more numerous exits,

(2) improve the fire suppression system,

(3) decrease flammability and toxicity of the aircraft interior components,

(4) improve the retention of overhead luggage bins,

(5) increase the seat back height,

(6) require restraints for all children,

(7) increase the robustness of the structure-floor-seat-occupant tie-down chain to match the limits of human tolerance to injury, and

(8) control the break-up of the aircraft fuselage.

Figure 11 is a graphic depicting the Crash Data Survey of transport, rotorcraft, and general aviation aircraft accidents and the resultant identification of injury mechanisms and improved crashworthiness technology to increase survivability.

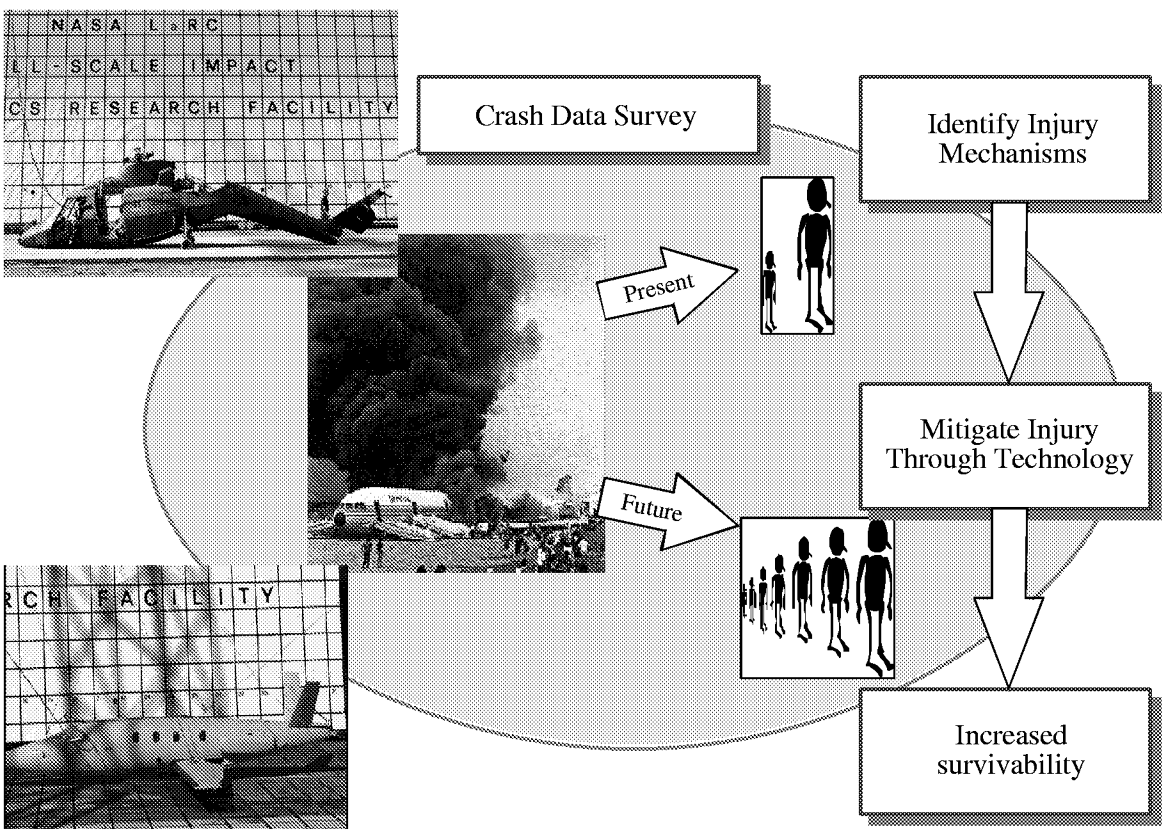


Figure 11. Crash Data Survey and resultant identification of injury mechanisms.

General aviation aircraft and rotorcraft have many different systemic and structural features from transport aircraft and different crash and survivability characteristics. The Crash Data Survey for rotorcraft and general aviation aircraft will be completed in early 2000 to guide the research for improving survivability for these class aircraft.

(F. W. Cazier, Jr.; f.w.cazier@larc.nasa.gov, 757-864-286)

Controlled Flight into Terrain

Limited visibility is the single most critical factor affecting both the safety and capacity of worldwide aviation operations. The Synthetic Vision Systems (SVS) Project will develop technologies over the next five years with practical applications that eliminate low-visibility conditions as a causal factor to civil aircraft accidents. Synthetic Vision Systems will also replicate the operational benefits of flight operations in unrestricted Visual Meteorological Conditions regardless of the outside weather condition.

A two-day SVS Project kickoff meeting in Asheville, NC, on November 2 & 3, 1999 was held to simultaneously launch eight unique SVS project cooperative agreements with industry and academia. There were more than seventy meeting attendees from over twenty-five diverse organizations including DOD, FAA, NIMA, and Airline representation. NASA personnel provided a summary of the five-year Synthetic Vision Project plan and each NASA Research Announcement cooperative agreement team provided an overview of their proposed effort.

Evaluation of a crew-centered synthetic vision display (see figure 12) was also completed. Flight evaluations of a state-of-the-art photo-realistic terrain database and NASA Langley Synthetic Vision Tactical Concept display were conducted from the "terrain impacted" Asheville airport. Overall, 16 flights that performed over 60 various approaches were conducted. Flight demonstrations featured image comparisons of external video from a High-Definition Television (HDTV) camera with overlaid flight to a synthetic vision scene with overlaid symbology. The tactical synthetic vision scene incorporated terrain, obstacles, flight symbology, airport features (runway, taxiways, tower, FBO, etc.), and air traffic icons. A Navigation Display (ND) was also employed to assist flight test maneuver execution. Forty people attending the concurrent Aviation Safety Program (AvSP) Synthetic Vision Systems (SVS) Project kickoff meeting participated in one of ten demonstration flights.

(Frank Jones, f.p.jones@larc.nasa.gov,757-864-5271)

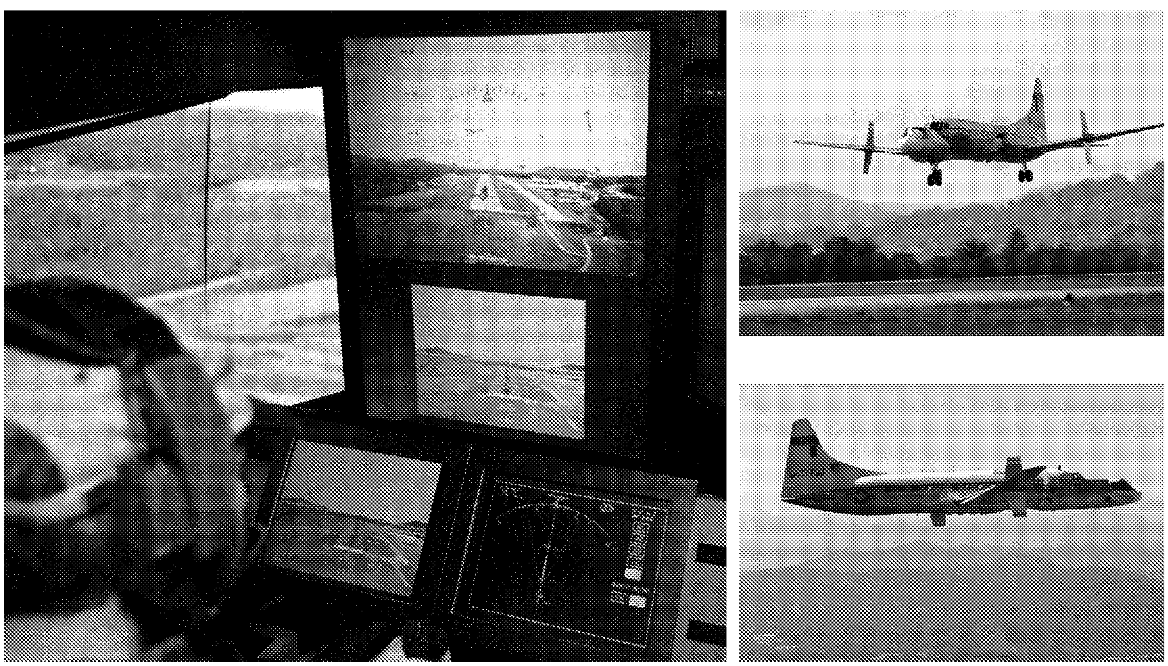


Figure 12. Synthetic Vision Displays.

Corrosion Detection System for Thick Aircraft Structure

The average age of commercial airplanes is increasing each year with more than 25 per cent of these airplanes over 20 years old. To ensure continued safe operation of the U.S. commercial aircraft fleet, NASA is developing advanced technologies that U.S. airlines and aircraft manufacturers may use to reliably and economically inspect the growing number of high time aircraft. As part of this effort, the Langley Research Center has developed breakthrough technology for corrosion inspection. The life of an aircraft airframe can be seriously affected by corrosion. The most common technique for detecting corrosion in aircraft currently is visual inspection for surface distortions. But corrosion may occur in regions of the aircraft that are partially or completely inaccessible for inspection due to overlaying structure.

Langley researchers have developed a Reverse Geometry X-Ray system for detecting hidden corrosion in aircraft structure. Two of these systems are shown in figure 13. One is a prototype laboratory system in a large radiation vault. A section of a Boeing 707 wing is being inspected. The laboratory system is capable of detecting material losses due to corrosion of as little as 2% in aluminum structures which are as thick as 5 cm. The method has been transfered to a portable system. The portable system developed under a contract to Digiray Corp. is being tested outside the LaRC hanger. These systems offer the potential for improved aircraft safety by enabling inspection for corrosion without disassembly and reassembly of the aircraft structure.

In the future, the methodology will be developed for detection of cracks in thick aluminum components typical of those found in aircraft wings.

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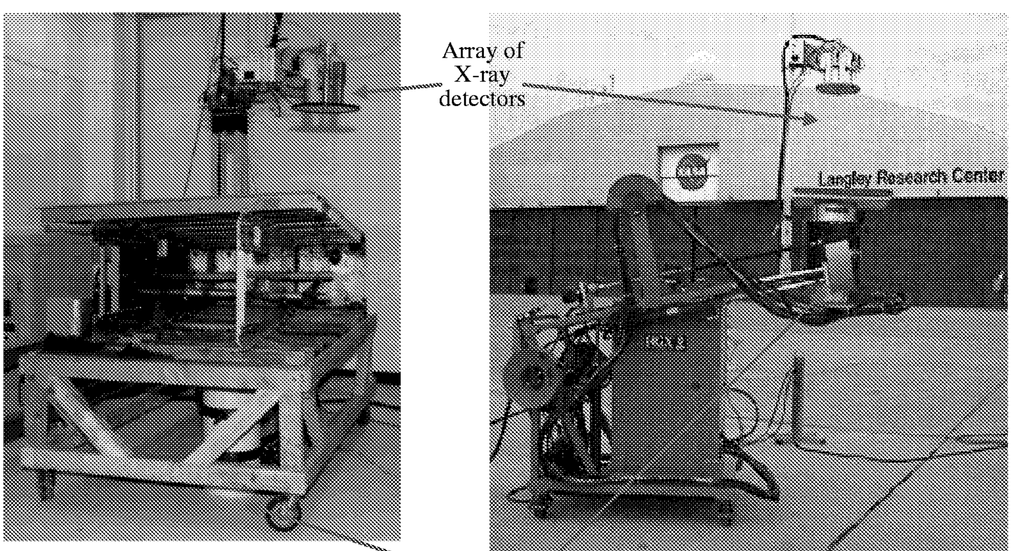
Radiative Forcing from Linear Contrails

The effort to monitor the effects of aircraft on the environment is becoming more critical as air traffic increases. The Subsonic Assessment (SASS) Program, part of the NASA Atmospheric Effects of Aircraft Program (AEAP), is examining the impact of increased air travel on the troposphere and lower stratosphere. One of the most visible and, perhaps, most important effect of high-altitude air traffic is the production of condensation trails or contrails. In many instances, these artificial clouds are linear streaks in the sky that may rapidly dissipate or, in the proper conditions, persist and grow. If they persist, contrails will act like natural cirrus clouds by reflecting solar radiation causing cooling or trapping infrared radiation from the surface causing a greenhouse-type warming. The net effect, warming or cooling, depends on many factors such as lifetime, thickness, and the size of the cloud's particles.



Laboratory Prototype of Reverse Geometry X-ray® System Imaging 707 Wing Section

Scanned X-ray Source

Portable System

Figure 13. Corrosion Detection System for Thick Aircraft Structure.

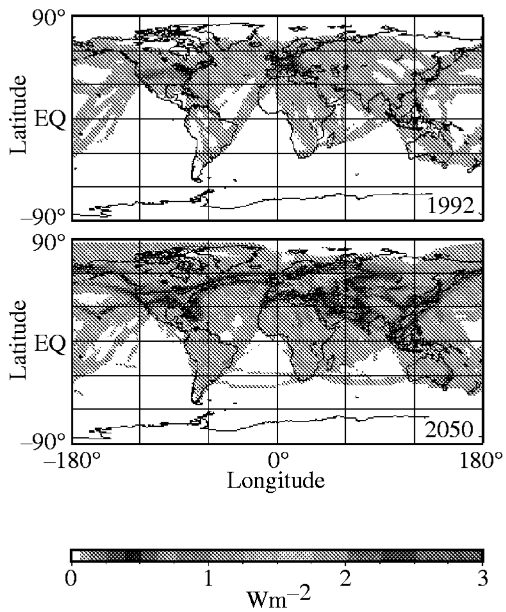


Figure 14. Estimate of net contrail radiative forcing based on recent and projected air traffic. (Color version is on report website.)

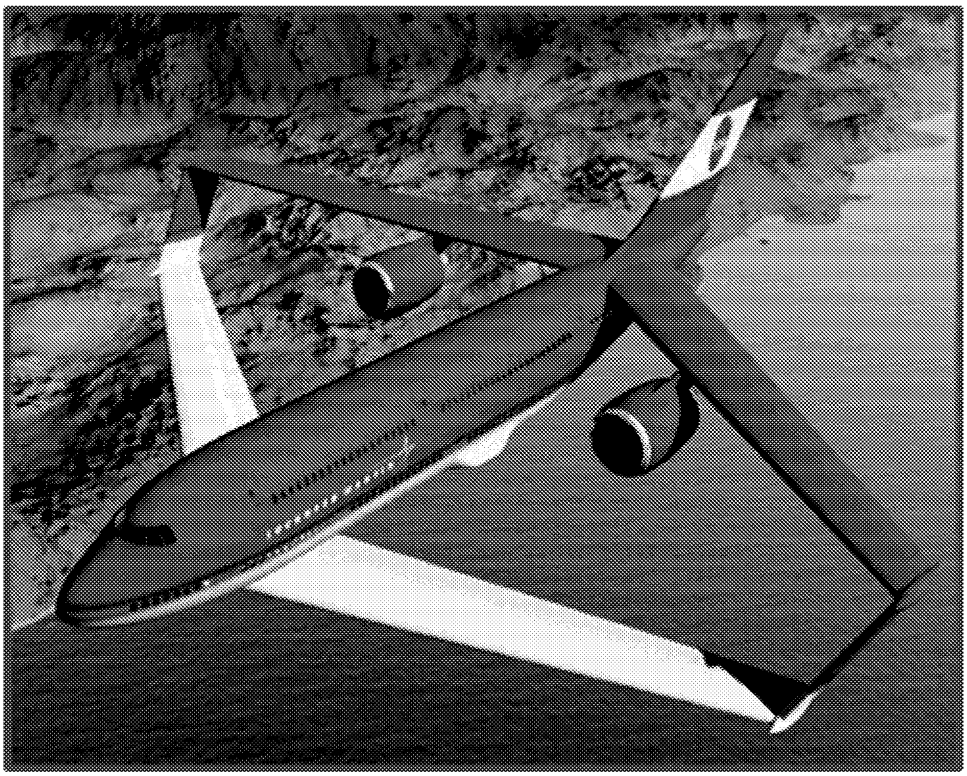
The change in the radiation budget due to these artificial clouds is termed radiative forcing, a quantity that is used to determine the climatic impact of various constituents in the atmosphere of both natural and human origins. To determine the role of contrails in climate change as part of SASS and the Intergovernmental Panel on Climate Change Special Report on Aviation and the Global Atmosphere, Langley researchers have teamed with scientists from Germany and other US agencies to assess current and predict future levels of contrail radiative forcing.

Linear contrails are those that have grown enough to be recognizable in satellite imagery, but have not yet transformed into natural-looking cirrus clouds. Previous SASS studies using satellite and surface-based datasets provide estimates of contrail optical properties, while numerical weather analyses and satellite-based analyses yield estimates of linear contrail coverage. Langley scientists combined these datasets with estimates of recent and future air traffic to determine the global distribution of contrail radiative forcing. In 1992, the mean contrail radiative forcing was estimated to be only 0.02 Wm^{-2}, a small net warming. The greatest effects, up to 0.6 Wm^{-2}, are evident over the USA and central Europe where the heaviest air traffic occurs (see figure 14). A midrange air-travel growth scenario yields a five-fold rise in contrail radiative forcing by 2050 with substantial increases in the areas affected. The maximum forcing remains in central Europe and the USA, but dramatic increases are expected in Russia and western Asia.

The estimated contrail radiative forcing constitutes only 1 and 3% of the total radiative forcing tallied for all human activities for 1992 and 2050, respectively. However, the effects can be much larger in particular regions like the USA. Furthermore, these estimates represent a minimum impact because many contrails grow much larger than can be determined from analysis of linear features in satellite imagery. Many uncertainties in the radiative properties and lifetimes of contrails remain for future research. The values used in this study were highly conservative. Langley investigators are continuing to refine these estimates, verify the assumptions used in the computations, and provide a reasonable estimate of the maximum possible impact of contrails on the climate.

(Patrick Minnis, p.minnis@larc.nasa.gov, 757-864-5671)

Pillar Two: Revolutionary Technology Leaps



NASA's Revolutionary Technology Leaps Goal is to revolutionize air travel and the way in which air and space vehicles are designed, built, and operated.

NASA envisions the expansion of our air transportation system along the dimension of much faster doorstep-to-destination speeds--whether those doorsteps and destinations are half a world away, or in a neighboring community--whether you are starting from or traveling to a small rural community or a major city. High-speed, supersonic transports will eventually cut in half the time required for long-distance, transoceanic travel. New, safe and efficient small aircraft and smart small airports will create a new air transportation network that will connect small suburban and rural communities with each other and with major cities and airports. These innovations and the resulting major expansion in personal mobility will be a hallmark of the new millennium.

Particle Image Velocimeter Measurements of Acoustic Particle Displacements in a Normal Incidence Impedance Tube

There exists a continual need for the reduction of generated noise by commercial aircraft turbofan engines. In practice, this reduction is made complicated by the large number of potential noise sources present in modern engines (e.g., noise generated by inflow disturbances, fan and turbine exhaust, etc.). A common method for turbofan engine noise reduction involves the use of passive liners along the interior walls of the engine nacelle. The search for appropriate liner materials which can efficiently reduce noise involves several areas of research including the development of new types of instrumentation which can measure the effects of flow and sound levels on the performance of the liner material.

One of the parameters used to characterize the performance of nacelle liners is the acoustic impedance of the liner material. Knowledge of the acoustic impedance is important because it allows the calculation of acoustic intensity in a given direction, and provides boundary conditions for numerical noise suppression models. However, direct measurement of acoustic impedance is difficult, requiring simultaneous measurement of the pressure and fluid particle velocity fields. The pressure field is relatively easy to measure; however, measurement of the particle velocity field is much more difficult given the small amplitude motions of the fluid particles in response to the sound field. Thus, a study was performed to determine whether advanced optical diagnostic techniques could be employed to effectively measure fluid particle displacements (and hence velocities). The basis of the study consisted of utilizing a Particle Image Velocimeter (PIV) system. PIV is a widely accepted technique in the fluid mechanics community to acquire instantaneous, two-dimensional planar velocity data nonintrusively in a variety of flows, and is used for numerous applications at Langley. The technique is based on tracking tracer particles introduced into the flow to ascertain velocity at many simultaneous locations. For this study, the PIV system was used to obtain images of tracer particles inside a Normal Incidence Tube (NIT). A NIT is commonly utilized in the measurement of acoustic impedances, and consists of a closed square tube with a high powered speaker and liner test material mounted at opposite ends of the tube. To obtain the measurements reported here, a standard NIT was modified through the addition of optical windows to allow PIV measurements to be made in the vicinity of a solid aluminum liner (representing a perfectly reflecting liner material).

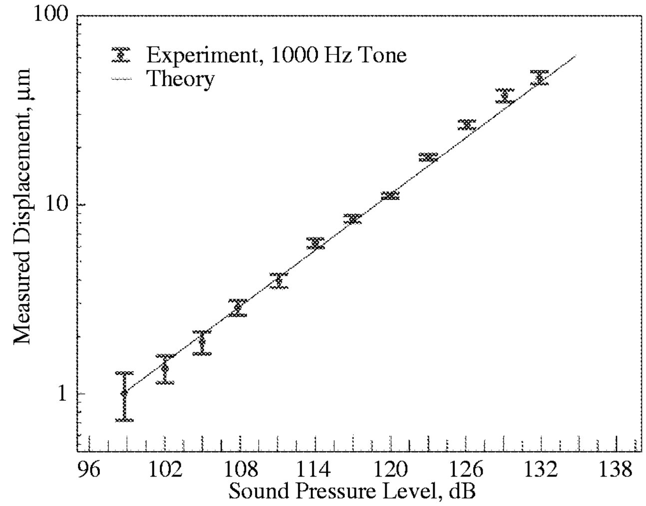


Figure 15. Variation in acoustic displacement as a function of sound pressure level.

The PIV optical system included two 600-millijoule Nd:YAG lasers for illumination and a high-resolution camera for image capture. The beams from the two lasers were combined together into a colinear beam and then fanned out into a thin light sheet which was directed through one of the windows in the NIT to illuminate a plane of interest. A 1320 x 1035-pixel, 8-bit digital camera coupled with a custom manufactured 500-millimeter, f/2.5 lens was used for image capture. Several regions of the particle field inside the NIT could be surveyed by translating the camera and/or the NIT parallel to the light sheet without requiring realignment of the laser system optics. To provide a proper tracer particle field inside the NIT, 2.7-micrometer hollow silicon dioxide spheres having an extremely low density were injected into the NIT. The requirement for a low density particle was important given the fact that there was no moving flow inside the NIT – only a sound field-induced oscillatory motion was present.

An example of the data collected from this study can be seen in the accompanying figure 15. A 500-Hz pure tone was injected into the NIT, and the sound pressure level (SPL) inside the tube was increased from 90 to 132 decibels (dB) in steps of 3 dB to determine the minimum threshold at which acoustic particle displacements could be resolved (one of the fundamental goals of this study). For each SPL, 20 double-exposed PIV images covering a field of view of 7.7 by 6.0 millimeters in the vicinity of the liner were collected and analyzed, yielding a total of 5700 displacement vectors which were then averaged. As expected, the acoustic particle displacement doubled for every 6 dB increase in SPL. The figure also indicates a minimum particle displacement detection limit of approximately one micrometer at an SPL of approximately 99 dB. This result indicates a remarkable ability to measure micrometer-range particle displacements through direct imaging in a zero-mean flow, and represent the first measurements of this kind obtained with PIV techniques. Further details of this work may be found in NASA Contractor Report 201664 and in AIAA Paper 98-2611, presented at the 20th AIAA Advanced Measurement and Ground Testing Technology Conference.

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Engine Noise Reduction by Blended Wing Body

The Blended Wing Body (BWB) aircraft (figure 16) represents an advanced unconventional subsonic transport concept which simultaneously addresses long range NASA goals for emissions, noise, capacity, safety, and cost of travel. The BWB design concept minimizes the required aircraft surface area per passenger by combining a rigid, wide airfoil-shape fuselage with high aspect ratio wings and with engines incorporated into the upper wing surface, aft of the passenger compartment. This works well for balance and improves safety since the engine turbines and compressors are completely clear of the main structural elements, pressurized compartments, and fuel storage. The fan intakes on the three high-bypass ratio engines which power the BWB are shielded from the ground by the centerbody. This is expected to reduce flyover noise by virtually eliminating fan inlet noise radiation to the ground. An experimental program was undertaken to validate the noise reduction benefits of the BWB design.

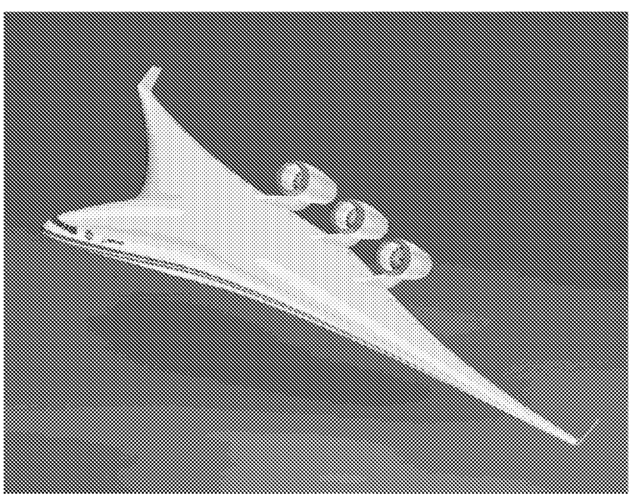


Figure 16. The Blended Wing Body Aircraft.

A 4% scale model of the BWB was installed in the Anechoic Noise Research Facility at NASA Langley Research Center. The Anechoic Noise Research Facility provides a sound reflection free environment in which the characteristics of noise sources can be studied in detail. The engine nacelles on the BWB model were hollow, but the internal engine noise source was simulated by a broadband point noise source. No attempt was made to simulate a specific high bypass ratio fan source, but rather, the broadband noise spectrum was analyzed over a range of frequencies corresponding to the expected blade passage frequency of the fan and of multiples of the blade passage frequency. The tone and broadband noises in this range of frequencies contribute significantly to the annoyance during aircraft flyover. The sound field was mapped out around the BWB model with the point noise source installed in one of the engine nacelles. The individual contributions of each nacelle were combined to give a calculated sound field for all three “engines” operating simultaneously. A similar mapping was made using a model of the engine nacelle only, with the BWB model removed. These data were combined to calculate the sound field for all three “engines” operating simultaneously without the wing in place. The difference between these two mappings is the calculated insertion loss, or noise reduction benefit, of the BWB.

Figure 17 shows the calculated reduction of overall noise by the BWB for an observer on the ground during an aircraft flyover. OASPL refers to overall sound pressure level, a cumulative, unweighted sound level in decibels calculated by integrating the acoustic energy (proportional to pressure squared) over the entire BWB frequency band. A representation of the BWB is superimposed on the noise reduction footprint to show noise shielding benefit in relation to the fuselage shape. It is seen that the noise reduction is greatest in the forward sector on the axis of the center engine nacelle. The noise reduction decreases in the forward sector off the axis because of the wing taper to the sides. The noise reduction decreases dramatically toward the aft sector because each engine exhaust extends beyond the trailing edge of the wing.

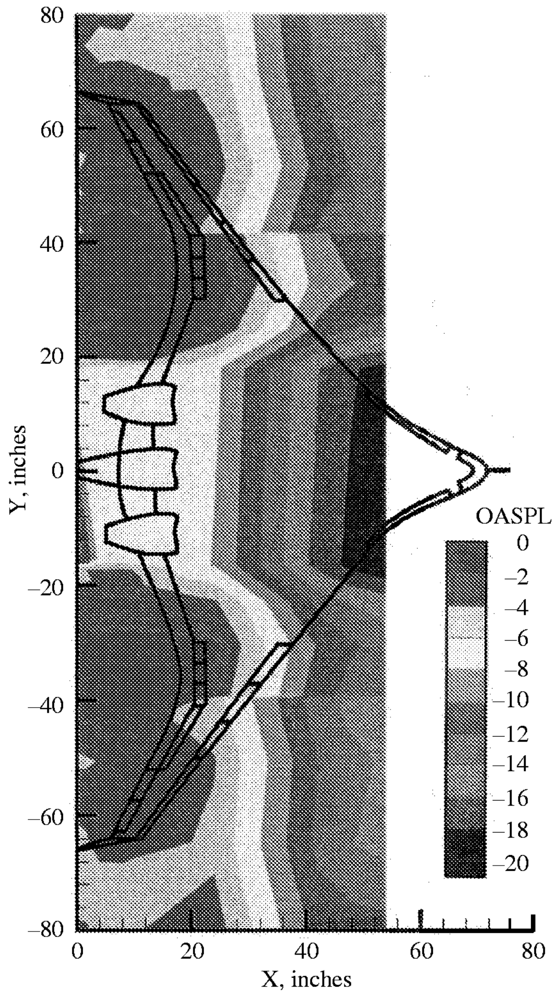


Figure 17. Calculated overall engine-radiated noise reduction by the Blended Wing Body in flyover. (Color version is on report website.)

The results of this study show that the BWB planform provides significant shielding of the center engine inlet-radiated noise (see figure 17). The wing taper reduces the shielding of side engine inlet-radiated noise. Since the engines extend beyond the trailing edge of the wing, no shielding benefit of engine exhaust-radiated noise is seen. While the BWB does not eliminate inlet-radiated noise, it represents a significant improvement over current designs which offer minimal engine radiated noise shielding. Concepts such as the Blended Wing Body design will allow America's aircraft manufacturers to satisfy the growth of air travel traffic while preserving the quality of the environment.

(Dr. Carl H. Gerhold, c.h.gerhold@larc.nasa.gov, 757-864-5279)

3D High-Lift Computational Analysis Methods Developed and Validated

In FY 1999, the Airframe Methods Element of the former Advanced Subsonic Technology (AST) Program successfully met a major milestone with the validation of the high-lift computational analysis methods. The goal of the Airframe Methods (AFM) Element was to reduce design cycle time by delivering integrated design methodologies and new aerodynamic concepts. These concepts and tools will enable revolutionary aircraft designs and faster design cycles while reducing aircraft operating costs, environmental impacts, and aircraft development risks. This element of the AST Program directly contributed to two of NASA's goals: to reduce the cost of air travel by 25 percent within 20 years, and by 50 percent within 20 years; and to provide next-generation design tools and experimental aircraft to increase design confidence, and cut the design cycle time for aircraft in half.

The design of a competitive commercial aircraft is influenced by many factors. Airline companies are interested in technologies that enable the mission to be successfully completed at the lowest cost. The design of advanced subsonic transports involves properly designing for all phases of the flight of the aircraft, including the ability to safely and efficiently take-off and land. For take-off and landing the cruise wing geometry is modified by the deployment of the high-lift system which often consists of flaps, slats, and/or spoilers. These devices enable the aircraft to obtain the lift required during take-off or landing. The objective of the high-lift computational analysis tools milestone was to validate that the analysis tools, which had been developed within the AFM program, would enable a reasonable prediction of the aircraft lift in a timely manner.

When the AFM High Lift (HL) program began there was no computational capability in use for the analysis of high-lift systems. The first step required an initial intensive effort into developing a computational model of one high-lift geometry and obtaining preliminary analysis results. This first effort was baselined to require about 300 days from start to finish. During an aircraft design process, numerous geometries and configurations are studied and generally there are only a few weeks available to design the aircraft's high lift system.

To make CFD (computational fluid dynamics) a viable candidate for HL configuration analysis during a design, it was apparent that a dramatic reduction was required in the time required to perform an analysis. During the 5 years of the program, the HL team

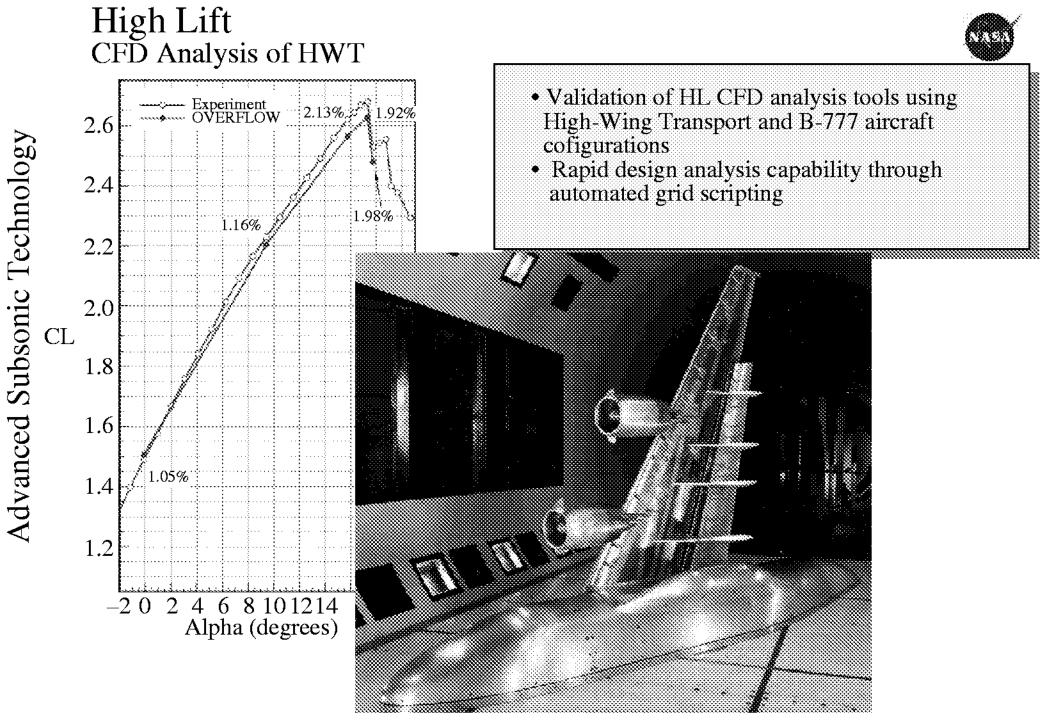


Figure 18. CFD Analysis Results of a High Wing Transport Configuration. (Color version is on report website.)

improved the codes and automated a significant portion of the workload, meeting many milestones. The final milestone was a validation that the Navier-Stokes codes and the processes developed over the previous 5 years could provide a timely and accurate analysis of an advanced HL configuration.

To demonstrate the ability of the analysis codes to produce a result in a timely manner, the team analyzed a flap geometry change of a high-wing transport configuration within a 5-day time frame. The team performed the necessary geometry and grid modifications to the configuration and obtained a final Navier-Stokes CFD solution all within the 5 day goal. Not only was this analysis performed quickly, but the results from the analysis were within the industry required level of accuracy of 2% (see figure 18). In order to further validate the methods, the team also performed analyses of over 30 conditions and configurations and compared the results to experimental and flight data. Finally, the team also analyzed a new flap design for a low-wing configuration starting with a computer aided design geometry file. The team successfully demonstrated that an average of only 3-4 days was required to analyze a change for this new flap geometry.

The successful completion of this milestone provides a means for aircraft designers to rapidly analyze HL configurations using CFD and provides the opportunity for the HL designers to automate the HL design process and to integrate the design into the overall aircraft design process. The ability to automate the HL analysis process provides a more streamlined and efficient approach and results in a decreased time to design a wing, all of which serve to reduce the cost of the aircraft design process and ultimately the cost of the aircraft.

(Elizabeth B. Plentovich, e.b.plentovich@larc.nasa.gov, 757-864-1919)

Cruise Multicomponent Wing/PAI Design Tools Calibrated

In 1999, the Airframe Methods Element of the former Advanced Subsonic Technology (AST) Program successfully met a major milestone with the calibration of the cruise multicomponent wing/propulsion-airframe-integration (PAI) design tools. The design of a competitive commercial aircraft is influenced by many factors. Airline companies are interested in technologies that enable the mission to be successfully completed at the lowest cost. In incorporating new technologies, aircraft performance and control characteristics must be able to be predicted for the complete configuration. The inclusion of wings, pylons, and nacelles in the cruise performance prediction is known as multicomponent design.

The objective of the cruise multicomponent wing/PAI design tools milestone was to demonstrate that the analysis and design tools, which had been developed within the AFM program, would successfully predict lift and drag coefficients for transonic flight conditions where no significant regions of separated flow existed.

The first step required a 2-engine and a 4-engine aircraft configuration be designed using the AFM-developed multicomponent tools. Wind tunnel models were then built and tested to demonstrate that the computer design methods could correctly predict desired characteristics for multiple components. The designs included realistic constraints that aircraft developers face, such as structural, manufacturing, and performance considerations.

The advanced 2-engine and 4-engine multipoint wing designs were tested in NASA Langley's National Transonic Facility wind tunnel. The results from these tests agreed with the results predicted by the computer design methods, thereby validating the cruise multicomponent analysis/design methods. The design of the 4-engine configuration was to demonstrate that there would be no adverse impact on buffet onset at the cruise Mach number and that a drag reduction of 2% would be achieved. The wind tunnel test validated that the design demonstrated no adverse impact on buffet onset and that drag was reduced by over 3%. For the 2-engine configuration, the design was to demonstrate an increase in $C_{L\ buffet}$ of 0.08 with no adverse impact on airplane drag. The wind tunnel test validated that the design did not impact airplane drag and increased $C_{L\ buffet}$ by 0.085 (figure 19).

The successful completion of this milestone provides a means for aircraft designers to optimize the wing design in the presence of other critical components and enables the overall performance of the aircraft to be improved. The ability to automate the wing design process provides a more streamlined and efficient approach and results in a decreased time to design a wing, all of which serve to reduce the cost of the aircraft design process and ultimately the cost of the aircraft.

(Elizabeth B. Plentovich, e.b.plentovich@larc.nasa.gov, 757-864-1919)

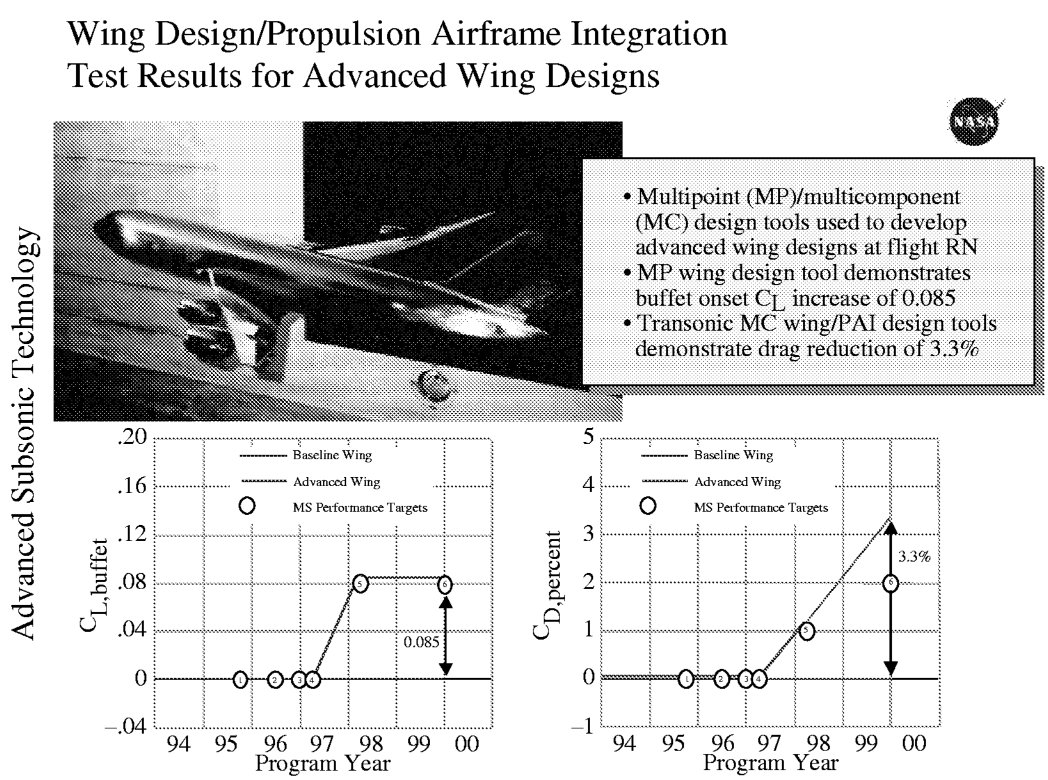


Figure 19. Test Results for Advanced Wing Designs. RN refers to Reynolds Number. (Color version is on report website.)

Advanced Concepts

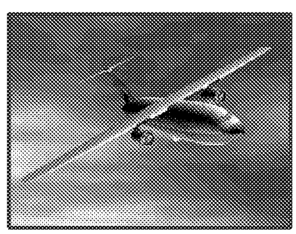
The Advanced Concepts research is directed at identifying new aircraft concepts, missions, and technologies, as well as the synergistic integration issues that arise from these changes. New configurations analyze the vehicles and decide whether further research investment is warranted by comparing them to conventional concept benchmarks. NASA uses systems analysis as a discipline to decide whether a concept or technology has benefits such as increased safety, higher performance or lower emissions. Advanced Concepts Systems Analysis is specifically focused at finding new types of aircraft that can significantly contribute to one or more of the Aerospace Technology Goals under Pillars One and Two (Global Civil Aviation and Revolutionary Technology Leaps).

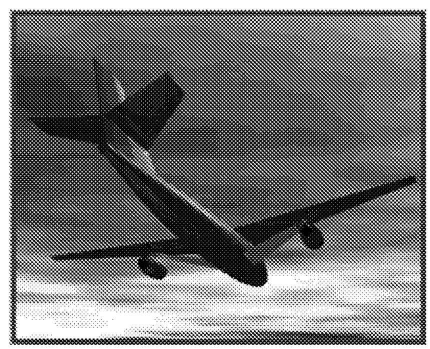
For 1999, five advanced vehicles were identified and analyzed by NASA and various collaborators: Strut-Braced Wing Transport (NASA Langley, Virginia Polytechnic Institute, and Lockheed Martin Aeronautical Systems), Box-Wing Transport (NASA Langley and Lockheed Martin Aeronautical Systems), Low-Emissions Transport (NASA Langley and Boeing Commercial Airplane Group), Low-Boom Supersonic Business Jet (NASA Langley and Lockheed Martin SkunkWorks), and the Intermodal Transports (NASA Langley and Boeing Phantom Works). Each of the concepts was analyzed to discover their potential benefits in terms of the NASA Aerospace Technology Goals (see figure 20).

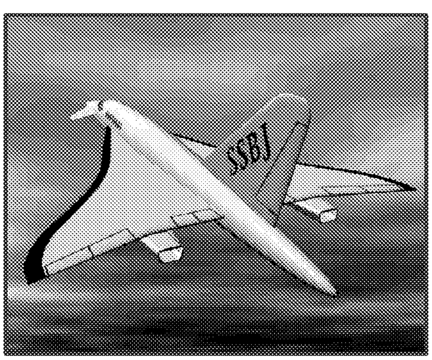
The Strut-Braced Wing Transport investigates high subsonic speed concepts that use a strut to attach the wing to the fuselage, allowing a lighter overall wing design and a drag benefit through decreased wing thickness. This investigation requires solutions to strut interference drag and compression buckling problems through the application of advanced structural and aerodynamic computer tools. This analysis capability provides the opportunity to breathe new life into an old idea and produces an aircraft that has 6-12% fuel-economy improvement over a conventional transport.

The Box-Wing Transport investigates improved capacity concepts, so that larger aircraft could operate within the tightening airport infrastructure requirements. Utilizing a biplane wing layout with the tips attached to each other provides improvements in the induced drag that permits smaller spans to be considered for aircraft with larger passenger numbers. Other


Intermodal Transport


Low-Emissions Transport


Strut-Braced Wing Transport



Supersonic Business Jet

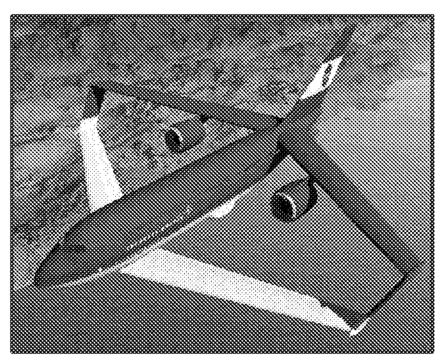

Box-Wing Transport

Figure 20. Advanced Concepts.

anticipated benefits (weight, fuel consumption and cost reductions) have so far not been realized due to wing weight penalties associated with thinner wing structure allowances.

The Low-Emissions Transport investigates how much the CO_2 emissions of a short-range aircraft (such as the 737) could be reduced using the state-of-the-art airframe and propulsion technologies. CO_2 reductions of almost 30% appear with high wing conventional configurations. Future studies may follow to investigate synergistic opportunities with unconventional planform shapes for emission reductions.

The Low-Boom Supersonic Business Jet is aimed at discovering whether an aircraft with no noticeable sonic boom can be designed. If it can, then supersonic flight over populated areas may be permissible. Overland supersonic flight would make supersonic transports much more economically attractive to airline operators and eliminate the dual cruise-speed penalties of previous designs.

The Intermodal Transport study investigates aircraft that can be utilized more per day because the payload section (passenger cabin or cargo shroud) can be quickly interchanged on the ground. These configurations have a large potential benefit to airline operators in terms of profit margin due to increased utilization, or time in the air versus on the ground, even with the slight penalties associated with increased fuselage weight. This cabin interchangeability allows passengers to fly during the day, cargo to fly at night, and the Armed Forces to use special payload modules in times of national emergency.

Two of these concepts were selected for further investment. The Strut-Braced Wing Transport design will be investigated in more depth to decide whether the potential fuel economy and weight benefits are achievable with more detailed design models. Research will include Computational Fluid Dynamics (CFD) modeling of the aerodynamics and Finite Element Modeling (FEM) of the structure. The Low-Boom Supersonic Business Jet design studies will continue. A low-boom model test and a performance wind-tunnel test will be performed in 2000.

(Mark D. Moore, m.d.moore@larc.nasa.gov, 757-864-2262)

Advanced Manufacturing Methods Reduce Cost of Airframe Structure

The airframe industry has identified reductions in the production and ownership cost of airplanes to be critical factors in reducing the cost of air travel. Aircraft have traditionally been manufactured using built-up riveted metallic structure employing many pieces. Reducing the number of parts and the number of assembly steps required in the manufacturing process is one key means of reducing cost. Researchers at

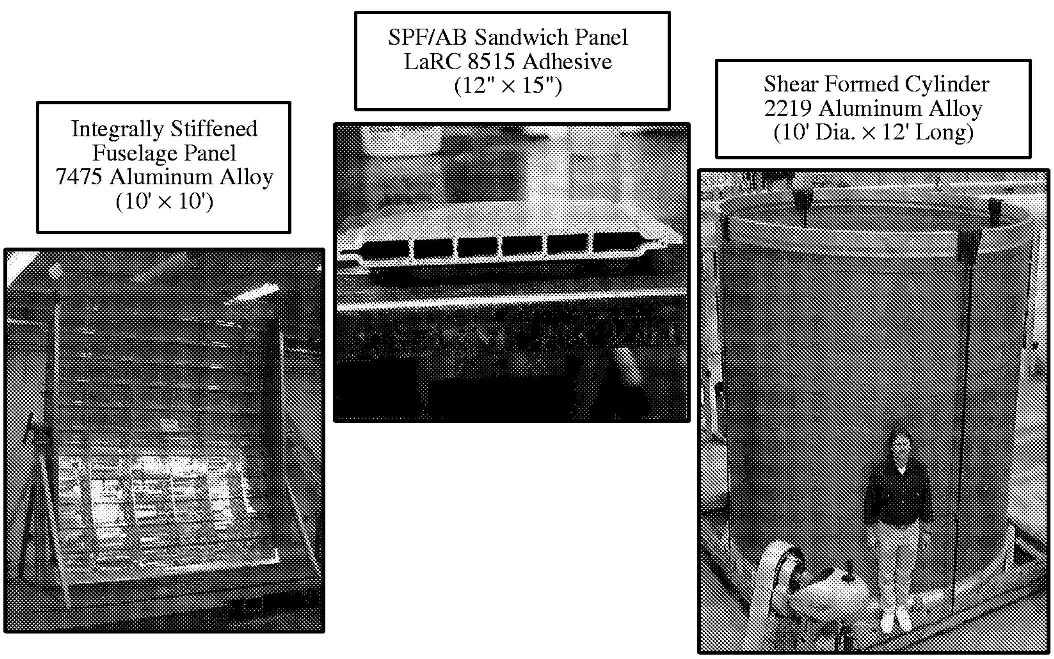


Figure 21. Advanced Manufacturing Methods.

NASA Langely Research Center, in conjunction with industry (Boeing, Lockheed-Martin, Northrop-Grumman and Alcoa) personnel, have been studying the feasibility of manufacturing parts of the fuselage structure with the stiffeners as a single piece, called integrally stiffened structures.

Figure 21 shows three of the structures which were manufactured under the Integral Airframe Structures project. The curved fuselage panel shown on the left was fully machined from 7475 aluminum plate to produce integral stiffeners and frame attachment pads and tested under simulated aircraft pressure and service loads. The fuselage panel demonstrated structural performance equivalent to riveted construction and was produced at a cost savings of 61% and over 90% part count reduction compared to riveted built-up structure. The sandwich panel shown in the middle is the first produced by a concurrent four-sheet superplastic forming/adhesive bonding (SPF/AB) process employing 8090 aluminum-lithium and LaRC 8515 polyimide adhesive. The SPF/AB sandwich panel demonstrated the potential for up to 30% weight savings compared with aluminum honeycomb core structure. The 2219 aluminum cylinder shown on the right represents the largest single piece aluminum cylinder produced using the shear forming process. The use of large shear formed cylinders with welded or bonded stiffeners has the potential to significantly reduce part count. These technologies will enhance performance and reduce the cost of airframe structures.

(Joan G. Funk, j.g.funk@larc.nasa.gov, 757-864-3092)

Aeroelastic Analysis of Active Aeroelastic Wing (AAW) Flight Vehicle

Active Aeroelastic Wing (AAW) technology integrates the disciplines of aerodynamics, controls, and structures into a flexible wing design to provide improved control power for maneuvering flight while reducing vehicle design weight through elimination of control surfaces. AAW technology provides these advantages by eliminating the need for control surfaces such as ailerons and using the whole wing to generate roll control.

Langley is developing a ground-to-flight scaling methodology for highly aeroelastic aircraft. This methodology will be based on computational fluid dynamics (CFD), wind tunnel data, and flight data. In partnership with AFRL, Langley will build and test a scaled aeroelastic wind tunnel model of F-18A AAW in the

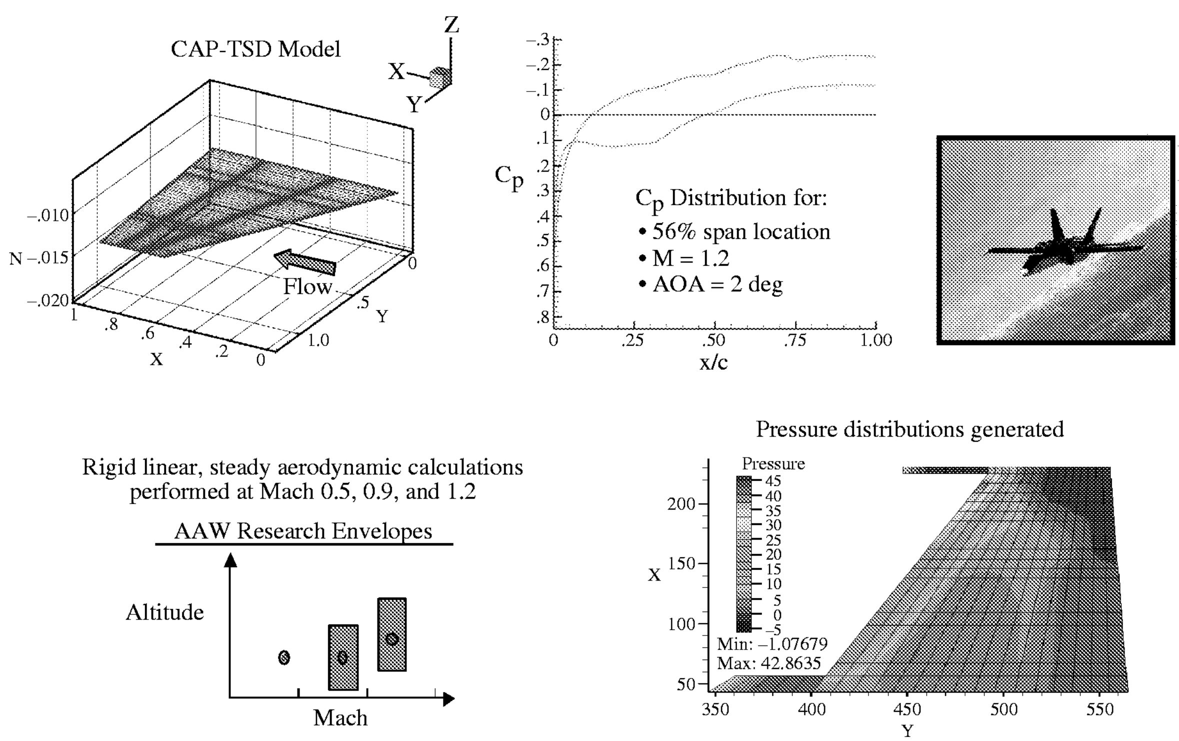


Figure 22. AAW Flight Vehicle Analysis. AOA is angle of attack, M is Mach Number. (Color version is on report website.)

Transonic Dynamics Tunnel starting in 2001. Through a cooperative program led by the Air Force Research Laboratory (AFRL), an F-18A research aircraft has been modified under AFRL contract to incorporate AAW technology. An 18-month AAW flight test program will be conducted at the Dryden Flight Research Center in 2000–01. At the request of AFRL, Langley aeroelasticians have performed aeroelastic analyses of the AAW flight vehicle in preparation for future flight and wind tunnel testing. Figure 22 shows some preliminary results of the pressure distributions from aeroelastic analysis of F-18A AAW flight vehicle. Analysis has been conducted using the Computational Aeroelasticity Program Transonic Small Disturbance (CAP-TSD) code, and these unsteady results will be compared against the baseline doublet-lattice method for the flight and wind-tunnel configurations. This modeling will be used for future wind-tunnel-to-flight correlation and will increase the design confidence for future advanced aircraft using AAW technology.

(Jennifer Heeg, j.heeg@larc.nasa.gov, 757-864-2795)

High-Speed Research Program Summary

In 1990, NASA initiated the High-Speed Research Program, also known as “HSR.” Its mission—to address the technology challenges for developing a second generation supersonic commercial airliner, a High-Speed Civil Transport (HSCT) (figure 23). The objective—to establish the technology foundation to support the U.S. transport industry’s decision for production of an environmentally acceptable, economically viable, 300-passenger, 5000 n-mi., Mach 2.4 aircraft. Studies concluded that such an airplane, launched in the early 21st century, should be compatible with current airports, use jet fuel, and be possible within 10-15 years. The highly successful HSR Program, although cancelled in 1999 because of economic constraints, was a partnership between NASA, Boeing, Honeywell, General Electric Aircraft Engines, Pratt & Whitney, and over 100 other companies and universities across the United States.

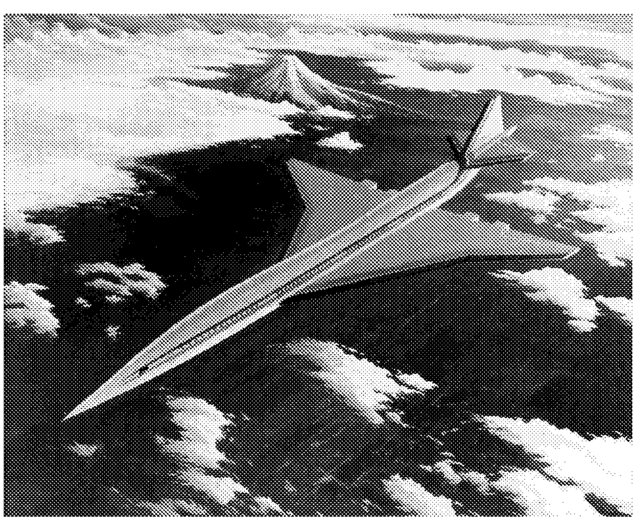


Figure 23. Artist's drawing of the High-Speed Civil Transport.

Researchers explored the environmental impact of such a plane relative to atmospheric effects, community noise, sonic boom impact, and atmospheric ionizing radiation. The Atmospheric Effects of Stratospheric Aircraft (AESA) team addressed the ozone issue. An international team of scientists developed global atmospheric models to predict the impact of exhaust emissions on ozone chemistry and climate change. A converted U-2 spy plane, the ER-2, and balloons provided global coverage to identify photochemical, radiative, and dynamic features of the stratosphere. Another concern was high levels of NOx emissions from current engine combustors. Two concepts were investigated in flame tube laboratory and sector tests at Glenn Research Center. Results showed reduced emissions were possible. For the combustor concepts, special liner material was developed from ceramic matrix composites. These composites have been demonstrated at design temperature and near mechanical load conditions using accelerated test techniques.

In selecting an engine cycle and airframe configuration designs, community noise was the dominant constraint. The HSR Program has made contributions to reducing both takeoff and approach noise levels. Developments in engine technology, including innovative nozzles and nozzle materials, have shown that reduced noise levels are possible. Sonic boom research made great strides in predicting noise levels and annoyance associated with sonic boom by using improved computational fluid dynamic techniques, wind-tunnel tests, and flight and ground measurements. Airplane design features that would significantly lower the sonic boom level were identified and validated. In aerodynamics research, design methods were developed for high-lift systems (figure 24) at low speeds and drag reduction at transonic and supersonic speeds. Researchers developed and validated methods to predict aeroelastic effects of models under load in supersonic and subsonic wind-tunnel tests (figure 25). These aeroelastic prediction methods were used to predict and model the stability, control, and handling qualities of the highly flexible HSCT designs. The external vision system (XVS) team, with guidance from the Federal Aviation Administration, developed technology to replace the forward cockpit windows in a

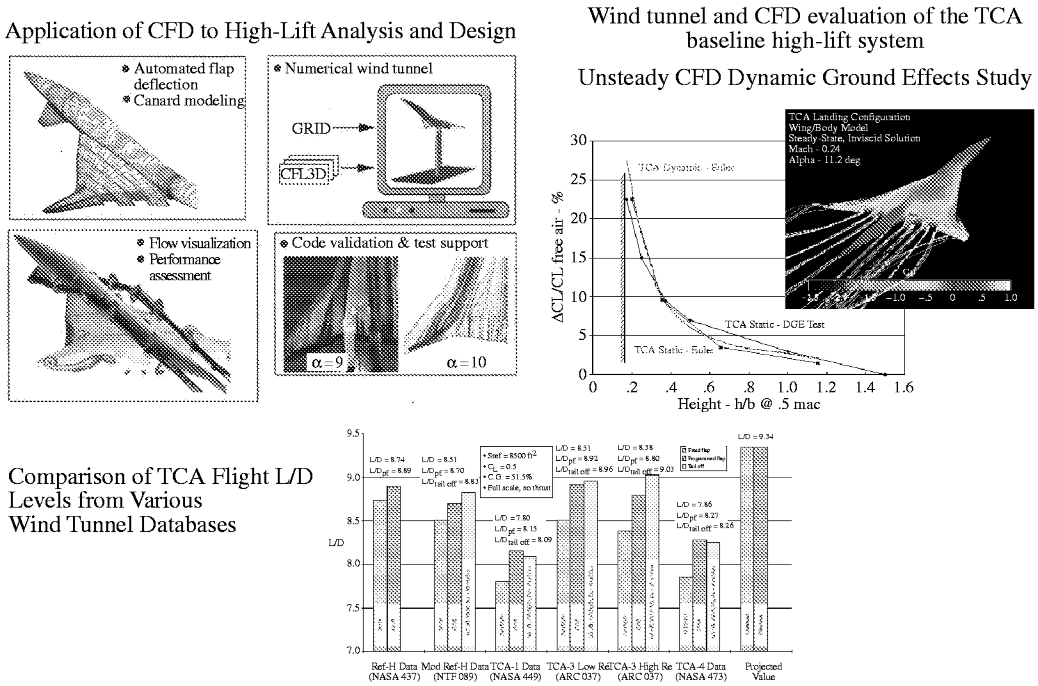


Figure 24. Computation Fluid Dynamics and wind-tunnel evaluations of the configuration high-lift system. (Color version is on report website.)

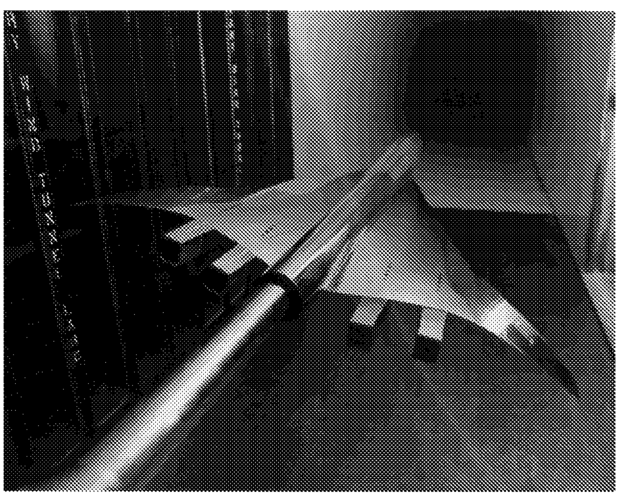


Figure 25. CFD and wind-tunnel results were used to understand the overall performance of the HSCT.

future supersonic passenger jet with large displays. These displays would use images enhanced by computer-generated graphics to take the place of the view out of the front windows. This XVS could provide safety and performance capabilities that exceed those of unaided human vision, while eliminating the need for a heavy, mechanically drooped nose, such as that on the Concorde (figure 26).

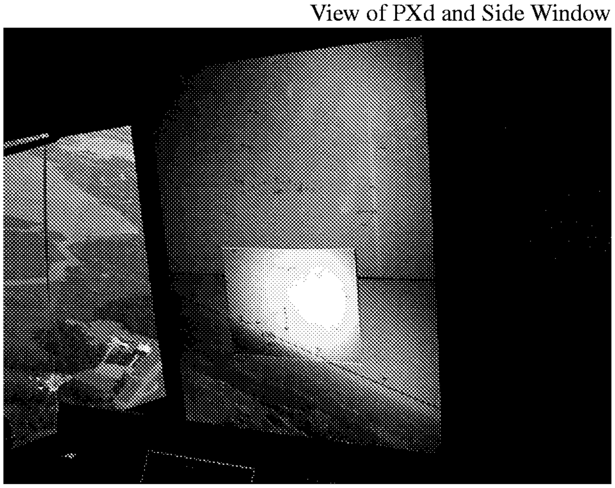
An HSCT airframe structure would require innovative structural concepts and advanced materials to tolerate speeds greater than 1,500 miles per hour, altitudes of 65,000 feet, and surface temperatures of more than 300°F. Over 140 different materials were analyzed (figures 27 and 28). Researchers developed new composite materials made from graphite fibers and polyimide resins to withstand the high temperatures and to make a future supersonic transport strong enough and light enough to be economically viable.

The NASA/industry team completed a series of ground and flight experiments on a modified Russian Tu-144 supersonic jet. It is the only commercial airplane in the world besides the Concorde flying at Mach 2—twice the speed of sound. These experiments, done in partnership with the Tupolev Design Bureau, provided the U.S. team with a unique, cost-effective way to gather full-scale data in an operational environment currently not available with any U.S. aircraft or facility. A research pilot from NASA Langley became one of the first two Americans to fly the Tu-144 and participate in the flight evaluations near Moscow.

The HSRP participants achieved technical and management excellence while making revolutionary technology leaps toward eliminating barriers for affordable supersonic travel. The designed configuration met or exceeded all of the original HSR Program goals, most notably, the takeoff noise goal which was met despite a significant increase in stringency over the duration of the Program. Significant technology has been transferred to further support NASA's strategic aeronautics and space plan in the areas of Reusable Launch Vehicles, subsonic transports and bombers, and high-performance military aircraft.

(Alan W. Wilhite, a.w.wilhite@larc.nasa.gov, 757-864-2982)

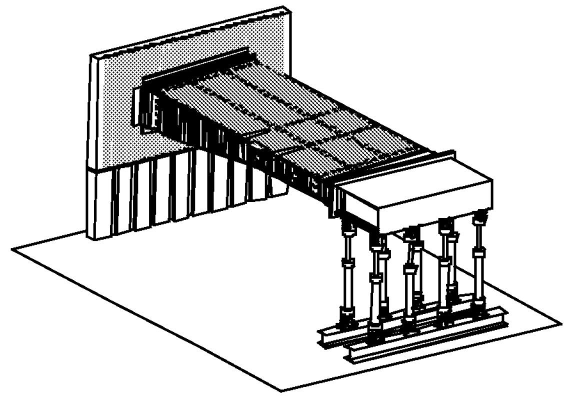
View of PXd and Side Window



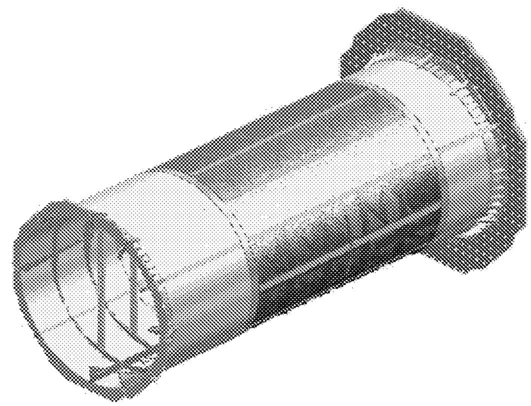
TIFS Aircraft in Flight

No-Droop Nose Concept Validation (TIFS FL5 Flight Test)

Figure 26. Total In-Flight Simulator (TIFS) research aircraft and a view of the Primary XVS Display (PXD) from inside the research cockpit.



Wing box component



Fuselage shell component

Figure 27. Materials and structural concepts were selected for the wing and fuselage components.

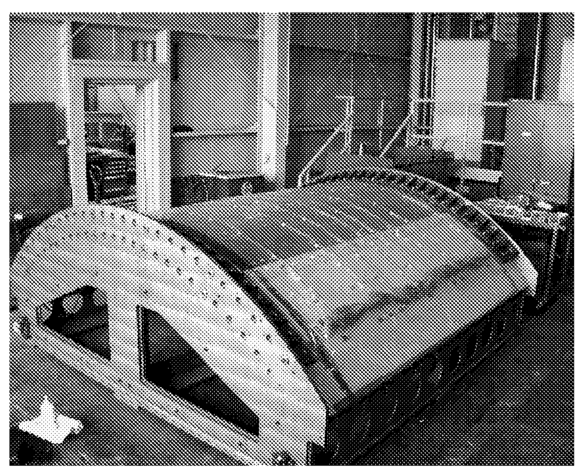
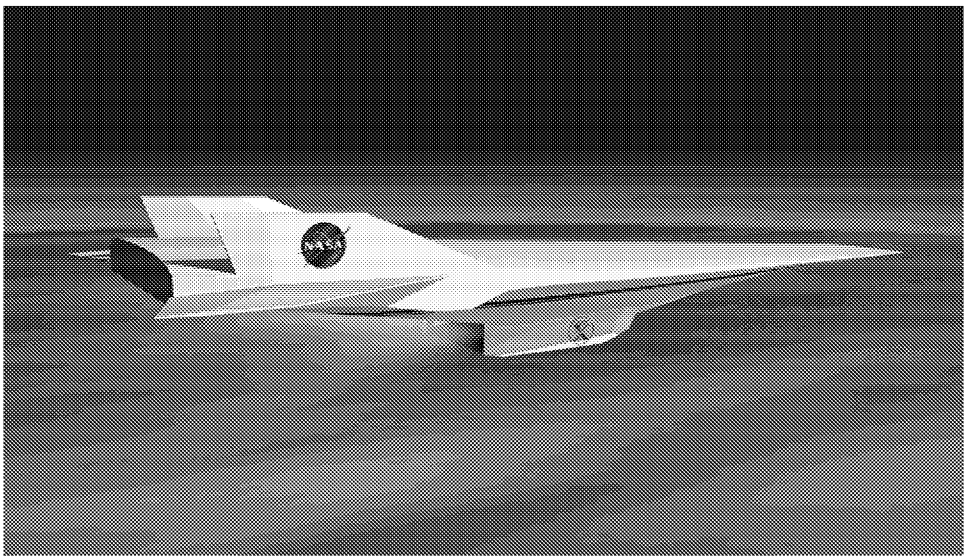


Figure 28. 6- by 10-Foot curved fuselage honeycomb sandwich panel was tested to 1 million pounds in the Langley COLTS facility.

Pillar Three: Advanced Space Transportation



NASA's Advanced Space Transportation Goal is to achieve the full potential of space for all human endeavor through safe, affordable and reliable space transportation.

Space is the next frontier for our evolving transportation system. As we move out from the planet, we open up new territory for exploration and development. We envision that technology will enable us to do two things. First, technology will extend our reach, enabling us to explore further into space. Second, as NASA stays at the leading edge of space exploration, technological advances will allow commercial ventures to establish space operations and develop the commercial potential of space--starting first with safe, reliable, low-cost access to space. This will require developing technologies that enable new launch and in-space transportation systems with orders of magnitude improvement in safety, cost and reliability.

Hyper-X Program

The Hyper-X Program is a joint Langley Research Center/Dryden Flight Research Center program to demonstrate an airframe integrated scramjet (supersonic combustion ramjet) engine in flight and to develop supporting technologies which will enable the future design and construction of both launch vehicles (Pillar 3) and aircraft which utilize scramjet propulsion (Pillar 2). An airframe integrated scramjet is a jet engine with no rotating machinery like current jet engines. Rather than using rotating compressor blades it utilizes the speed of the vehicle and the contour of the vehicle undersurface to compress the incoming flow. The engine is termed a scramjet because the flow through the engine stays above the speed of sound. The fuel is added and burned at supersonic speeds. For launch vehicle applications the benefit scramjets have over rockets is that they utilize the oxygen in the atmosphere to burn the fuel rather than having to carry the oxygen along with the vehicle. The elimination of the need to carry the oxidizer along translates into increased payload. In the first phase of the Hyper-X Program three 12 ft. long research vehicles (X-43A) are being constructed and will be flown at Mach 7 and 10 (figure 29). For each flight the vehicle (figure 30) will be mounted on the front of the first stage of a Pegasus launch vehicle, the Pegasus will be mounted under the wing of the Dryden B-52, and the B-52 will fly off the California coast where the Pegasus will be dropped and its engine started. The Pegasus will take the X-43 to either Mach 7 or 10 at approximately 100,000 ft. where the X-43 will separate from the Pegasus and light its engine. After its fuel is expended the X-43 will perform maneuvers to determine aerodynamic characteristics to compare with those found in the wind tunnel before splashing down in the Pacific. The first flight at Mach 7 is currently scheduled for 2000.

There have been a number of significant activities which occurred in the Hyper-X Program in 1999. There were wind tunnel tests of a high fidelity model in both the Langley 20-Inch Mach 6 and 31-Inch Mach 10 Tunnels to obtain detailed aerodynamic characteristics (figure 31). There were tests of both a partial width engine and an actual flight spare engine in the Langley 8-Foot High Temperature Tunnel at full flight conditions to evaluate fueling techniques and to determine engine performance for comparison with the flight data. There were several ground tests to verify the hardware which will be used to separate the research vehicle from the booster. This work culminated in a full-up test where the actual vehicle for the second flight was separated from the booster adapter which

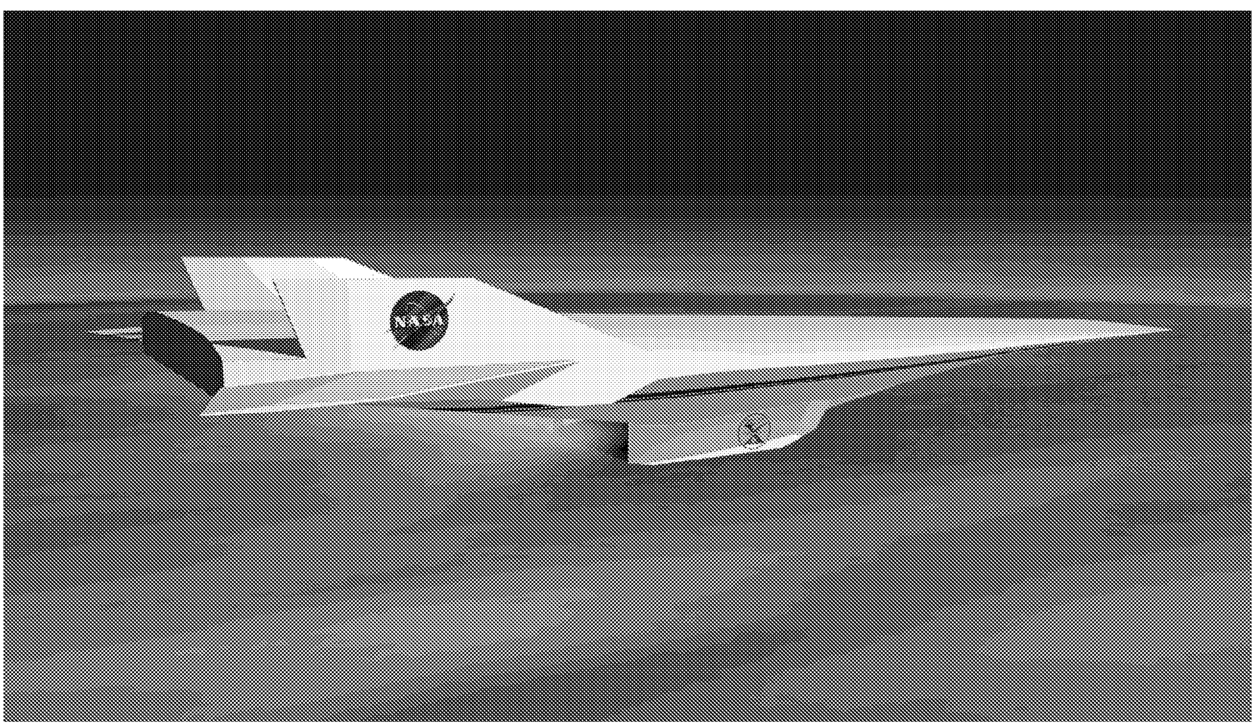


Figure 29. Artist's Concept of Hyper-X in Flight.

will be used in the first flight using the same type explosive bolts, ejection pistons, and initiator hardware as that which will be used in flight (Figure 30). The most important event of the year was the delivery of the vehicle for the first flight by the Micro Craft led contractor team to Dryden where it will undergo testing and check-out over the coming months before flight (Figure 32).

(David E. Reubush, d.e.reubush@larc.nasa.gov, 757-864-3749)

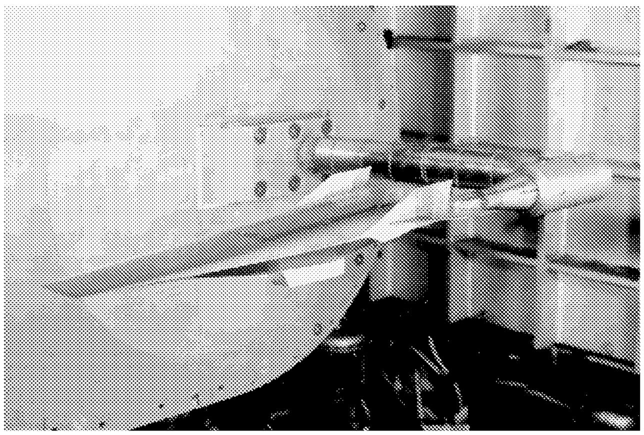


Figure 31. High Fidelity Hyper-X Model Tested in Langley 20-Inch Mach 6 and 31-Inch Mach 10 Tunnels.

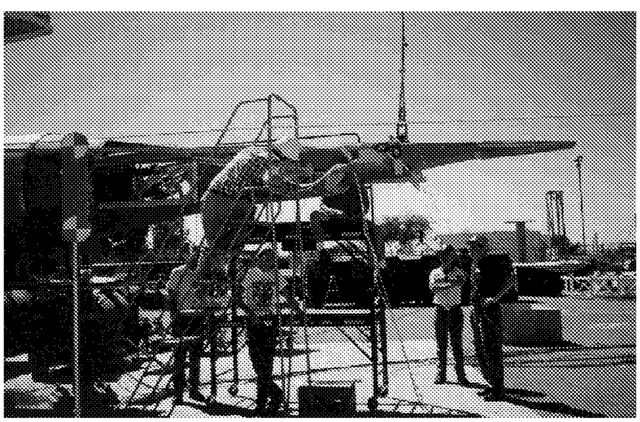


Figure 32. Hyper-X Flight Vehicle Undergoing Preparation Prior to Full-Up Separation Test.

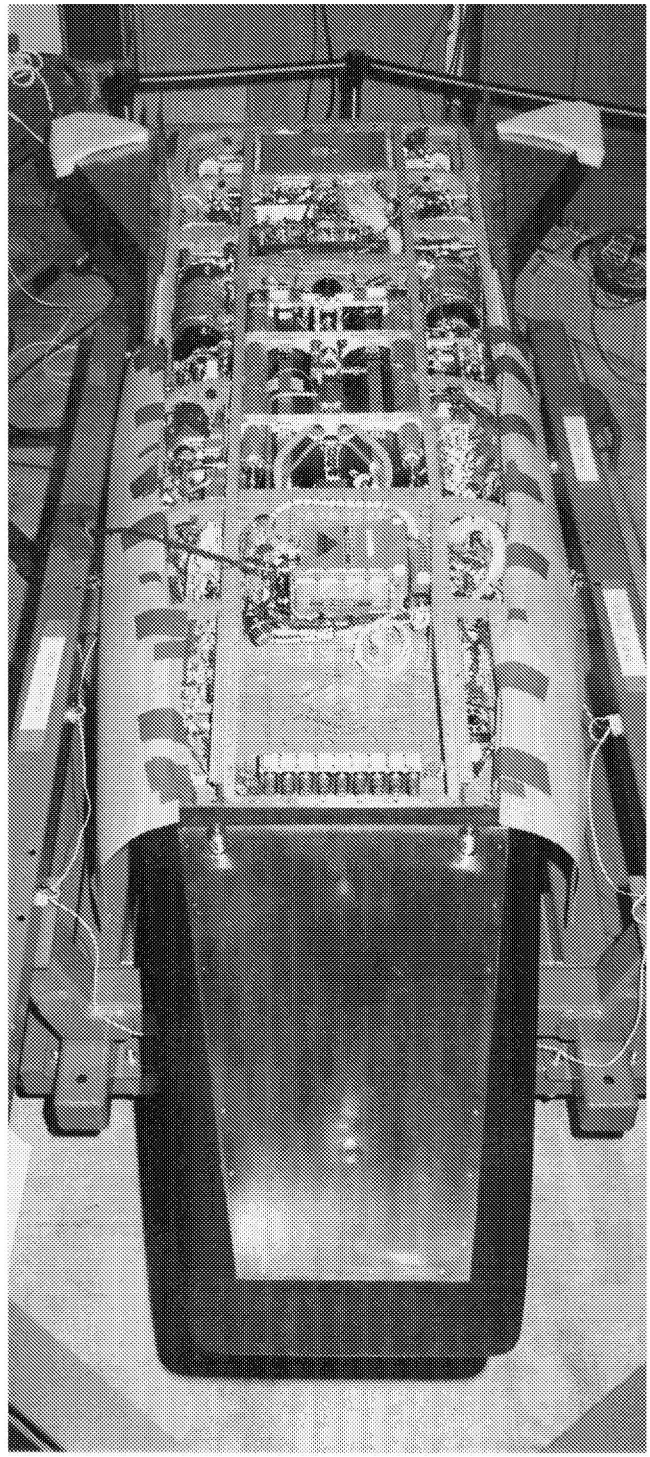
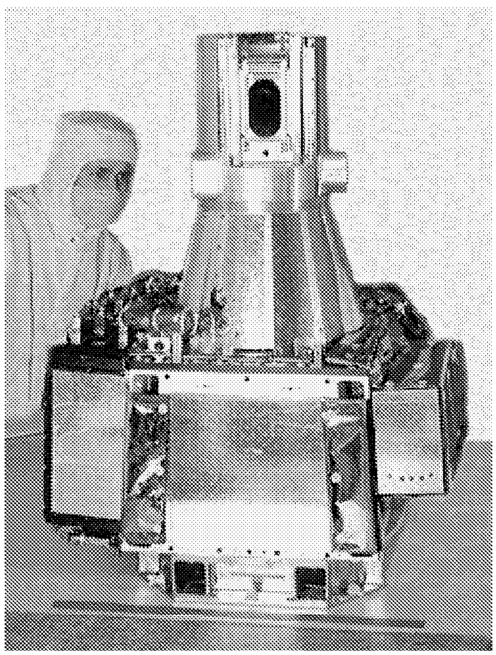


Figure 30. First Hyper-X Flight Vehicle With Upper Surface Panels Removed.

Earth Science Enterprise



NASA's Earth Science Enterprise is dedicated to understanding the total Earth system and the effects of humans on the global environment.

We understand some facets of our environment fairly well: short-term weather forecasts, basic hurricane tracking, and detecting changes on the Earth's surface. However, much critical information is missing: we cannot predict how the climate will shift a year from now, and what the effects will be on people whose livelihoods depend on that climate, from farmers to urban planners.

NASA's Earth Science Enterprise (ESE) captures our spirit of exploration and focuses it on the Earth. NASA and its inter-agency and international partners are striving to discover patterns in climate which will allow us to predict and respond to environmental events - such as floods and severe winters - well in advance of their occurrence. Nations, regions, and individuals can then use this knowledge to prepare for these events, likely saving countless lives and resources.

NASA uses the unique vantage point of space to provide the scientific basis for informed policymaking, and the research to support the operational missions of other US Governmental organizations. Results of ESE science research and applications provide an objective starting point for the development of sound global environmental policy.

NASA’s mission is to develop understanding of the total Earth system and the effects of natural and human-induced changes on the global environment. In support of the US Global Change Research Program, NASA has established the following Earth System Science research themes:

Atmospheric Chemistry

What are the causes and impacts of long-term climate variability and can we distinguish natural from human-induced drivers?

Hydrological and Energy Cycle

How can we provide global observations and scientific understanding to improve our knowledge of the global water cycle?

Land Cover/Land Use

What is the best approach to document and understand the trends and patterns of change in regional land-cover, biodiversity, and global land use?

Ozone

How can we best detect changes, causes, and consequences of changes in atmospheric ozone?

Natural Hazards and Solid Earth

How can we enhance unique ESE remote sensing science and technologies to contribute to disaster characterization and risk reduction from hurricanes, earthquakes, wildfires, volcanoes, floods and droughts?

Climate Variability and Change

What is the seasonal-interannual variability?

What are long-term changes?

Laboratory Spectroscopy of Methane

One of the main goals of NASA's Earth Science Enterprise is to expand scientific knowledge and understanding of atmospheric chemistry. Numerous space-based instruments and balloon-, aircraft-, and ground-based measurement campaigns have been conducted for this purpose. Detailed knowledge of the infrared spectra of methane and other atmospheric gases is necessary for accurate remote sensing measurements of atmospheric composition and structure. Researchers at NASA Langley and the College of William and Mary have collaborated in high-resolution laboratory spectroscopic studies of infrared absorption lines of methane and several of its more abundant isotopes (see figure 33). This group examined how methane absorption lines are broadened and their positions are shifted by increasing pressures of air, nitrogen, or methane itself. The laboratory data were analyzed to obtain parameters which can be used to model the atmospheric spectrum in regions where methane lines are strongly overlapping. This information must be taken into account when the methane bands are used for remote sensing, particularly in the Earth's lower atmosphere. This information was important to the success of the HALOE experiment on the Upper Atmosphere Research Satellite, and several experiments planned for the Earth Observing System. Articles reporting some results of this research have been accepted for publication in the Journal of Molecular Structure in late 1999 and in the Journal of Quantitative Spectroscopy and Radiative Transfer in mid-2000.
(Mary Ann H. Smith, m.a.h.smith@larc.nasa.gov, 757-864-2701)

CERES Instruments Demonstrate Unprecedented Radiometric Performance

The first Clouds and the Earth's Radiant Energy System (CERES) instrument was launched in November 1997 on the Tropical Rainfall Measuring Mission (TRMM) spacecraft from the National Space Development Agency of Japan's Tanegashima Space Center. CERES is part of NASA's Earth Science Enterprise, a long-term research program designed to study the Earth's land, oceans, air, ice, and life as a total system.

Successful monitoring of long term climate variability within this system requires instruments whose

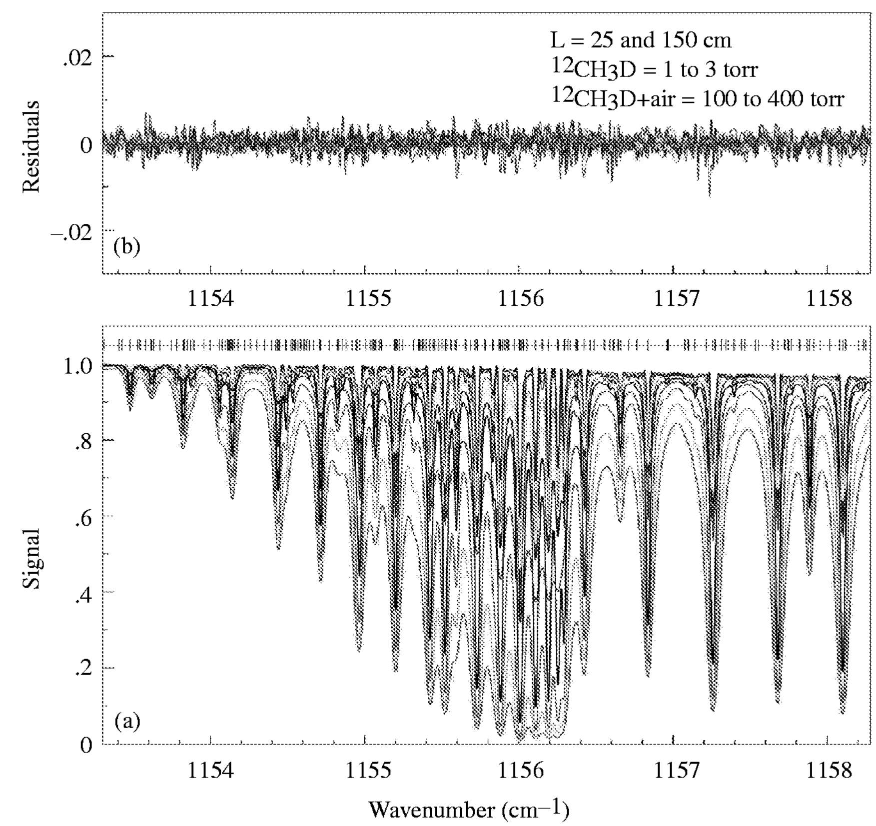


Figure 33. ^{R}Q (J", K"=0) branch in the ν_6 band of $^{12}CH_3D$ near 1156 cm^{-1}. (Color version is on report website.)

measurement traceability and stability is better than one percent for incoming solar energy flows and a half percent for Earth emitted terrestrial energy flows. These requirements define the pre-launch radiometric performance goals for the CERES instruments. Analyses completed by the CERES Instrument Working Group for the first twenty months of on-orbit data have shown that the instrument's measurement ability has remained constant to better than two tenths of a percent for both the solar and terrestrial energy flows. This exceeds the original goals by a factor of 2 to 5 and is 2 to 10 times better than the previous instrumentation, Langley's Earth Radiation Budget Experiment (ERBE).

In order to validate this performance level, Langley scientists have developed unique and novel vicarious calibration monitoring techniques to supplement on-board calibration monitoring equipment. Vicarious calibration monitoring techniques include simultaneously measuring reflected solar and emitted thermal energy from deep cold convective clouds over the tropics, and monitoring the mean thermal energy emitted by the Earth in the tropics. CERES instrumentation also supported the Indian Ocean Experiment (INDOEX) and the Nauru 99 field measurement campaigns by making highly accurate measurements over the geographical regions to which the ground measurements will be compared.

The next sets of CERES instruments were launched in December 1999 on the Earth Observing System (EOS) Terra platform, and in late 2000 on the EOS Aqua platform. With the verified on-orbit performance of the CERES instrument on the TRMM spacecraft, the CERES investigation is poised to provide major improvements in our understanding of the interaction between clouds, radiation, and climate.

(Kory J. Priestley, k.j.priestley@larc.nasa.gov, 757-864-8147)

HALOE Stratospheric HCl Observations Validate the Effectiveness of the Montreal Protocol

The NASA Langley Research Center Halogen Occultation Experiment (HALOE) has been collecting observations of stratospheric Hydrogen Chloride (HCl) and other trace gases from the Upper Atmosphere Research Satellite (UARS) since October 1991. A majority of the chlorine (Cl) atoms that enter the stratosphere are in the form of Chlorofluorocarbons. Chlorofluorcarbons photolyze at higher altitudes with high energy sunlight and release Cl and fluorine (F). Cl acts as a catalyst that can rapidly accelerate the destruction of ozone. Cl and F atoms recombine with other trace gases to create stable reservoirs like HCl and Hydrogen Fluoride (HF). HF has a very long lifetime in the middle atmosphere; Cl can be released from HCl by heterogeneous chemistry like that occurring on Polar Stratospheric Clouds, which play an important role in the formation of the Antarctic Ozone Hole, so its lifetime is much shorter.

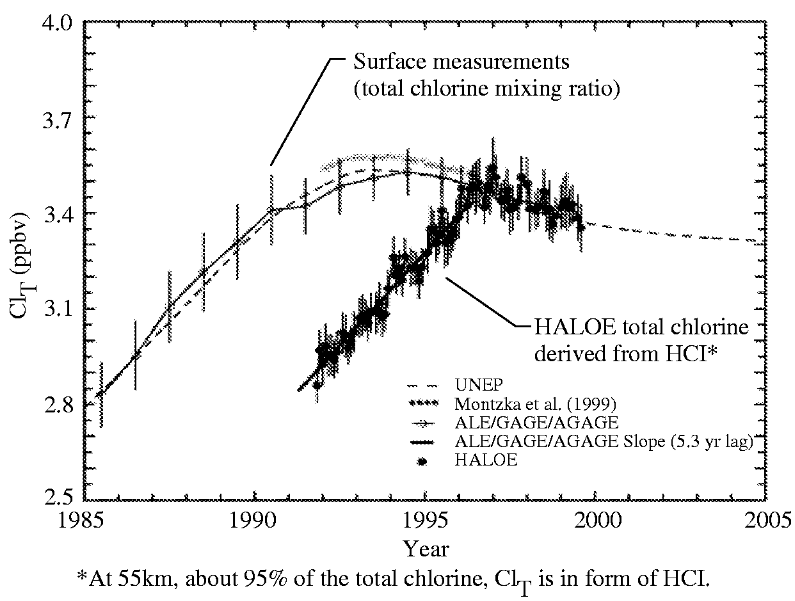


Figure 34. Atmospheric Chlorine Time Series.

At an altitude of 55 kilometers (~34 miles), almost all (~95%) of the Cl reaching that height is in the form of HCl. By measuring the time difference between the surface Cl values and those at 55km, it is possible to estimate the transport time from the surface to 55 km, which from HALOE data is about 5.3 years. Figure 34 presents the trend in globally-averaged total Cl derived from HALOE HCl measurements at 55 km, and its source gases from two on going ground-based monitoring networks: the Climate Monitoring and Diagnostics Laboratory (Montzka, et al, 1999) and the combined Atmospheric Lifetime Experiment (ALE), Global Atmospheric Gases Experiment (GAGE), and Advanced GAGE. The United Nations Environment Programme (UNEP) scenario (dashed curve) shows the expected behavior in ground-based total Cl as a result of countries adhering to the Montreal Protocol and its subsequent amendments. The HALOE inferred trend in Cl matches the trend in all three ground-based observation curves some 5.3 years later. This is evidence that the Montreal Protocol and its subsequent strengthening amendments are having the desired effect on the stratospheric Cl budget (Anderson, et al, 2000).
(Lance E. Deaver, l.e.deaver@larc.nasa.gov, 757-864-5696)

NASA Data Boosts Global Renewable Energy Industry

A critical goal of the NASA Earth Science Enterprise (ESE) is to enable the productive use of science results and technology in the public and private sectors. To this end, researchers in NASA Langley's Atmospheric Sciences Competency have developed a Surface Solar Energy (SSE) web site to encourage and facilitate the use of satellite derived solar radiation and meteorological data in the global renewable energy industry. Under contract to NASA Langley to assist in the development of applications for the data are the non-profit educational institution Solar Energy International (SEI) and sub-contractors Sun Frost, a maker of solar powered vaccine refrigerators for use in remote locations, and the Center for Renewable Energy and Sustainable Technology (CREST), a small solar equipment design business. A large increase in the numbers of users of the site has resulted from collaboration with the Canadian Natural Resources Department (NRCan) to provide the data and a web based interface to their RETScreen™ software package for the screening and feasibility analysis of renewable energy projects. The US Department of Energy National Renewable Energy Laboratory is an additional partner in this effort, providing the web site's extensive ground station solar energy data.

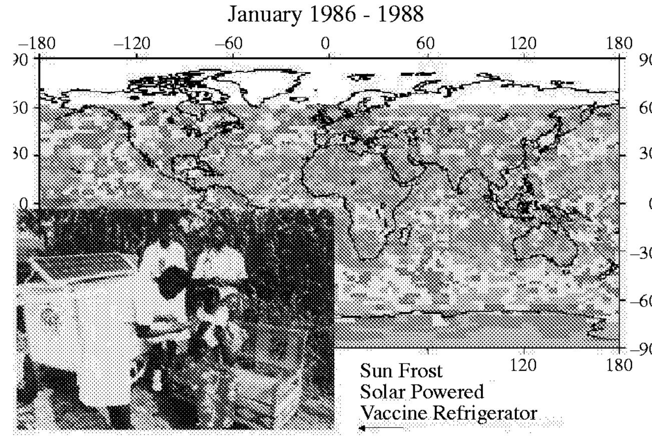


Figure 35. The equivalent no sun day's parameter helps designers reduce the costs of battery back-up storage for solar equipment such as this Sun Frost vaccine refrigerator. (Color version is on report website.)

The first (Release 1) SSE web based data set enabled applications of solar energy projects in remote areas. Using the data, solar cooking projects in refugee camps were justified by Solar Cookers International (SCI). According to Jay Campbell, the SCI director, this quality of information is simply unavailable from other sources, and allows us to make better decisions for our consultations and project plans. Solar cooking projects for remote village economic development were assessed for viability by Consultants on Household Use of Solar Energy (CHUSE). Dr. Larry Schussler of Sun Frost was able to use the data to create a more cost-effective vaccine storage refrigerator (see figure 35) for use in certain remote equatorial areas. Several organizations, including Solar Energy International and the Francophone Institute of Energy, used the data and web site for educational purposes.

Comments from initial users and suggestions resulting from the above mentioned partnerships resulted in the development of a Release 2 version of the SSE web site. Release 2 went on-line in June 1999. The new site includes additional background information and is organized to be easier to use and more understandable to users from the renewable energy community. It provides additional parameters for the design of stand-alone photovoltaic systems; solar-powered agricultural water-pumping, crop-drying, and refrigeration equipment; and orientation of buildings in remote areas (passive solar design). These additional data allow the web site to be used for a much larger class of applications. As a result of the

US/Canadian collaboration, more than 5000 licensed users of the Canadian RETScreen tool are linked to the Release 2 site for direct data download. The SSE/RETScreen alliance may lead to the ESE data playing an important role in global energy policy decisions. According to Canadian Natural Resources Minister Ralph Goodale, NRCan's goal is for RETScreen to become an international standard for helping determine the potential of renewable energy projects. Data downloads from Release 2, involving users from more than two dozen countries, have been occurring at a rate 7 times faster than from Release 1.
(Ann B. Carlson, a.b.carlson@larc.nasa.gov, 757-864-7050)

Effects of Volcanically-elevated Sulfate Aerosol on Stratospheric Ozone: 3-D Coupled Model Simulations

Global-change studies assessing the response of Earth's atmosphere to both anthropogenic and natural changes must rely on simulation models which incorporate all relevant processes and correctly represent the interactions between those processes. The Langley Research Center IMPACT (Interactive Modeling Project for Atmospheric Chemistry and Transport) model is a global, three-dimensional computer model of Earth's atmosphere from the ground to an altitude of 90 km. The dynamical, radiative, and photochemical processes of the atmosphere are depicted in the model, and the use of the modeled ozone distribution in radiative heating calculations allows the chemistry to interactively influence the circulation and thermal structure of the simulated atmosphere. Realistic representation of such interactions is necessary to accurately investigate perturbations which contribute to changes in ozone over seasonal to decadal time scales.

The IMPACT model has recently been used to examine the response of the middle atmosphere to a large volcanic injection of sulfate aerosol into the tropical stratosphere, such as occurred following the June 1991 eruption of Mt. Pinatubo in the Philippines. Observations have shown that such volcanic aerosol enhancement can diminish stratospheric ozone for several years following the eruption. Sulfate aerosol particles influence the stratosphere in two ways: aerosol absorption of both solar and terrestrial radiation yields a direct heating perturbation, and heterogeneous chemical reactions enabled by the particles alter the concentrations of chemical species important in determining the ozone abundance.

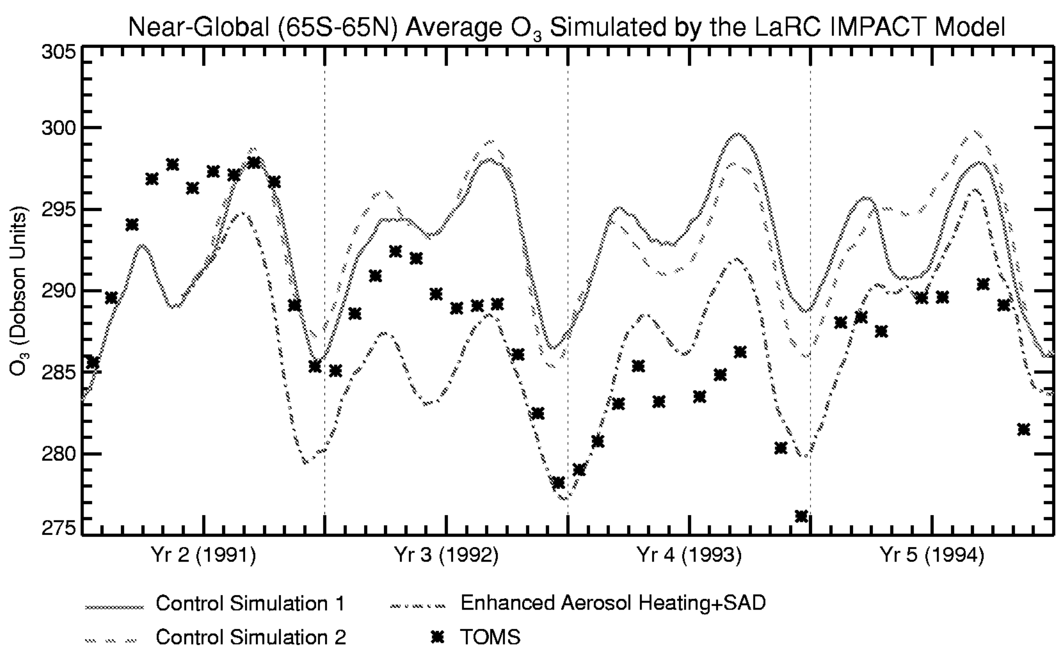


Figure 36. Time evolution of column ozone from an IMPACT model simulation with volcanically elevated sulfate aerosol, two control simulations, and Total Ozone Mapping Spectrometer satellite observations from 1991 to 1994. The eruption of Mt. Pinatubo occurred during June 1991.

Two enhanced-aerosol simulations were integrated for 3 1/2 years following the volcanic injection: one which included only the aerosol radiative perturbation, and one which included both the radiative perturbation and elevated aerosol surface area in the chemistry calculations. These simulations were compared with two multiple-year control simulations to assess the relative contributions of heating and heterogeneous chemical processing.

Figure 36 shows the time evolution of total column ozone from the control simulations, the simulation with both elevated aerosol heating and surface area density, and TOMS (Total Ozone Mapping Spectrometer) instrument satellite observations. Shown are near-global (latitudes between 65°S and 65°N) area-weighted averages, expressed in Dobson Units. Differences between the two control simulations, including differences between individual years, illustrate the natural interannual variability in column ozone. Differences between the control simulations and the elevated-aerosol simulation which are larger than the natural variability illustrate the response to elevated aerosol. Largest natural variability, of approximately 5 Dobson Units, occurs during the northern hemisphere spring and early summer. The decline in column ozone of approximately 10 Dobson Units observed by TOMS from 1991 through 1993 is generally well reproduced by the elevated aerosol simulation. Analysis of the simulations shows that during the first 12 months following the eruption, this decline is due to both increased photochemical destruction (initiated by the heterogeneous chemical processing) and altered circulation patterns (initiated by the aerosol heating). Through the remaining 2 1/2 years following the eruption, the decline is almost entirely a result of increased photochemical destruction. The decrease in ozone yields a slight cooling throughout the lower stratosphere, which partially counteracts the warming induced by aerosol heating.

These simulations demonstrate our capability to accurately simulate the response of Earth's atmosphere to perturbations which have contributed to ozone change over past decades. The results, including the extraction of trends that are significant with respect to interannual variability, diagnosis of both dynamical and photochemical forcings for the observed changes, and identification of chemical-dynamical feedbacks, give confidence in predictions of how the coupling between chemistry and climate might modulate the expected recovery of stratospheric ozone over the next few decades.

(Jassim A. Al-Saadi, j.a.al-saadi@larc.nasa.gov, 757-864-5164)

Pacific Exploratory Mission (PEM-Tropics B)

Part of NASA's Global Tropospheric Experiment (GTE), the PEM-Tropics B campaign investigated ozone and sulfur chemistry over the South Pacific during March and April of 1999. Although managed by Langley, the investigative team was comprised of representatives from 5 government research labs and 14 academic institutions. The suite of sensors deployed on NASA's DC-8 and P-3B research aircraft (see figures 37 and 38) provided the most comprehensive package ever fielded for the purpose of characterizing atmospheric composition.

Investigators onboard the DC-8 focused primarily on ozone photochemistry and on the oxidizing power of the atmosphere. Key improvements from previous GTE campaigns included a measurement system for HOx radicals, critical species for atmospheric oxidation and ozone production. Another new addition was

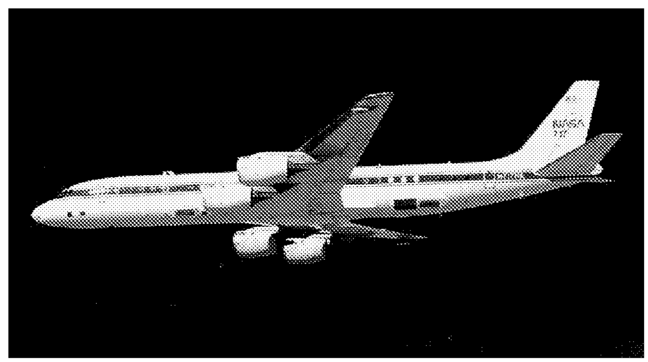


Figure 37. NASA's DC-8 Airborne Research Platform.

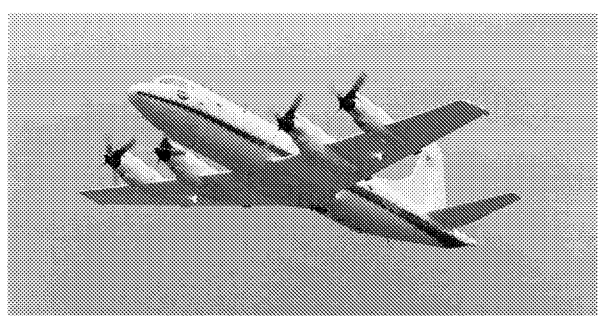


Figure 38. NASA's P-3B Airborne Research Platform.

Langley's Lidar Atmospheric Sensing Experiment (LASE) which provided remote sensing of water vapor above and below the aircraft. Observations revealed an exceedingly clean atmosphere, providing an important contrast to the extensive biomass burning pollution observed during PEM-Tropics A over the same region during the dry season (August-September, 1996).

P-3B investigators focused on marine sulfur chemistry and its coupling to new particle formation. Important new measurements from this aircraft included a Chemical-Ionization Mass-Spectrometer (CIMS) system capable of measuring dimethylsulfoxide (DMSO). Once believed to be predominantly formed only from the gas phase oxidation of dimethylsulfide (DMS) released from the ocean, the new measurements have demonstrated that DMSO is also released directly from the ocean. This new finding dramatically alters current thinking about the oxidation chemistry of DMS. In addition, important data relating to the early stages of new particle formation was gained from an ultrafine condensation particle counter (UCPC) using pulse height analysis. This system extends the lower limit for particle measurements by providing information on particle size distribution between 3 and 10 nanometers.

(Richard J. Bendura, r.j.bendura@larc.nasa.gov, 757-864-5830)

SAGE III Mission

The launch of the Stratospheric Aerosol and Gas Experiment (SAGE) III instrument (see figures 39 and 40) on-board the Russian Meteor-3M spacecraft is presently scheduled for the year 2000. Researchers at NASA Langley have been performing various tests on the SAGE III instrument to fully characterize its measurement capability. SAGE III is a remote sensing instrument built for a joint Earth Observing System (EOS) mission between the U.S. National Aeronautics and Space Administration (NASA) and the Russian Space Agency (RSA). It is to be launched from the Baikonur Cosmodrome in late 2000. SAGE III is a spectrometer that measures attenuated solar and lunar radiation from 290 nm to 1550 nm wavelength range which can be inverted to yield vertical profiles of ozone, aerosols, NO_2, H_2O, NO_3, OClO, and temperature in the atmosphere for studying long-term trends and global changes.

SAGE III was built by Ball Aerospace Company and delivered to Langley in the fall of 1998. Over the last twelve months, researchers at Langley have performed sun-look and moon-look tests with the SAGE III instrument to verify and calibrate the performance of the instrument. Recently, a series of laboratory calibration tests and polarization response tests have been

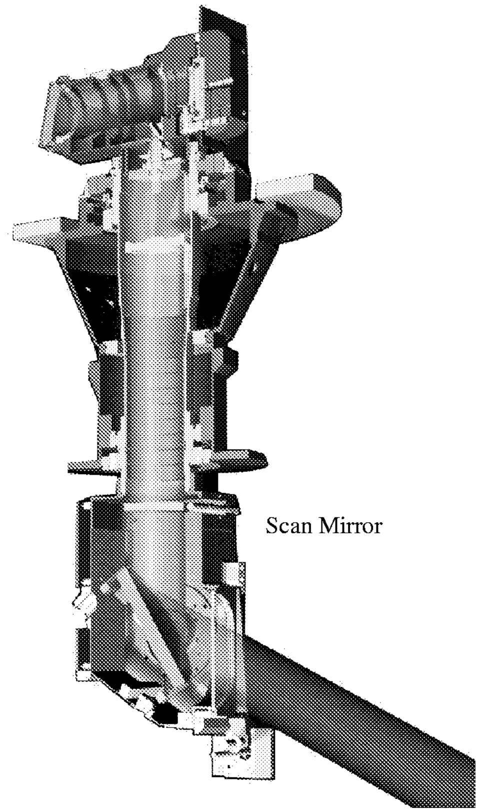


Figure 39. Major elements of the SAGE III instrument.

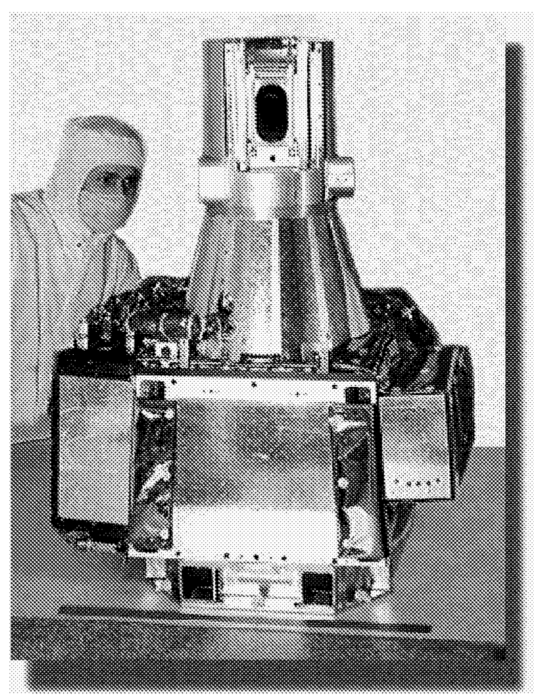


Figure 40. SAGE III METEOR-3M Instrument.

performed on the instrument before it is shipped to Russia for integration onto the Meteor-3M spacecraft.

The SAGE III Meteor-3M mission will be placed in a sun synchronous orbit that yields solar measurement opportunities between 50 and 80 degrees North and 30 and 50 degrees South. The high northern latitude coverage will provide insight into the processes leading to ozone depletion during boreal winter and provide coverage that complements the mid- and low-latitude coverage provided by SAGE II and other SAGE III missions.

The second SAGE III instrument is scheduled to be a part of the International Space Station (ISS) payload beginning in 2003. ISS will be placed in a 51 degree inclined orbit that yields SAGE III solar measurement opportunities from 70 degrees South to 70 degrees North over the course of one month.

(William P. Chu, w.p.chu@larc.nasa.gov, 757-864-2675)

PICASSO-CENA Mission

Langley Research Center and the French space agency CNES are collaborating on the development of the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations- Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) satellite mission to be launched in early 2003. The PICASSO-CENA mission is designed to obtain profile measurements on the optical characteristics of clouds and aerosols (small suspended particles) that affect the Earth's radiation budget. The instrument suite will take advantage of the synergy available between active and passive remote sensing techniques and consists of a 3-channel lidar, an A-band spectrometer, an Infrared Imaging Radiometer, and a Wide Field-of-View camera. The mission is planned for 3 years.

PICASSO-CENA (see figure 41) will fly in near formation with the already planned EOS Aqua satellite to provide a coincident set of data on aerosols and cloud properties, radiative fluxes, and atmospheric state variables essential for accurate quantification of the effects of clouds and aerosols on the Earth's radiation budget. To enhance this measurement set in regions with optically thick clouds, PICASSO-CENA will be joined in orbit by the CloudSat satellite mission which includes a cloud radar to provide vertical profile measurements of cloud liquid water and ice content. CNES

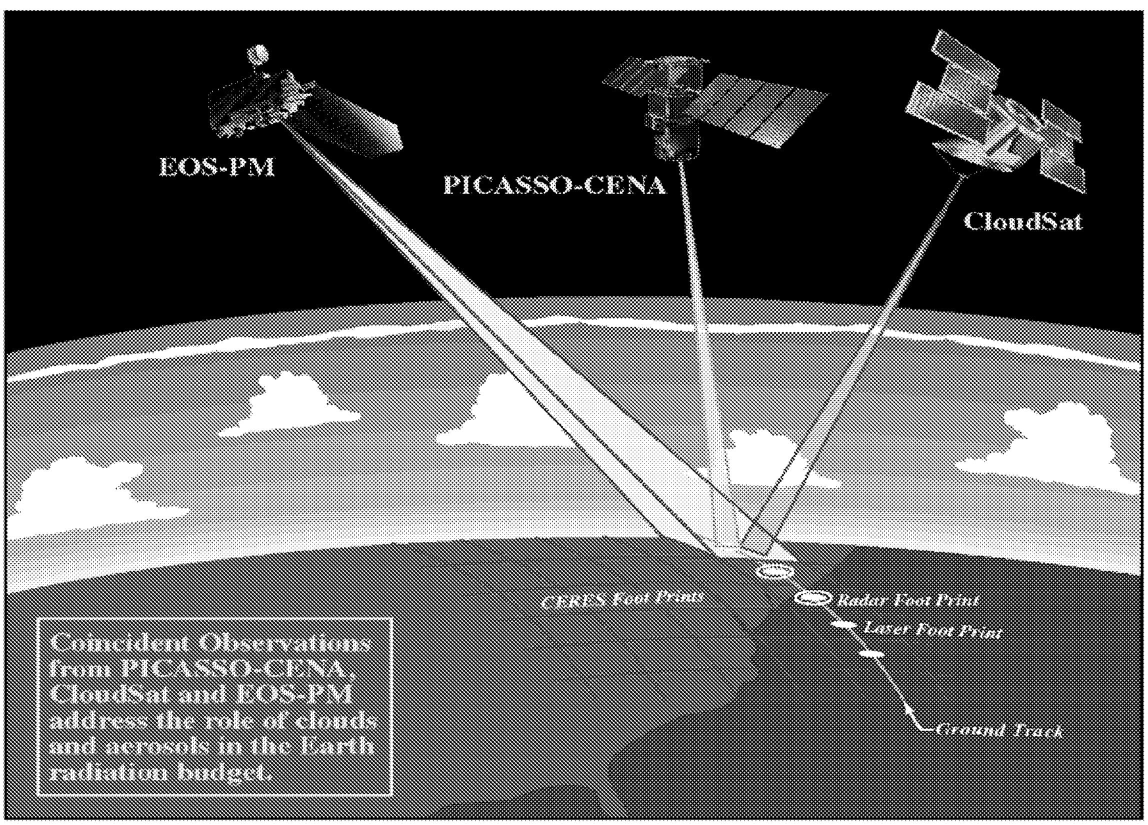


Figure 41. PICASSO-CENA adds unique vertical profile observations to EOS PM and CloudSat measurement suite.

will further contribute with the recently selected PARASOL mission that will fly a Polder instrument in formation with PICASSO-CENA and Aqua to provide coincident measurements on the polarization of reflected sunlight from clouds and aerosols. A Polder is a multiple-wavelength wide field of view polarization-sensing satellite radiometer for earth observations. Additional measurements on aerosols and tropospheric chemical distributions will be obtained from the EOS Chem mission, which will fly about 15 minutes behind EOS Aqua. This constellation of five different satellite platforms will provide the most comprehensive global set of measurements of clouds and aerosols to date and will improve numerical weather forecast models and global circulation models used for predictions of climate change.

The spacecraft will be launched in 2003. PICASSO-CENA consists of a unique partnership among Langley; France's Centre National D'Etudes Spatiales (CNEA); the Institut Pierre Simon Laplace; Hampton University of Hampton, VA (a Historically Black University); Ball Aerospace and Technology Corporation, Boulder, CO; and NASA's Goddard Space Flight Center, Greenbelt, MD. The provision by France of a PROTEUS spacecraft, the infrared imaging system and science analysis support make this mission a true international partnership.

(David M. Winker, d.m.winker@larc.nasa.gov, 757-864-6747)

SOLVE Measurements of the Arctic Stratosphere

Researchers at NASA Langley participated in the largest and most comprehensive field experiment to date to measure ozone amounts and changes in ozone in the Arctic stratosphere. The NASA sponsored SAGE III Ozone Loss and Validation Experiment (SOLVE) was conducted jointly with the Third European Stratospheric Experiment on Ozone (THESEO 2000) and was based at Kiruna, Sweden. Over 350 scientists and technicians were involved during three phases from November 1999 through March 2000. These collaborative campaigns obtained measurements of ozone and other atmospheric constituents using satellites, four aircraft (including the NASA DC8 and ER2), high-altitude balloons, and ground-based instruments. These observations will provide insight into processes that control ozone at mid and high latitudes, which are needed to improve model predictions of future ozone change.

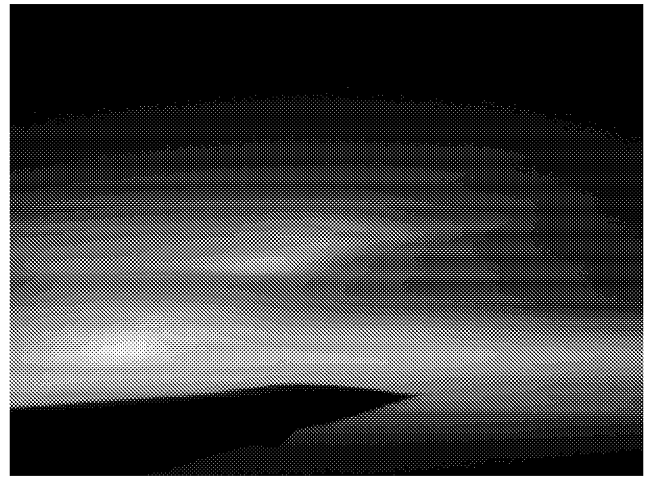
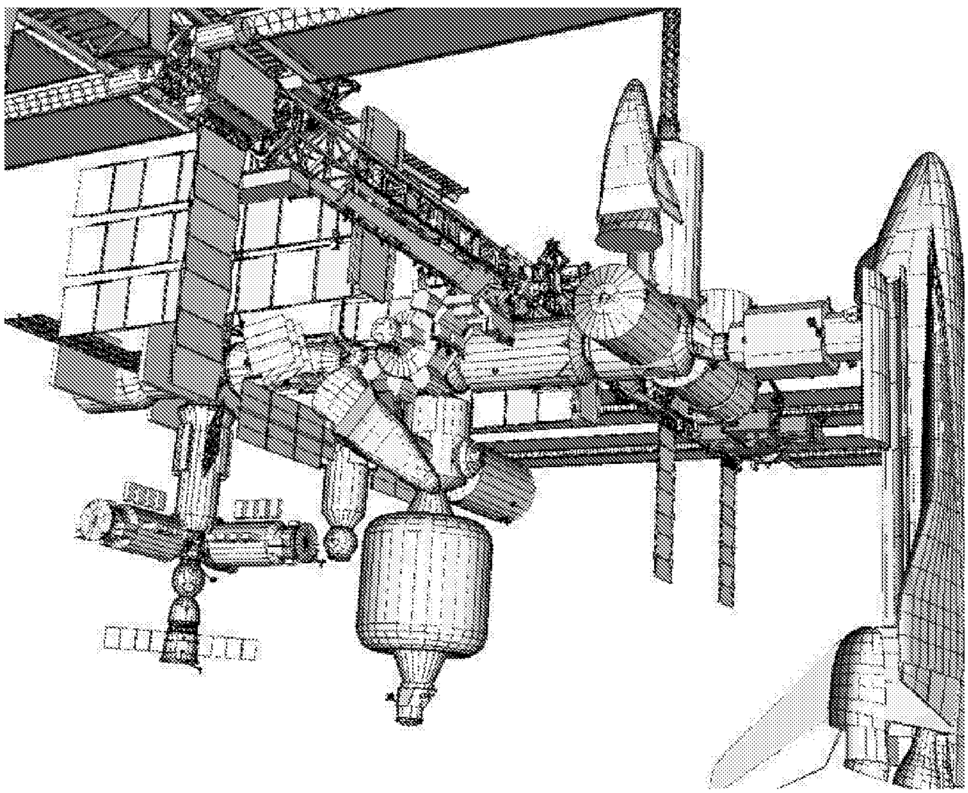


Figure 42. Polar stratospheric clouds (nacreous clouds) over Greenland viewed from the NASA DC-8 aircraft during SOLVE. (Color version is on report website.)

During SOLVE, state-of-the-art Langley built remote sensing and in situ instruments onboard the NASA DC-8 aircraft provided measurements on the distribution of aerosols (small particles), ozone, water vapor, and other trace gases. An important objective of the mission was to study the formation and composition of polar stratospheric clouds (see figure 42). The formation of polar stratospheric clouds each winter plays an important role in the activation of ozone-destroying radicals that produce a rapid loss of ozone at high latitudes in early spring. These clouds consist of mixtures of sulfuric acid, nitric acid, and ice that vary with temperature. Langley instruments and theory teams identified a large number of polar stratospheric clouds existing under a variety of atmospheric conditions that will aid in better understanding their formation and dissipation.

(Charles R. Trepte, c.r.trepte@larc.nasa.gov, 757-864-5836)

Human Exploration and Development of Space Enterprise



NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

Mission

To open the Space frontier by exploring, using and enabling the development of Space and to expand the human experience into the far reaches of Space.

Purpose

To improve the quality of life on Earth, to inspire and motivate our citizens, and to bind people together.

Goals

- Provide safe and affordable human access to space, establish a human presence in space, and share the human experience of being in space;
- Prepare to conduct human missions of exploration to planetary and other bodies in the solar system;
- Use the environment of space to expand scientific knowledge; and
- Enable the commercial development of space and share knowledge, technologies, and assets that promise to enhance the quality of life on Earth.

International Space Station Synergistic Engineering Environment

The ISS Synergistic Engineering Environment (SEE) allows geographically distributed engineers and scientists to immerse themselves along with their analytical simulations and data into a synthetic space station environment. The current prototype has the ISS in Earth orbit (see figures 43 and 44) coupled to a real-time dynamics simulation with the motion of the Earth, sun and moon mathematically modeled. Payloads (such as SAGE III) can be modeled so that engineers can take into account the complex interactions of the ISS flight dynamics, instrument scanning specifications, orbital geometry and other nearby payloads. The environment has a small portion of the interior of the ISS modeled and when further developed will enable engineers throughout NASA to collaboratively plan, simulate and demonstrate on-orbit and ground based

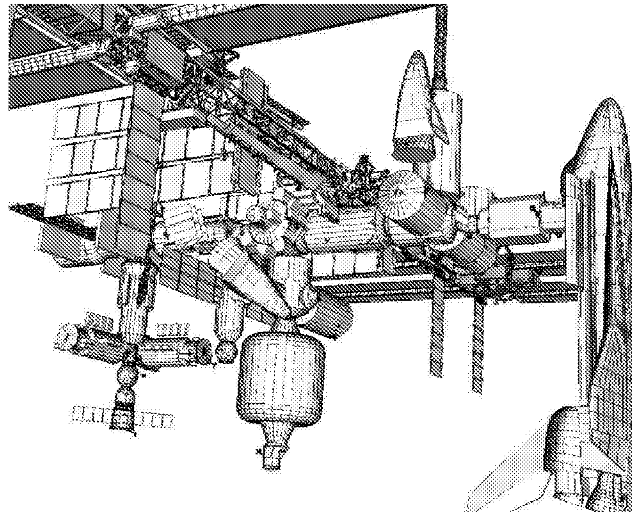


Figure 43. ISS prototype.

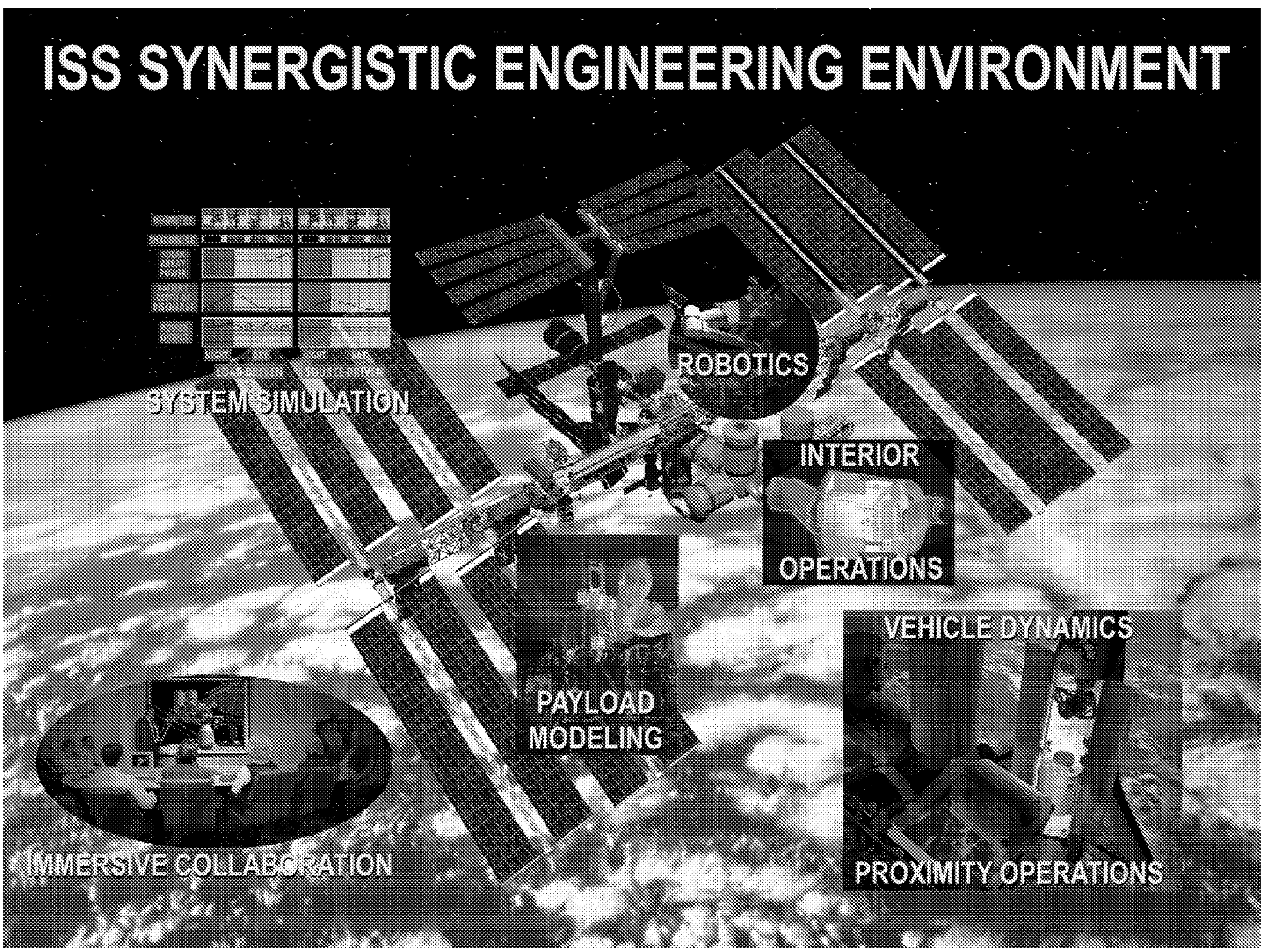


Figure 44. ISS SEE Capabilities.

operations and procedures. The real-time fusion of engineering CAD models, an ISS dynamics and control simulation, a relative motion simulation and proximity/collision detection will improve proximity analysis capabilities (such as Crew Return Vehicle (CRV) separation). Work is also progressing on a real-time inverse kinematics solver for facilitating robotic operations assessments in the presence of a dynamically changing space station environment. The SAGE III program office is using the ISS SEE for mission planning and analysis. A facility incorporating the above capabilities is operational at the Johnson Space Center (JSC). The facility has been named the ISS Synergistic Engineering Lab (Synergy Lab) and will initially be utilized by the ISS Vehicle Integrated Performance (VIPER) team. Initial benefits include 1) Fusion of ISS analytical capabilities and models enables immediate understanding of complex operational issues among a geographically distributed group of people; 2) Cost and time savings resulting from reduced travel; 3) Enhanced fidelity for identification of anomalies in data capture during operations for attached payloads and 4) Improved rapid contingency analysis capability.
(Patrick Troutman, p.a.troutman@larc.nasa.gov, 757-864-5804)

International Space Station Evolution Data Book

The International Space Station (ISS) Evolution Data Book (EDB) provides a focused and in-depth look at the opportunities and drivers for the enhancement and evolution of the International Space Station (ISS) during its assembly and beyond its Assembly Complete (AC) stage. These enhancements would expand and improve the current baseline capabilities of the ISS and help to facilitate the commercialization of the ISS by the public sector. The intended users of this document include the ISS organization, the research community, other NASA programs and activities, and the commercial sector interested in opportunities that the ISS offers.

The purpose of the ISS Evolution Data Book is three-fold. First, it provides a broad integrated systems view of the current baseline design of the ISS systems and identifies potential growth and limitations of these systems. Second, it presents current and future options for the application of advanced technologies to these systems and discusses the impacts these enhancements may have on interrelated systems. Finally, it provides this information in a consolidated format to research and commercial entities to help generate ideas and options for developing or implementing new technologies to expand the current capabilities of ISS and to assist them in determining potential beneficial uses of the ISS. The content of this document ventures beyond the current designs and capabilities of the ISS toward its future potential as a unique research platform and engineering testbed for advanced technology. It provides an initial source of information to help stimulate the government and private sectors to develop a technological partnership in support of the evolution and commercialization of the ISS.

The ISS Evolution Data Book is composed of two volumes (see figures 45 and 46). Volume 1 contains the baseline descriptions. Section 1 is an introduction to Volume 1. Section 2 provides an overview of the major components of the ISS. Section 3 summarizes the ISS baseline configuration and provides a summary of the functions and potential limitations of major systems. Section 4 outlines the utilization and operation of the ISS, and furnishes facility descriptions, resource timelines and margins, and a logistics/visiting vehicle traffic model. Volume 2 contains information on future technologies, infrastructure enhancements, and future utilization options and opportunities. Section 1 is an introduction to Volume 2. Section 2 identifies the advanced technologies being studied by the Pre-Planned Program Improvement (P3I) Working Group for use on ISS to enhance the operation of the station. Section 3 provides information on the advanced technologies that go beyond the efforts of the P3I Working Group. Section 4 covers the commercialization of the ISS. Section 5 provides options for advanced research opportunities. Section 6 summarizes the analysis performed for several Design Reference Missions (DRMs) that are being investigated for post-AC utilization and enhancements. Section 7 provides utilization opportunities that may enhance the efforts of the Human Exploration and Development of Space (HEDS) missions
(Jeff Antol, j.antol@larc.nasa.gov, 757-864-5804)

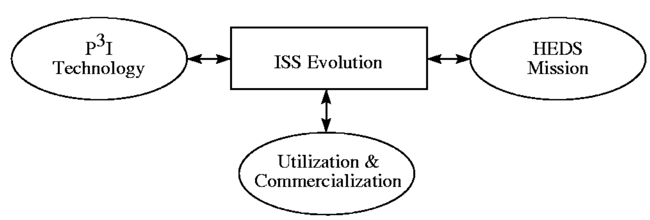


Figure 45. Example Evolution Configuration of the International Space Station.

BASELINE ISS

Part I: Baseline Assembly Complete Description

- Sub-system Descriptions, which include scars, if any, for growth:
  - Power
  - Thermal
  - Communications
  - GN&C
  - Data System
  - Crew Systems
  - Propulsion
  - Structures & Mechanisms
  - Robotics

Part 2: Baseline Utilization & Ops Plans

- Experiment Facility Descriptions
- Resource Timelines & Margin Summary
- ISS Cargo Traffic

EVOLUTION

Part 3: Advanced Technologies & Utilization Opportunities

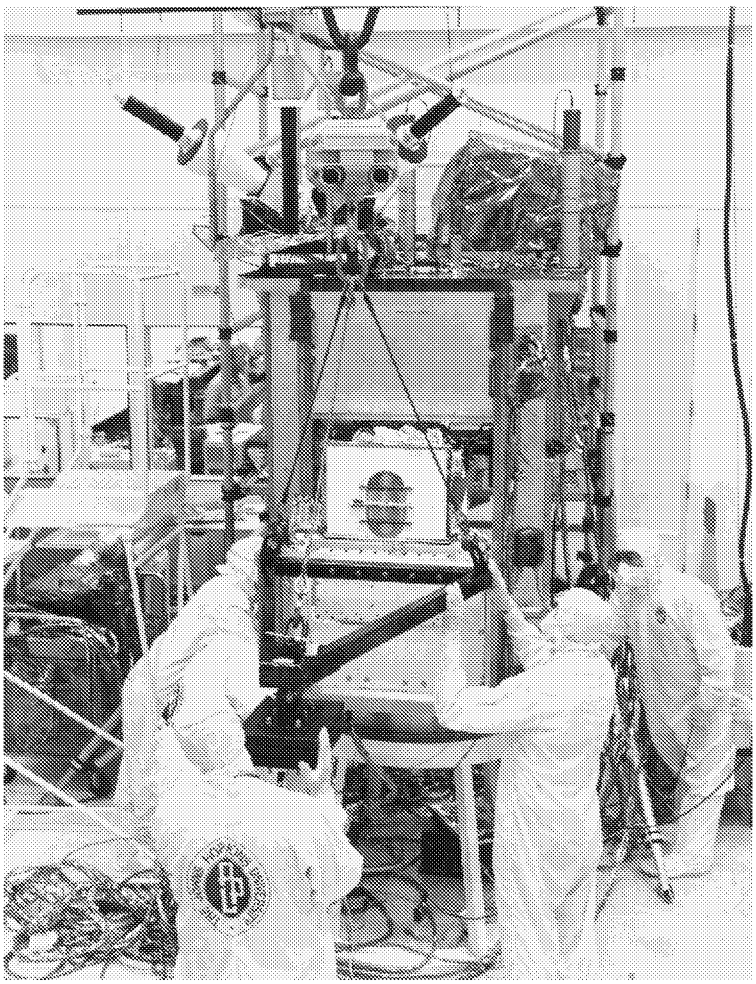
- Pre-Planned Program Improvement (P^3I) Technologies
- Proposed Research and Commercialization Activities

Part 4: Design Reference Missions for ISS Evolution

- Implementation of (P^3I) Technology Sets Energy Storage Enhancement
- Free-Flyer Servicing
- Advanced Communications Tower
- TRANSHAB
- Tether for ISS Orbit Maintenance
- Advanced Space Transportation Systems

Figure 46. Example Evolution Configuration of the International Space Station.

Space Science Enterprise



From origins to destiny, the Space Science Enterprise seeks to chart the evolution of the Universe and understand its galaxies, stars, planets, and life.

Mission

- Solve Mysteries of the Universe
- Explore the Solar System
- Discover Planets Around Other Stars
- Search for Life Beyond Earth

Enterprise Goals

1. Establish a virtual presence throughout the solar system, and probe deeper into the mysteries of the Universe and life on Earth and beyond.
2. Pursue space science programs that enable and are enabled by future human exploration beyond low-Earth orbit.
3. Develop and utilize revolutionary technologies for missions impossible in prior decades.
4. Contribute measurably to achieving the science, mathematics, and technology education goals of our Nation, and share widely the excitement and inspiration of our missions and discoveries.

Science Goals

1. Understand how structure in our Universe (e.g., clusters of galaxies) emerged from the Big Bang.
2. Test physical theories and reveal new phenomena throughout the Universe, especially through the investigation of extreme environments.
3. Understand how both dark and luminous matter determine the geometry and fate of the Universe.
4. Understand the dynamical and chemical evolution of galaxies and stars and the exchange of matter and energy among stars and the interstellar medium.
5. Understand how stars and planetary systems form together.
6. Understand the nature and history of our Solar System, and what makes Earth similar to and different from its planetary neighbors.
7. Understand mechanisms of long- and short-term solar variability, and the specific processes by which Earth and other planets respond.
8. Understand the origin and evolution of life on Earth.
9. Understand the external forces, including comet and asteroid impacts, that affect life and the habitability of Earth.
10. Identify locales and resources for future human habitation within the solar system.
11. Understand how life may originate and persist beyond Earth.

Sounding of the Atmosphere Using Broadband Emission Radiometry (SABER)

The SABER instrument, the key science sensor on the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) satellite, will probe the mesosphere and lower thermosphere, the least studied region of the Earth's atmosphere extending from 60 km to 180 km in altitude. High altitude and low density have limited data on this region to spotty coverage provided by ground-based instruments, sounding rockets, and limited coverage by the Upper Atmosphere Research Satellite. The goal of the SABER instrument is to explore the mesosphere and lower thermosphere globally and achieve a major improvement in our understanding of the fundamental processes governing the energetics, chemistry, dynamics, and transport of this atmospheric region.

Sponsored by the NASA Office of Space Science, the SABER instrument (figure 47) was designed and built by Utah State University's Space Dynamics Laboratory, under the guidance of the Langley Research Center. The TIMED satellite launch is planned for late 2000 or 2001. From its 625-km orbital altitude, the SABER instrument views infrared emissions from the atmosphere at the Earth limb, or edge of the Earth disk. It accurately measures infrared energy given off by molecules of carbon dioxide, ozone, water vapor, oxygen, nitric oxide, and the hydroxyl radical. During ground test and calibration, the SABER instrument proved to be 1000 times more sensitive than the previous generation of infrared limb sounding instruments, and is highly insensitive to scattered sunlight from clouds and the Earth's surface.

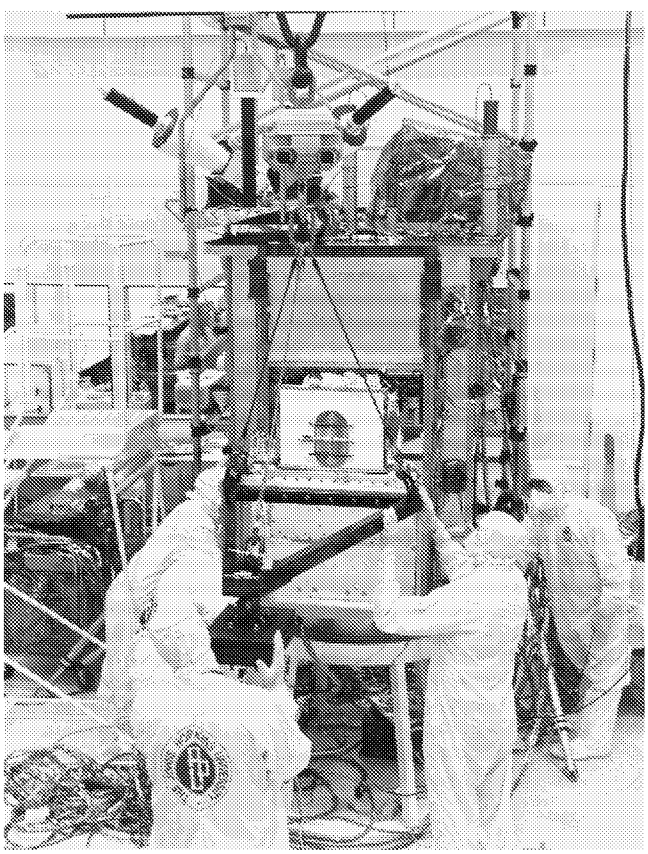


Figure 47. Installation of SABER on the TIMED Spacecraft.

A team of scientists from the Langley Research Center, Hampton University, Air Force Research Laboratory, Instituto de Astrofisica de Andalucia (Spain), and Gordley and Associates Technical Software developed new state-of-the-art algorithms and computer codes to complement the excellent performance of the flight instrument. These codes accurately extract information from the instrument data about the temperature, pressure, heating, cooling, chemistry and dynamics of the region. These algorithms include breakthrough approaches to overcoming the special problems of analyzing infrared emissions from such a low-density region of the atmosphere.

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Entry Analysis for the Stardust Comet Sample Return Capsule

The fourth NASA Discovery class mission is a comet sample return mission known as Stardust. It will be the first mission to return samples from a comet. The spacecraft was launched in February 1999 and will fly past the comet Wild-2. Stardust will come within 100 km of the comet nucleus and deploy a sample tray to collect cometary and interstellar dust particles (see figure 48). Upon Earth return in January 2006, the entry capsule (containing the comet samples) will be released from the main spacecraft, enter the atmosphere decelerating with the aid of a parachute, and land at the Utah Test and Training Range. The entry velocity will be the highest of any Earth-returning mission. A new heat shield material made of PICA (Phenolic Impregnated Carbon Ablator) will be used to protect the Sample Return Capsule from the intense heat of reentry. The analysis of the cometary and interstellar particles is expected to yield important insights into the evolution of the sun and planets and possibly into the origins of life itself.

NASA Langley has played a major role in the definition of the entry, descent, and landing sequence of the Stardust sample return capsule. The objective of the Langley effort was to analyze and aid the design of the

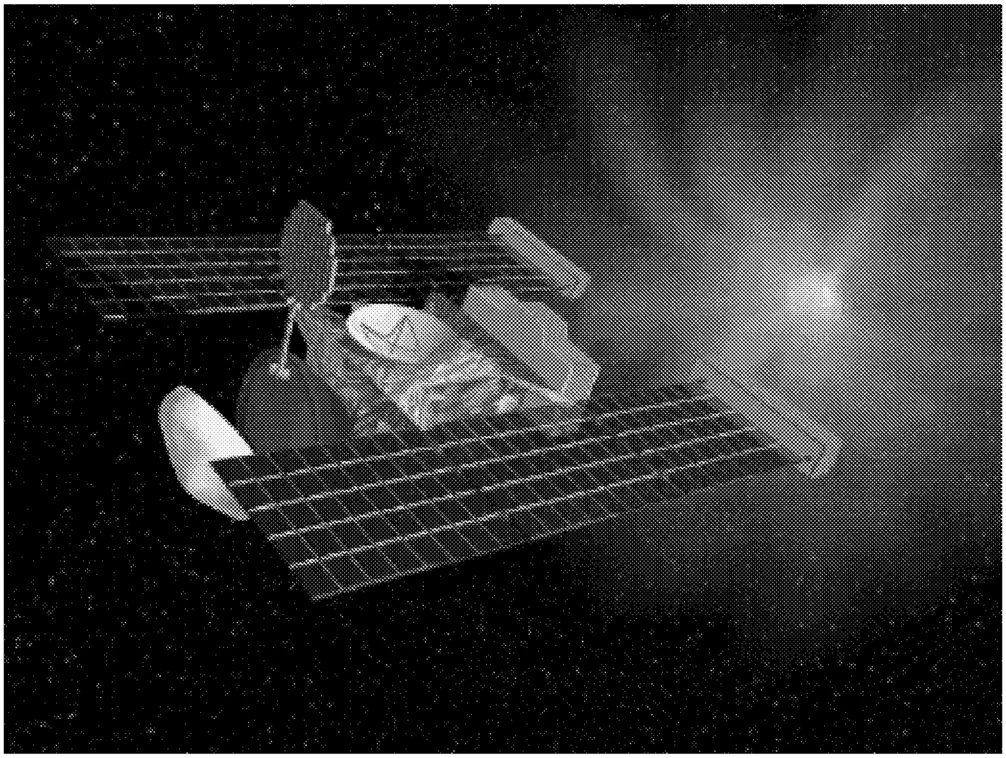

Figure 48. Stardust spacecraft sample acquisition flight configuration.

entry sequence, and to ascertain its robustness to off-nominal conditions during the entry. In addition, the overall landing footprint size was determined to certify the Utah Test and Training Range as the landing site. The initial activity involved validating the design concept of the capsule entry, descent, and landing sequence. This analysis revealed two aerodynamic instabilities that produced unacceptable capsule attitude dynamics during the Earth entry. These instabilities, if not eliminated or at least suppressed, could lead to mission failure. An extensive study was launched by Langley to determine modifications which would minimize the impact of the instabilities on the mission. Based on these analyses, the entry spin rate of the capsule was increased, and a stabilizing drogue parachute was added, deploying in the supersonic portion of the trajectory. As a result of the change in the parachute deployment procedures, the capsule avionics system was augmented to include a g-switch and two timers. Additionally, the higher entry spin rate required a change in the capsule separation mechanism on the main spacecraft. An analysis of this modified entry sequence shows that the attitude of the capsule during the entry is within Stardust program limits, and the corresponding landing footprint size was found to be within the boundaries of the Utah Test and Training Range.

NASA's Stardust spacecraft has deployed the aerogel particle collector its controllers hope to retrieve in 2006, extending one of its sides into open space to capture microscopic bits of interstellar dust for later analysis.

According to a Jet Propulsion Laboratory status report, spacecraft telemetry indicated the deployment sequence worked as planned. The aerogel collector was extended outside the spacecraft capsule after the heat shield was moved out of the way. The collector was to remain in that position at least through May 25, 2000 collecting interstellar particles in a panel of extremely low-density silicon aerogel one-centimeter thick. Particles too large to be trapped in the collector will simply blow on through, but scientists hope to collect enough of them for study after the capsule is returned to a parachute landing at the Utah Test and Training Range in 2006.

Once the interstellar collection period was over, the collector was to be retracted into the capsule until mid-2002, when a second attempt will be made to capture interstellar particles. In 2004 the probe will fly through the coma of the comet Wild-2 to collect its particles in a three-centimeter aerogel panel on the other side of the one used for interstellar dust.

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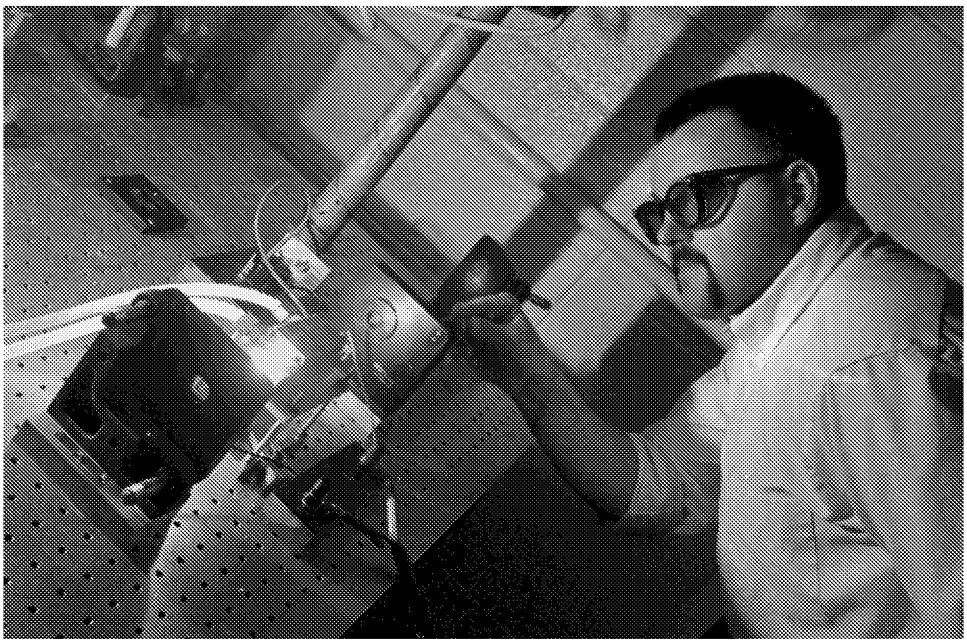
Summary of Langley Technology Partnerships



NASA Langley Research Center has established its technology presence in strategic areas that will enhance the United States' competitive position in the global economy. The Center's focus is economic development with an emphasis on high technology. In recognition of its efforts in this area, Langley received the 1999 Award from the Federal Laboratory Consortium for Technology Transfer.

Summary of Langley Technology Partnerships

The Secretary of Trade and Commerce

The Technology Commercialization Program Office hosted a visit by Virginia's Secretary of Trade and Commerce, Barry DuVal, and a team of 35 economic development professionals. The visit was part of a 2-day statewide tour of federal research and development facilities. Secretary DuVal announced during their visit the formation of a State Task force for Federal Asset Retention of Research and Development Facilities, a community-based, state-coordinated association committed to supporting Virginia's major R&D facilities. The task force will be an important partnership between the community and state to advance our shared interests in the success of these crucial federal assets for the benefit of all U.S. citizens.

Synthetic Vision: Clear Skies All the Time

NASA is negotiating with industry teams to design an innovative, affordable cockpit technology that will provide general aviation pilots with a clear electronic picture of the environment outside their windows, regardless of the weather or time of day. Synthetic vision will use existing technologies such as Global Positioning System signals, terrain databases, and advanced displays to show potentially hazardous terrain, air traffic, landing and approach patterns, runway surfaces and obstacles.

Hampton Roads Technology Incubator: Helping Commercialize NASA Technology

Langley Research Center has entered into a 2-year partnership with the Hampton Roads Technology Incubator (HRTI) for the purpose of ensuring the success of entrepreneurs who are licensing Langley-developed technologies. HRTI was created when NASA expanded its nationwide small business incubator program to include Langley. There are now nine NASA-related incubators in the U.S., which, like the HRTI are designed to: facilitate commercial application of NASA technology by local start-up or existing high-technology firms; foster partnerships between educational institutions and local high-technology businesses; and encourage local community public and private business participation.

The ultimate goal of this partnership is to increase the number of successful technology-based companies. To date, four companies have been accepted as charter members of the incubator, all involving licensed Langley technology or partnerships.

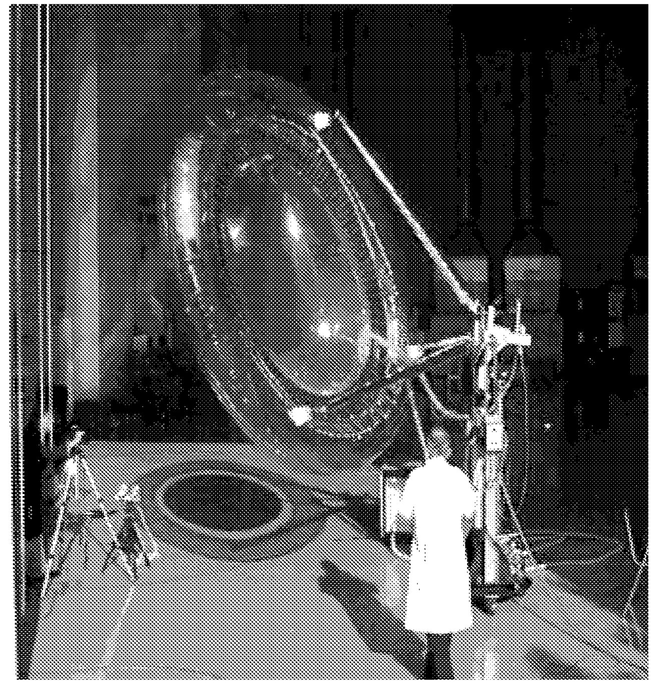


Figure 49. R&D 100 Award and Partnership.

R&D 100 Award and Partnership (see figure 49)

A space-age thermoplastic hailed as a breakthrough in solar propulsion and power has been named one of the 100 most significant new technical products of 1999 by R&D Magazine. The NASA invention (LARC CP-1 and CP-2) has been adapted for use on solar-powered satellites by SRS Technologies in Huntsville, Alabama. In August 1999, the company made a further commitment to commercial development of the technology by signing an exclusive manufacturing and marketing license with Langley.

Painless Dentistry (see figure 50)

Lantis Laser, Inc., Hewitt, NJ, has licensed from NASA Langley Research Center a multi-wavelength laser. The technology was originally investigated in support of one of NASA's remote sensing programs as a method of measuring water vapor or the density of atmospheric constituents. That investigation led to the discovery that it was possible to selectively produce two or more useful wavelengths from a single laser source. Lantis Laser and Langley Research Center will partner to refine the performance of one of their inventions and to apply the results to the development of a new class of dental lasers.

The goal of Lantis' research is to produce, from a single laser system, the two specific wavelengths that have been approved by the FDA for use in dentistry.

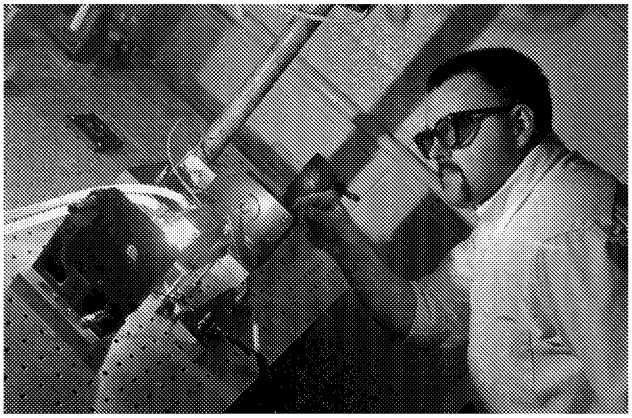


Figure 50. Painless Dentistry.

One of these wavelengths is effective on hard tissue, such as teeth, and will replace the dentist's drill. The other wavelength is effective on soft tissue, such as gums, and will replace the scalpel for gum surgery. In approximately 95% of procedures anesthesia is not required.

Only 5% of the approximately 140,000 practicing dentists in the United States currently use a laser system for preparing a tooth for filling or for gum surgery. The greatest barrier to the rapid growth of this technology in the dental profession has been the cost of the equipment. By replacing two laser systems with one, the dual wavelength laser will be commercially attractive.

Aviation Research May Help Diabetics (see figure 51)

Technologies derived from NASA aviation research may soon be used to help patients with diabetes. Preliminary observations show that NASA's artificial vision technology can be effective in visualizing and controlling blood flow to a person's hands and feet for those at risk from neuropathy or nerve damage associated with diabetes. The biomedical application comes from research conducted over a several-year period aimed at enhancing aviation safety. It combines the two technologies of non-invasive biosensors and powerful computer graphics. The graphics technologies are used in research with cockpit artificial vision systems to help pilots see in low- or no-visibility situations, and as data visualization tools to help designers study air flow patterns around new aircraft shapes.

In studies begun in Fall 1999, diabetes patients will wear a 3-D virtual reality headset to visualize the contraction and expansion of their own blood vessels,

Figure 51. Aviation Research May Help Diabetics.

using biofeedback methods to increase blood flow. Blood flow will be measured through sensors attached to patients' fingertips. The system uses skin surface pulse and temperature measurements to create and display a computer model of what's actually happening to blood vessels under the skin. Just as pilots are enabled by artificial vision to "see" places they couldn't see previously, patients are enabled by this virtual reality device to see where they can't—beneath the skin. The studies will be conducted by the Strelitz Diabetes Research Institutes of Eastern Virginia Medical School in Norfolk, Virginia. Studies will also begin at the same time with the Behavioral Medicine Center at the University of Virginia Health System to evaluate the technology for the treatment of other blood flow disorders.

High Performance Insulation Technologies Using Polyimides (see figure 52)

NASA Langley and Unitika America jointly developed a polyimide foam to meet an aerospace industry demand for high-performance structural foam with increased stiffness but without significant weight penalties. NASA Langley Research Center in cooperation with Unitika America, has developed a line of innovative insulation technologies based on polyimide foam, which can be foamed in place for installation and repair—dramatically saving both labor and material costs.

Figure 52. High Performance Insulation Technologies Using Polyimides.

RETINEX (see figure 53)

Researchers at NASA Langley Research Center and Science and Technology Corporation (STC) have invented a new method for enhancing digital images. The method is a form of retinex image processing developed from Edwin Land's retinex (retina+cortex) theory of human color vision. An outgrowth of basic scientific research and its application to NASA's remote sensing mission, the retinex method is an automatic general purpose algorithm which greatly improves the visual realism and quantity and quality of perceived information in the digital image. Previous methods of image enhancement were either insufficiently powerful or required tedious and expensive manual user interactions, and were not comprehensive.

The specific method is called the Multi-scale Retinex with Color Restoration (MSRCR) and has been jointly patented by NASA and STC. This patent recently received the NASA Space Act Award as one of NASA's most significant inventions of 1999. STC has created a new company, TruView Imaging (TVi), specifically to commercialize this new imaging technology. TVi is in the process of licensing retinex to develop commercial software packages and hardware processors for video and large format imaging, as well as embedded processing for smart cameras and document applications. The benefit of this new technology is that it enables an entirely new level of visual realism and visual quality in digital imaging and does so with the ease, low cost, and speed of automatic operation.

Laser Technology Licensed to Big Sky

Aerospace technology originally developed for studying Earth's atmosphere from space has been licensed to a U.S. company to increase the reliability of lasers used for everything from medical applications and product fabrication to detection of gas leaks. NASA Langley Research Center, Hampton, Virginia, has licensed the technology to Big Sky Laser Technologies, Inc., Bozeman, Montana. As more and more laser users are taking lasers out of the lab and into

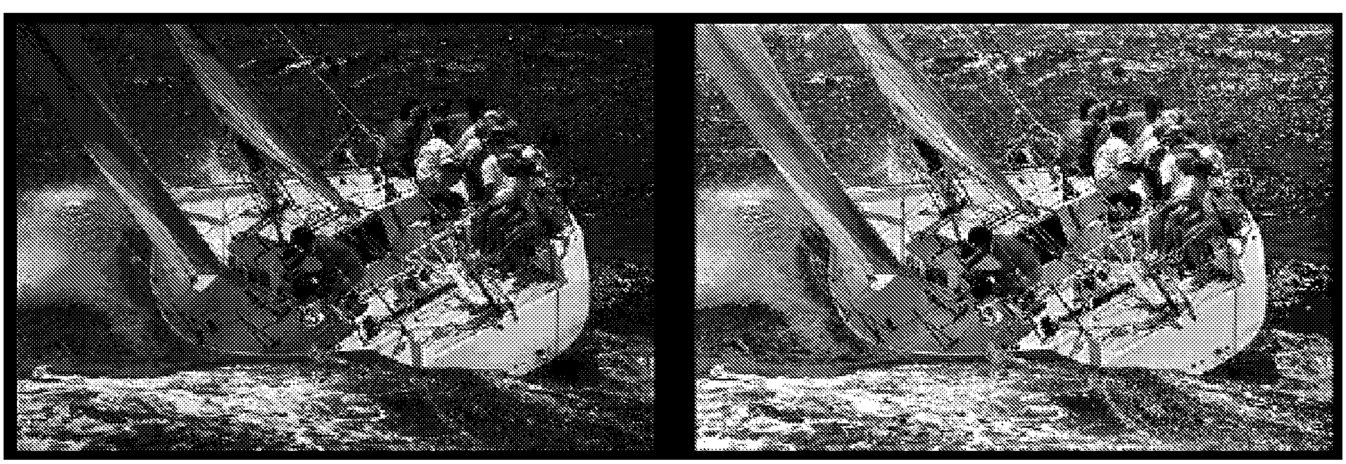


Figure 53. RETINEX. **(Color version is on report website.)**

industrial applications, NASA's "laser protection circuit" technology promises to allow lasers to perform more reliably in real-world applications. Expected applications include monitoring pollution and tracking its sources; detection of methane and other hazardous gas leaks; use in the offices of dermatologists, medical doctors, and plastic surgeons; use in factories for fabrication, marking and laser cleaning; and for a world of applications that have not yet been imagined.

Fatigue Monitoring

A method and apparatus that can assess the state of "incipient" fatigue—metallic structure that has been fatigued, but has not yet actually initiated a crack—has been demonstrated to be effective in determining the health of turbine blades in service with several fossil fuel fed electrical power generating facilities. This activity, aimed at maturing and furthering the development of this ultrasonic-based nondestructive evaluation (NDE) technology, is being carried out under a Space Act Agreement with Virginia Power.

As an acoustic wave passes through a material, nonlinearities in the material produce harmonics of the acoustic wave. The amplitudes of the incident wave and its harmonics are related by a nonlinearity parameter. This parameter is influenced by several material conditions, including fatigue state.

Although this technology can potentially be used for a broad range of NDE applications, the immediately targeted use is for the detection of incipient fatigue in turbine blades. Current techniques are capable of detecting fatigue only after some cracking has occurred—a situation in which material failure closely follows. Such failures can result in extremely high financial loss, as in the case of an electric power-generating turbine, or in putting human lives at peril, as in the case of an aircraft engine failure.

Other accomplishments

In an attempt to stimulate the development of new technologies, there were 48 SBIR (Small Business Innovative Research) Phase I proposals selected and 17 SBIR Phase II proposals selected. In addition, there were 5 Phase I STTR (Small Business Tech Transfer) and 3 Phase II STTR awards for a total value of $15 million.

NASA Langley Research Center was selected as one of six Centers to receive 2-year funding to support development of partnerships with Minority-Owned and Women-Owned businesses. This funding will enable these businesses to benefit from the NASA Technology Transfer and Commercialization Program. Through these partnerships, businesses will have access to technologies and processes that may help them and increase their competitiveness in the marketplace.

During the year, there were 121 invention disclosures, 27 patent applications, and 28 patents granted from Langley Research Center. There were 8 patent licenses and 11 sublicenses executed. Thirty-three Space Act Agreements were signed.

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This report contains highlights of some of the major accomplishments and applications made by NASA Langley Research Center and its university partners and industry colleagues during 1999. The highlights illustrate the broad range of research and technology activities carried out by NASA Langley and the contributions of this work toward maintaining United States' leadership in aeronautics and space research. The Center's historic national role since 1917 continues in Aerospace Technology research with an additional major role in Earth Science research. Langley also partners closely with other NASA Centers and the Jet Propulsion Laboratory in Space Science and the Human Exploration and Development of Space. A color version is available at http://larcpubs.larc.nasa.gov/randt/1999/. For further information, contact Dennis Bushnell, Senior Scientist, Mail Stop 110, NASA Langley Research Center, Hampton, Virginia 23681-2199, (757)-864-8987, e-mail address: d.m.bushnell@larc.nasa.gov.