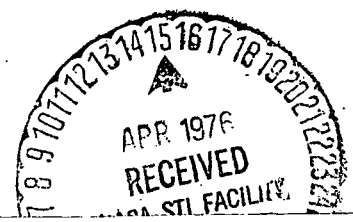
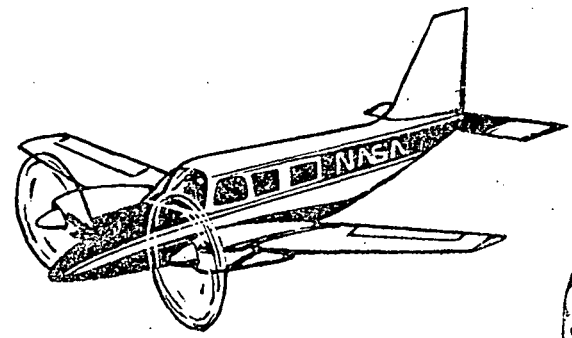


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# General Aviation Technology Program



(NASA-TM-X-73051) GENERAL AVIATION  
TECHNOLOGY PROGRAM (NASA) 20 p Avail: NASA  
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**NASA**  
National Aeronautics and  
Space Administration

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## GENERAL AVIATION

### Research and Technology Program

The importance of the general aviation segment of the U.S. Civil Air Transportation System continues to grow. Each year virtually every indicator of effectiveness increases. The continuing growth in hours flown, people, cargo and mail carried and acres of crops serviced are reflected in the increased production and sale of new airplanes and equipment around the world. This year, for the first time, industry statistics show \$1 billion in sales.

These increases over the past few years have been paralleled by the growing emphasis placed on general aviation by NASA. In terms of resources, the NASA general aviation program has grown from \$2.7 million in FY 1973 to \$8.5 million in FY 1977. From a small number of individual projects, the NASA program has progressed to a coordinated effort addressing nearly all of the major technological problems in light aviation.

Industry participation and support of the NASA effort has grown even faster than the program itself. Through the Research and Technology Advisory Council's Panel on General Aviation Technology, the technical workshop series and joint research efforts, the specific needs of general aviation are being reflected in NASA research programs.

In several areas, results from NASA research efforts are being refined in product development programs by the industry. Notable among these are aerodynamic improvements in the form of new airfoils. Flight control and high lift devices and airfoil modifications are currently in prototype flight testing. Techniques developed by NASA for spin testing have been widely accepted and used by the industry over the past two years.

To insure an adequate base of new technology to support the continued growth in the utility of the light airplane, NASA plans to carry out general aviation-oriented efforts in each of the aeronautical disciplines. The objectives of the NASA program are to provide new technology across the board for improvements in safety, efficiency and for reduction of the environmental impact of general aviation.

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As the use of small aircraft expands, particularly as a means of transportation, safety becomes of increased concern. Although the rate of both accidents and fatalities continues to decline, increased operations result in a slightly increasing number of fatalities each year.

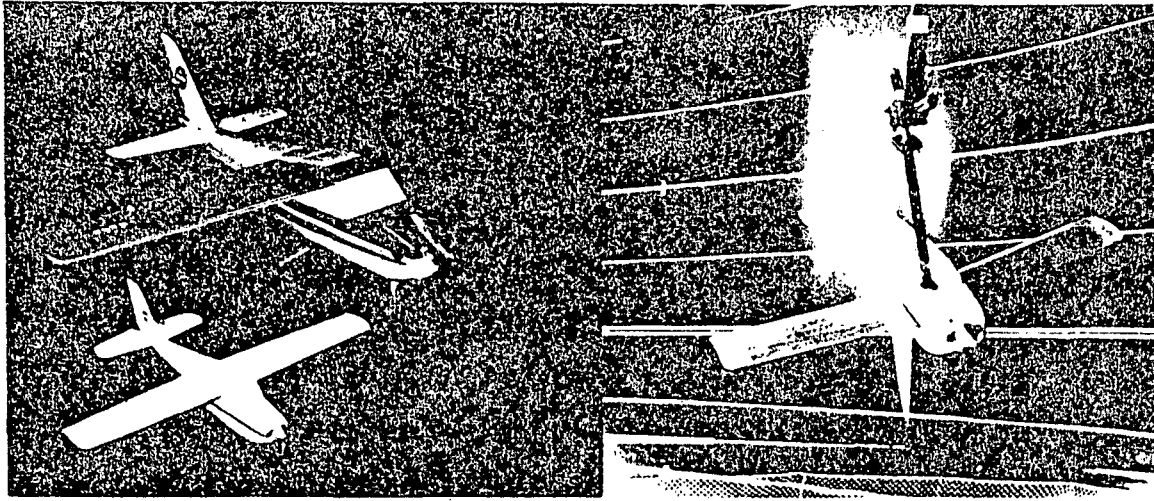
### Stall/Spin Research

While there are many factors responsible for accidents, the largest single factor in general aviation fatal accidents is the stall/spin. The research objective of the NASA general aviation stall/spin research effort is to provide design data and criteria for efficient light aircraft that will not stall or spin unintentionally. As represented in Figure 1, parametric data on spin entry and recovery are being generated in a long range program that will ultimately provide a basis for future aircraft design. The majority of the data is acquired using the spin tunnel and radio controlled models. Sufficient full-spin testing will be accomplished to verify accuracy of the model data. To date, more than 2,500 test runs in the spin tunnel and 300 free-flight radio controlled model flights have been completed. This represents about 35 per cent of the planned program. Because of delays in fabrication of the modified tail assemblies, the first series of full-scale spin tests will begin in the spring of 1976.

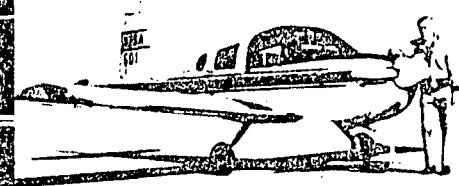
Interim results in the form of technical reports summarizing available data and providing spin recovery parachute design parameters have been disseminated. The now widely used radio controlled model test technique was an early development from this effort.

A separate effort, but an integral part of the stall/spin solution, is concentrating on predicting and modifying the stall characteristics of the wing through aerodynamic changes. Results from this effort hold promise for designing into a wing the specific stall behavior required without loss in efficiency or performance. Demonstration of the analytically derived technique will be carried out through wind tunnel testing and flight validation.

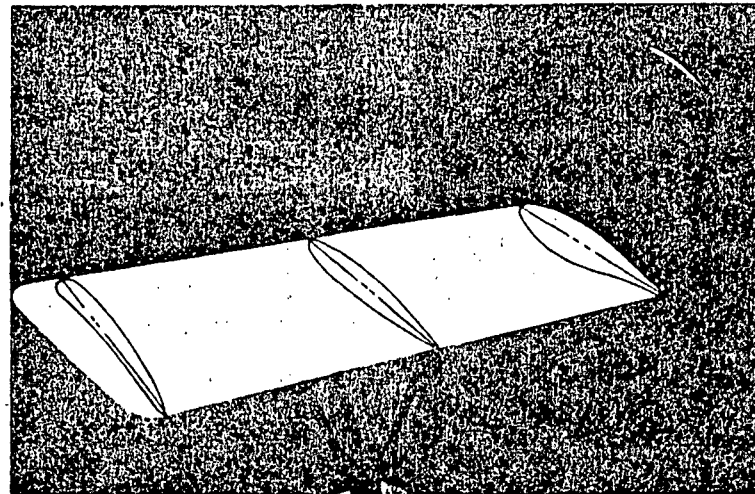
# NASA STALL/SPIN RESEARCH



MODELS FOR DEVELOPMENT OF DATA BASE



FULL SCALE AIRCRAFT FOR VALIDATION



AERODYNAMIC DESIGN FOR OPTIMUM STALL RESISTANCE

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Figure 1

### Crashworthiness

A second major effort addressing safety in general aviation is illustrated in Figure 2. This program will develop design data and procedures for improved structural crashworthiness. A joint NASA-FAA-industry program, it is developing structural design procedures to provide for greater protection of passengers in the event of a crash. Theoretical analyses and prediction of the dynamic behavior of the aircraft structure under crash impact loads are the basis for new design procedures. Full-scale simulations of aircraft crashes are being carried out -- to provide data for validation of theory and to evaluate airframe components under actual crash impact conditions.

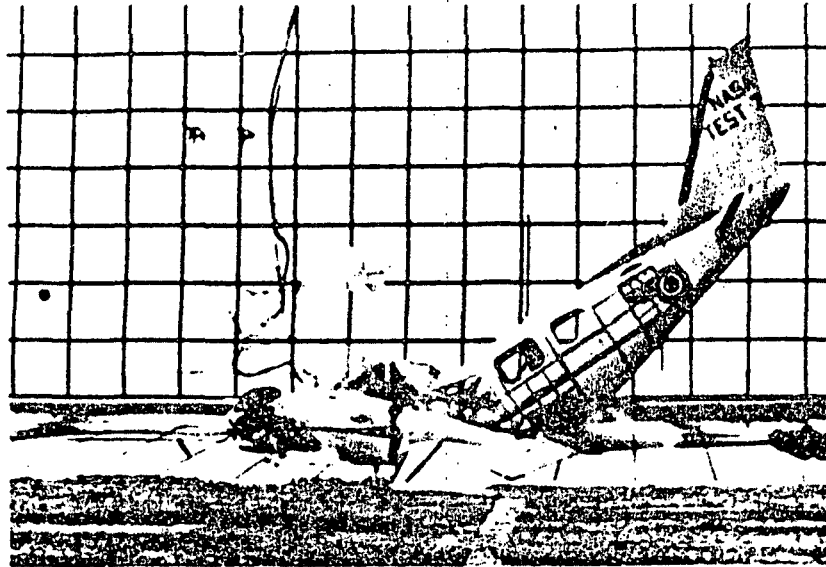
To date, nine full-scale tests have been conducted, including one CH-47 helicopter. Six additional tests will be carried out during the next year. Preliminary data thus far indicate that the greatest loads are vertical and are encountered during the secondary impact. The implication is that energy absorbing seats may provide greater benefit than anticipated. A NASA/industry workshop is scheduled for the spring of 1976 to summarize the results to date.

### Pilot Operations

Pilot procedures and operations in the uncontrolled environment of general aviation airports are being explored in the several programs represented in Figure 3. As described in previous statements, a statistical definition of aerodynamic loads experienced across the spectrum of aircraft types and operations is being developed. The latest report on the analyzed data was issued in December 1975. Approach and landing procedures have been documented and reported. Traffic patterns flown at and near uncontrolled airports are being studied to understand their relationship to midair collision potential.

As a result of studies of traffic near the uncontrolled airport, a concept has been developed that holds promise for providing a reasonable increment of protection and advisory service to aircraft operating from these fields. Based on the combination of existing commercial radar, mini-computers and voice synthesizers, it appears that an automated pilot warning and advisory system can be developed.

# NASA RESEARCH FOR IMPROVED CRASH WORTHINESS

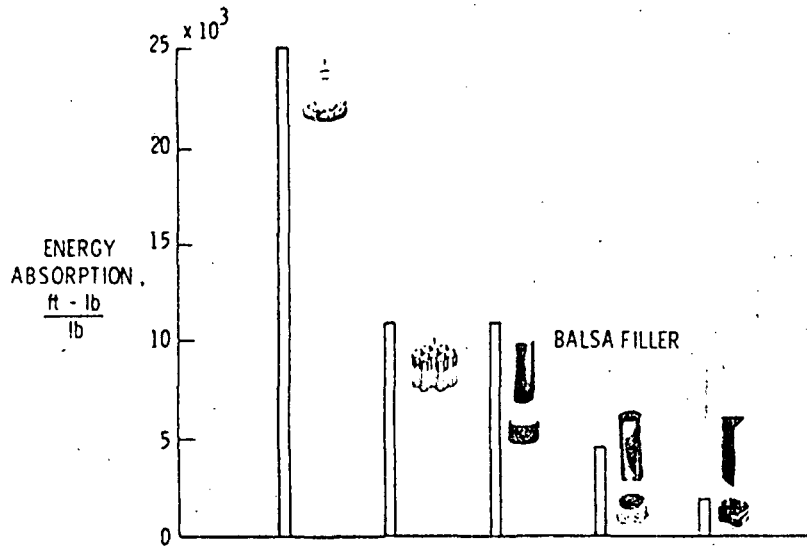


**FULL SCALE TESTS**

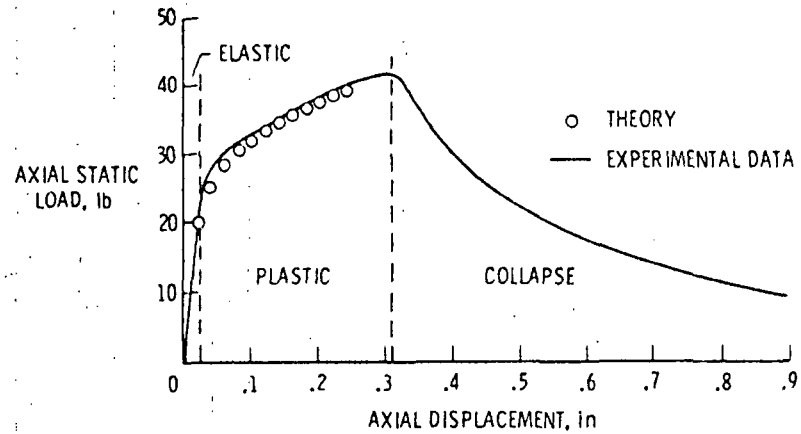
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**COMPONENT TESTS**

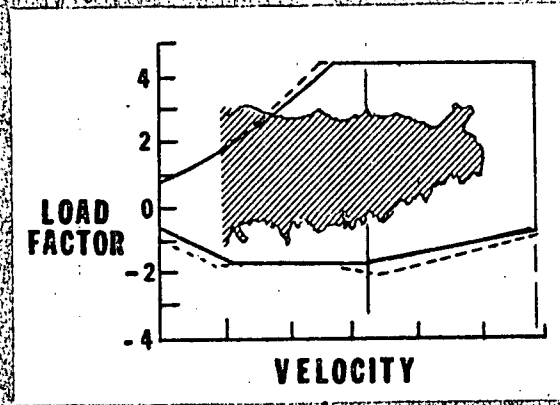


**ANALYTICAL PREDICTION**

Figure 2

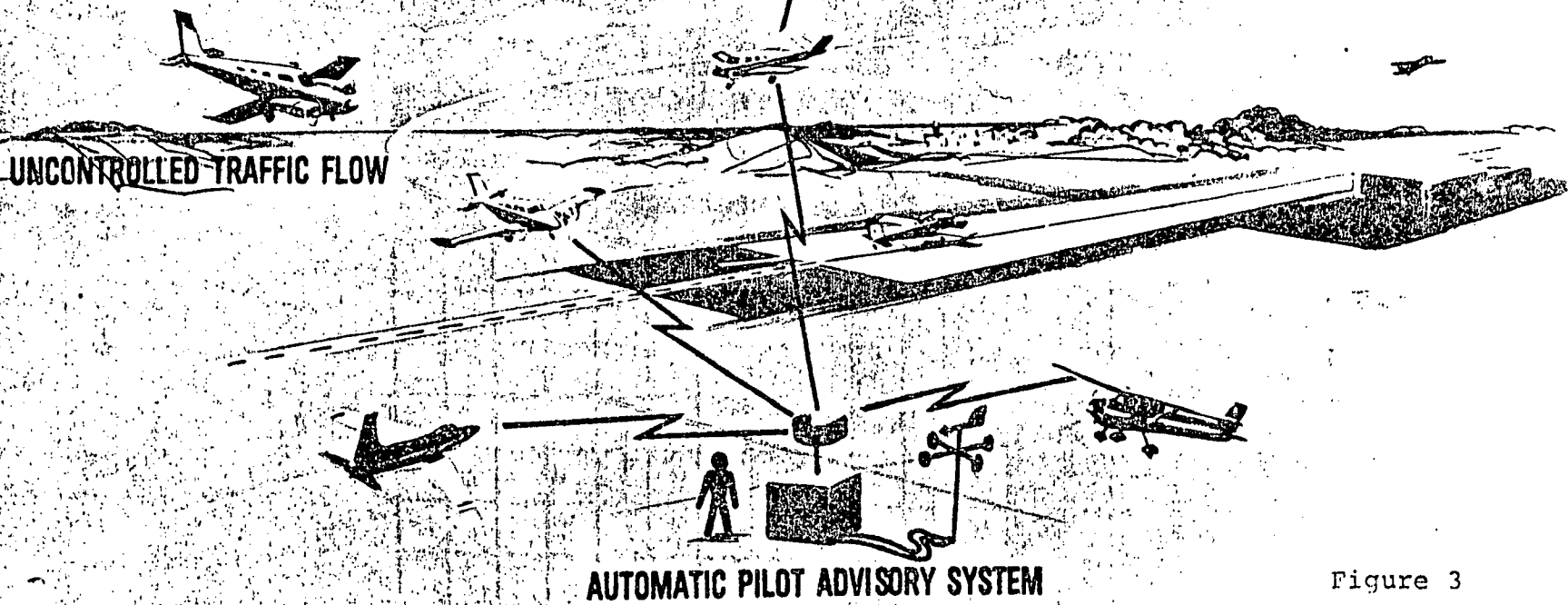
# NASA RESEARCH ON PILOT PROCEDURES AND OPERATIONS

## AERODYNAMIC LOADS



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Figure 3



Such a system would detect and announce the location and direction of all traffic within a limited area surrounding the airport. Potential collision threats would be identified and a warning automatically broadcast. Automatic sensing and announcement of airport conditions such as wind, pressure and temperature could be included. Components are currently being evaluated, with a breadboard demonstration planned by the end of this year. Estimates are that with a reasonable production quantity, the unit price would be about the same as the cost of a single engine trainer airplane.

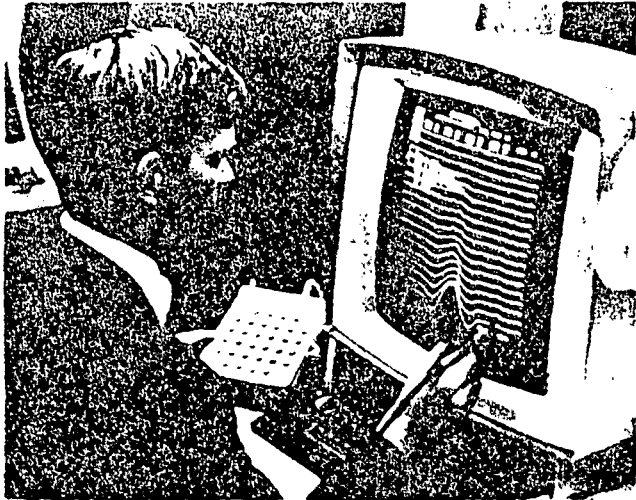
Entry into IFR conditions for an inexperienced pilot can cause problems ranging from loss of geographic orientation to full loss of control. Efforts toward use of fluidics for flight control and sensors are showing promise for extremely low cost and very high reliability. Two wing leveler autopilots have been demonstrated in the past year. This work is being extended to show feasibility of a three-axis autopilot. Emphasis this year will be on demonstration of all fluidic stall onset sensors.

#### Flight Efficiency

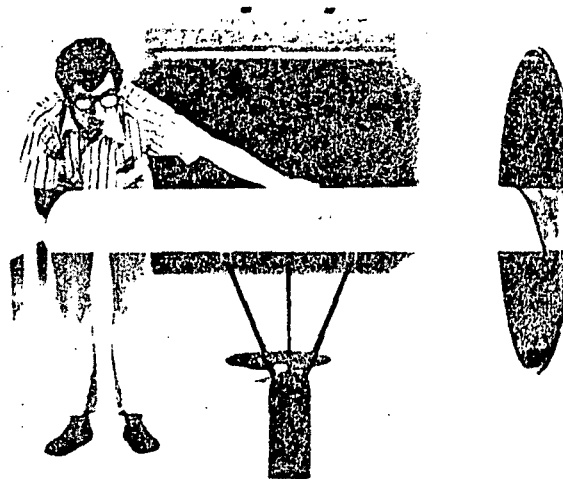
Overall efficiency of the light aircraft in terms of payload versus gross weight or speed versus horsepower has not changed significantly for several decades. Modern aerodynamic, propulsion and systems technology, if it can be developed to meet the economic levels of general aviation, can provide significant advances in airplane and systems efficiency.

Previous NASA emphasis has concentrated on low speed aerodynamics, particularly with respect to airfoil development. As shown in Figure 4, the initial result of this effort was the GAW-1 airfoil. Seventeen per cent thick and optimized for general aviation application, it exhibits significant improvements over previously available airfoils. Wind tunnel tests of the GAW-2 have now been completed and reported. This 13 per cent thick airfoil shows marked improvements in both lift and drag capability over its predecessor. Design data on flaps and control devices for these airfoils are also being developed. Expansion of this series of airfoils will continue, exploring both thicker and thinner sections and a range of design lift coefficients.

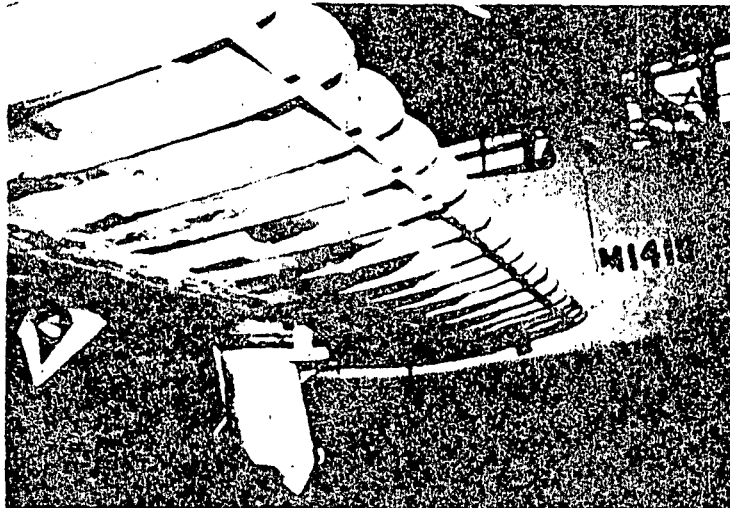
# NASA AIRFOIL DEVELOPMENT



COMPUTATION



WIND TUNNELS



FLIGHT VALIDATION

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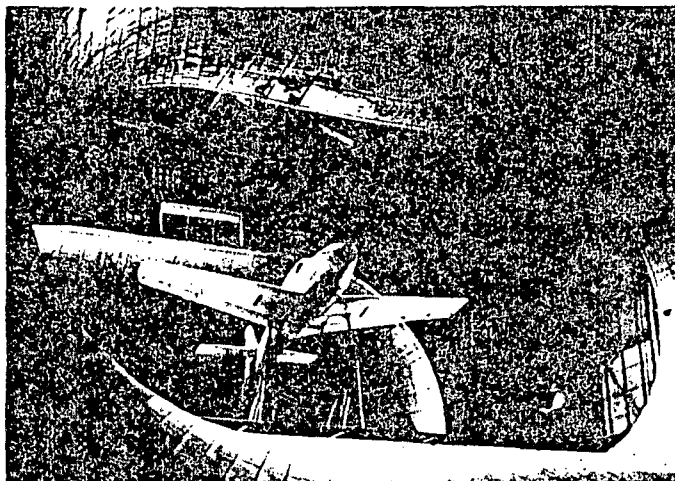
Wind tunnel-derived airfoils are the basis for virtually all existing light aircraft designs. Traditionally an airfoil is chosen from "handbook" or wind tunnel data permitting the designer to select the available airfoil data that comes nearest his needs. Modern computational aerodynamics have now reached a level of precision in the low speed range that permits an airfoil to be optimized for each specific application. NASA has used these techniques extensively in support of in-house programs, as do the large transport manufacturers. To provide these tools in a form accessible to the entire general aviation community, NASA is establishing an airfoil design facility under contract. Once its capability has been verified, the facility will provide design service to both the industry and NASA on a self supporting basis.

Illustrated in Figure 5, increased airplane efficiency is synonymous with reduced aerodynamic drag. While much applicable work was done on drag reduction in the low speed range during World War II, it was highly configuration specific. Many evolutionary changes in light aircraft design since that time have resulted in configurations that are considerably different.

An example of this is the use of the flat, horizontally-opposed air cooled engine. The drag generated in cooling the engines is variously estimated to be between 5 and 20 per cent of the total cruise drag of the airplane. Current practice in the design of cowlings and internal flow is for the most part a cut-and-try procedure, since no design data base exists. Two universities, working closely with several airframe manufacturers under NASA sponsorship, are conducting research into the critical areas of engine cooling drag. Studies of engine cooling fin design, internal flow optimization and testing techniques are being undertaken. The result of this continuing effort will be a design procedure with supporting data and test procedures that will minimize losses in efficiency through excessive engine cooling drag.

The total drag of an airplane is a summation of a number of identifiable components. While many of these can be studied independently, the drag resulting from interference between the flow fields of the various components requires a complete airplane for study. An effort at the Langley Research Center will provide a modern set of design data for drag reduction for current and future light aircraft configurations.

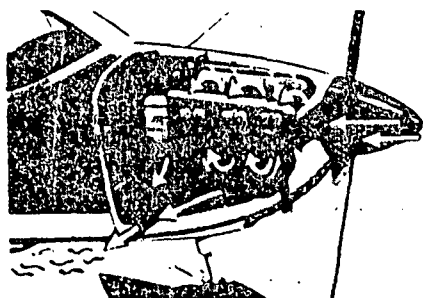
# IMPROVED EFFICIENCY THROUGH DRAG REDUCTION



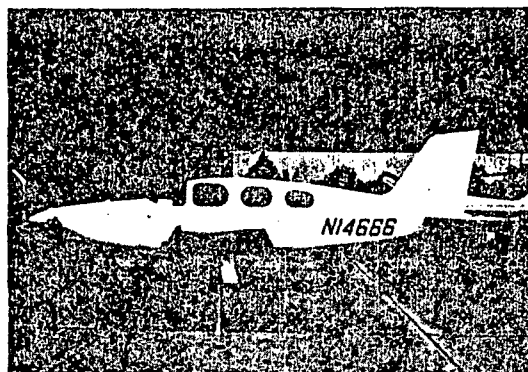
FULL CONFIGURATION DRAG CLEAN UP

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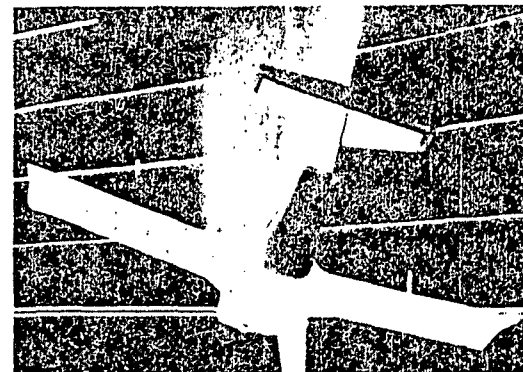
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ENGINE COOLING



SKIN FRICTION



INTERFERENCE

Figure 5

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Small-scale wind tunnels, full-scale wind tunnels and instrumented flight tests will provide data for reducing total airplane drag. Scheduled to start in FY 1977, this effort will carefully review previous techniques for drag reduction as applied to current configurations and speeds. Where existing concepts or data do not apply, new procedures will be developed.

### Propulsion Research

In direct opposition to drag is the thrust provided by the propulsion system. Heavily oriented toward reduction of environmental impact, as shown in Figure 6, several specific propulsion efforts are also directed toward improved efficiency.

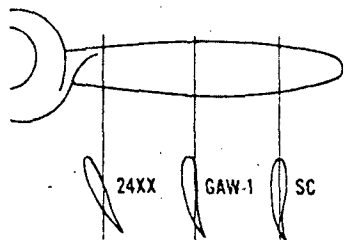
The first of these efforts is addressing propeller efficiency. This year NASA will conduct full-scale wind tunnel tests on the ducted fan. The ducted fan has some promise of advantages in lower form drag and reduced noise. Studies of free propellers have included measurement of the fluctuating loads experienced by propellers under actual flight conditions.

This spring, flight evaluations of a supercritical propeller will be carried out on the Advanced Technology Light Twin (ATLIT). Later, consideration will be given to studying the use of computerized airfoil optimization techniques in the design of propellers. Coupled with potential weight savings possible through composite materials, significant gains in thrust efficiency may be possible.

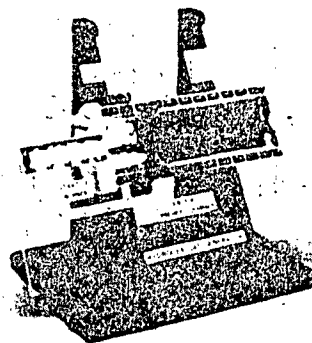
During the past year considerable progress has been made in application of the Hydrogen Enrichment Concept to aircraft engines. A team consisting of the Jet Propulsion Laboratory, Beech Aircraft Company and Avco-Lycoming are carrying out the development of a system for proof-of-concept testing.

System design studies completed this past summer predict a 24 per cent reduction in fuel used during cruise flight. A complete flight rated system is being fabricated for laboratory and simulated altitude testing. The actual flight demonstration is scheduled for completion early in 1977.

# RESEARCH TO IMPROVE PROPULSION EFFICIENCY



**OPTIMIZED PROPELLERS**

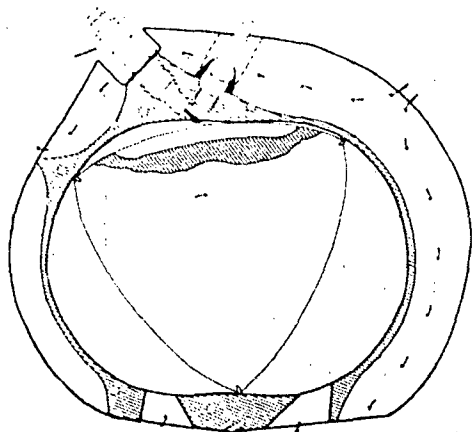


**ON BOARD HYDROGEN GENERATOR FOR  
20%+ FUEL SAVINGS**

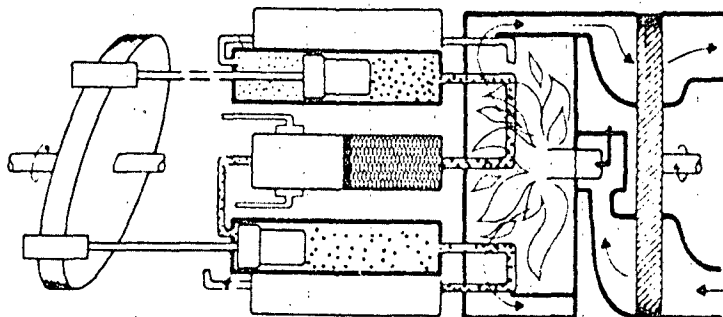
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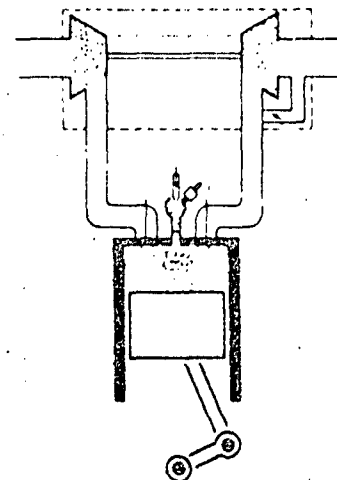


**ROTARY**



**STIRLING**

**ALTERNATE ENGINE CONCEPTS**



**DIESEL CONVERSION**

Figure 6

Existing reciprocating engines are efficient and reliable -- a position achieved through continuous refinement over many years. Opportunities for significant improvements in the basic engine or cycle efficiency are not readily apparent. The Lewis Research Center has undertaken a long-range study of alternative engine concepts that may lend themselves to future light aircraft propulsion. Several candidates have been identified for exploration during the next several years. The various rotary concepts, present Stirling and Diesel engine designs, are, in general, not practical for aircraft use. Through modification, however, they may become viable candidates. First area of exploration under this program is the conversion of an existing aircraft engine to a low compression Diesel cycle. Additional controls and preheating of the induction air may be required, but potential improvements in efficiency and performance may offset the added complications.

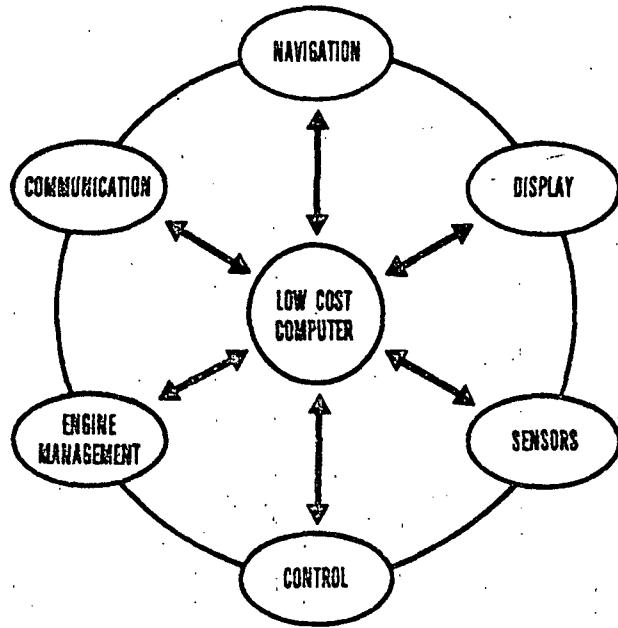
#### Avionic Research

An efficient airplane is not necessarily a productive machine. To accomplish its primary role of transporting people and goods, a light airplane must also function within the airspace system. Requirements for entry and operation within this system are continually increasing both in terms of piloting task and avionic equipment. As illustrated in Figure 7, NASA has long-range programs that ultimately will provide the basis for industry to design avionic systems to more effectively integrate the light airplane with the airspace system.

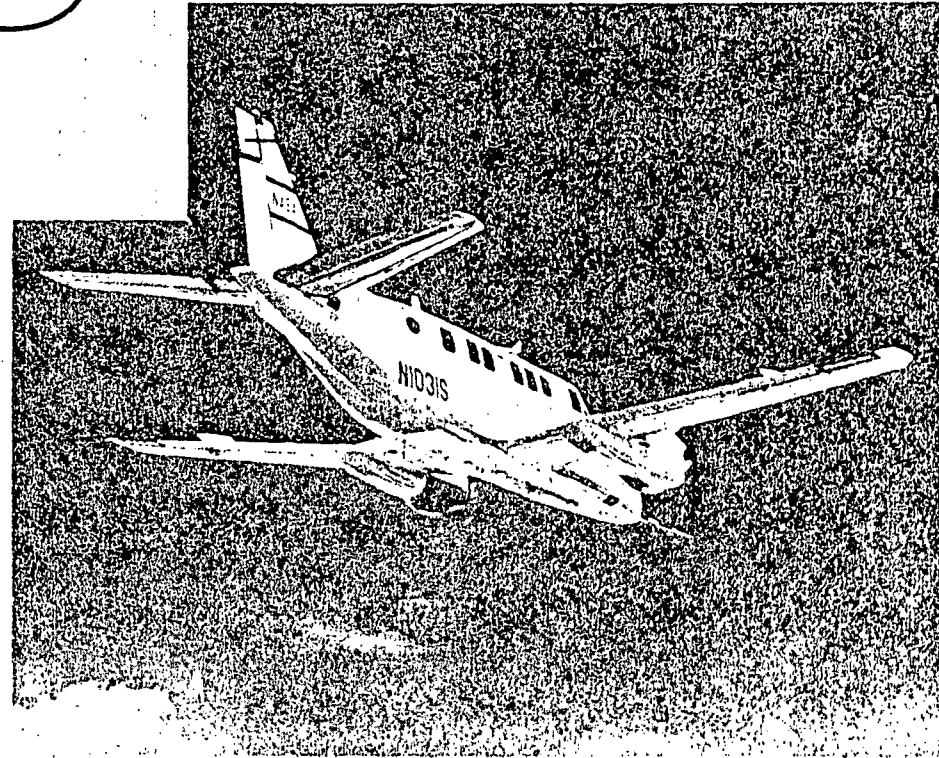
Potential for broader integration of all avionic functions into a single system concept is being evaluated in a program at the Ames Research Center. Forecasts of the avionics state of the art and the airspace system requirements for the 1980s are being developed under contract. Using these forecasts, integrated system concepts will be generated and evaluated. The avionics industry is being surveyed simultaneously to insure that plans or activities for the 1980 period are considered in our conceptual system definitions.

Flight demonstration of the separate surface attitude command control system is already well underway on a Beechcraft Model 99 commuter airliner. The system as flying and as envisioned in application is a "single thread" or non-redundant concept that is parallel to the primary system.

# AVIONICS SYSTEM RESEARCH



## SEPARATE SURFACE STABILITY AUGMENTATION SYSTEM FLIGHT EVALUATION



INTEGRATED AVIONICS SYSTEM CONCEPTS

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Figure 7



Portions of the control surfaces have been separated from the primary pilot control loop and are dedicated to the electronic command. Authority of the electronic command is limited by the physical size of the dedicated surface. Consequently should a failure occur, it would be perceived by the pilot as an out-of-trim condition, easily overridden with the normal flight control system. Preliminary results from the flight program and subjective evaluation of the pilots indicate that the concept is providing the anticipated improvements in both flying and ride qualities.

### Environmental Impact

The Environmental Protection Agency has issued emission standards governing general aviation piston engines manufactured after 1979. Federal Air Regulation Part 36f prescribes allowable noise levels for propeller driven aircraft. In some areas, business jet aircraft are restricted from certain operations under strict local curfews. New airport construction is influenced by environmental concerns. Environmental impact of the general aviation fleet must be reduced both to meet regulations and to become a more acceptable partner.

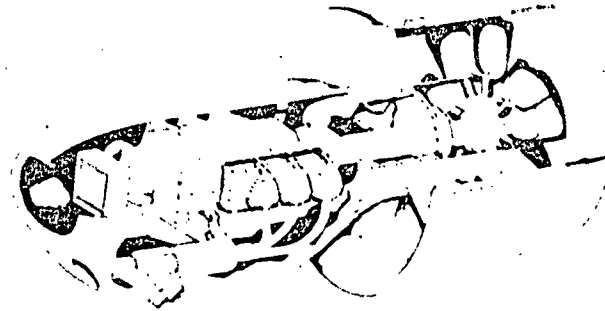
Figure 8 illustrates several NASA programs toward reduced environmental impact. NASA, the FAA and two reciprocating engine manufacturers have been working to study exhaust emissions from 10 representative aircraft piston engines and to determine the effect of varying the fuel/air ratios of emission levels and operation.

It has been demonstrated that noise from propeller driven airplanes can be reduced to barely perceptible levels. These same demonstrations also show totally unacceptable penalties on performance and efficiency. NASA efforts in propeller noise reduction seek to develop and demonstrate advanced noise reduction technology that will meet or exceed noise standards with minimum performance penalty and no compromise in flight safety. Detailed measurements will also be made of noise signatures of several typical light aircraft. These data will provide a baseline for future wind tunnel and flight testing of new propeller concepts.

# RESEARCH TO REDUCE ENVIRONMENTAL IMPACT



**PISTON ENGINE EXHAUST EMISSION REDUCTION**



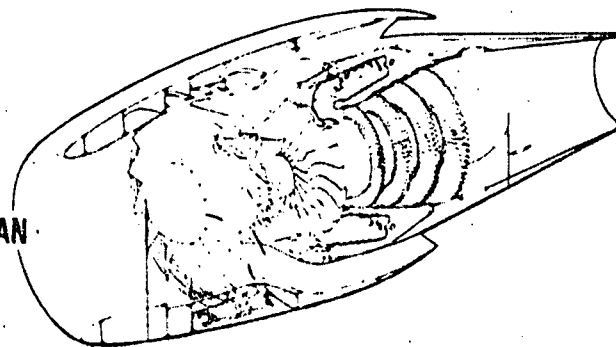
**PROPELLER/PROPULSOR NOISE REDUCTION**

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## QUITE CLEAN GENERAL AVIATION TURBOFAN

**HIGH BYPASS RATIO TURBOFAN**



**EXISTING CORE ENGINE**

Figure 8

Small turbofan engines used in business jet aircraft are faced with the same environmental constraints as large transport engines. Significant research has been devoted to reducing the noise and emissions from transport-size turbofan engines. NASA now has an experimental program to demonstrate applicability of large engine research to the small turbofan. The program is called the Quiet Clean General Aviation Turbofan (QCGAT) Program.

Application of new technology to the business jet will ultimately result in quieter aircraft. However, most of the more than 1,600 business jet aircraft currently flying in North America are powered by engines not specifically designed for low noise. NASA, jointly with the FAA and the National Business Aircraft Association, carried out a program to document approach noise levels of representative business jet aircraft. For existing airplanes, test data are required to formulate operational procedures to minimize community noise exposure.

Five aircraft were flown through four different approaches. Using the standard three-degree approach as a baseline, data were taken during four-degree, three-degree low drag and two-segment approaches. In each case, definite noise reductions were recorded. However, it was also shown that the pilot workload progressively increased.

#### Agricultural Aircraft

In addition to the technical programs just described, an additional area has been identified as a possible candidate for specific NASA research efforts. The area under consideration, as represented in Figure 9, is the development of new technology to increase productivity of aircraft used in agriculture. Pending results of further analysis, a program will be defined and is being planned.

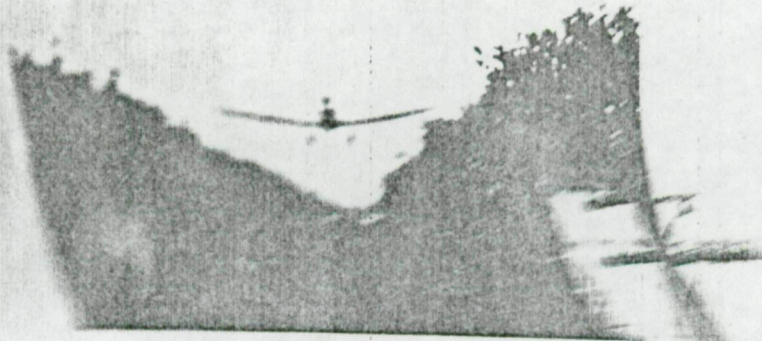
A brief study begun by NASA in November 1975 is documenting the significant role played by aircraft in U.S. and world food production and is identifying areas where NASA research may provide additional benefits.

In 1974, the Research and Development Committee of the National Agricultural Aviation Association (NAAA) performed an analysis which indicates that a 10 per cent increase in the \$100 billion annual farm production can be directly attributed to the use of aircraft.

# PROBLEMS IN AGRICULTURAL AVIATION



DISTRIBUTION  
SYSTEMS  
ACCURACY



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This \$10 billion return is generated from aerial application of seeds, fertilizer and pesticides to 200 million acres each year. This acre total represents multiple applications to the same cropland, since of the 350 million acres under cultivation in the U.S., it is estimated that only 15 per cent (52.5 million acres) benefit from aerial application.

Use of the airplane and its benefits can be significantly increased if several problems can be overcome. Chemical drift control and the related problem of precise application are the major concerns. Available equipment and techniques often apply twice the amount of chemicals actually required. Corrosion of the aircraft structure is another major concern. Aircraft efficiency in terms of takeoff and landing, cruise or ferry speed, application speed, turning and stability and control can be improved. A systems approach to design of both airplane and application equipment as a unified dispersal system appears to be the most appropriate first step.

Strong support for NASA research in this area has been shown by both the industry and user community.

#### Summary

General aviation research is receiving strong and growing support within NASA. Problems and concerns of the industry reflected by recommendations of the Research and Technology Advisory Council's Panel on General Aviation are being addressed in our research programs. NASA's communication with the industry and user community continues to improve, on a formal level and through more direct involvement in the research activities.

Results from several recent programs are being used by industry in designing new aircraft. While many technical problems remain, mechanisms for developing solutions through NASA research now exist.



March 1976