OVERVIEW OF NASA AERONAUTICAL PROPULSION
RESEARCH AND TECHNOLOGY PROGRAM

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Abstract

Traditional research objectives in aeronautical propulsion emphasize improved performance with broadened operating capabilities, reduced weight, increased durability and greater cost effectiveness. Newer objectives include reduced environmental impact (noise and exhaust pollution emissions) and increased emphasis on energy conservation. NASA's propulsion research and technology program encompasses all these objectives, and includes basic research in the many related technical disciplines, systems analyses, component technology, full scale engine and propulsion system investigations and technology demonstrations. The program involves five NASA research centers, contracted industrial research and university research grants. This paper summarizes the NASA program, with emphasis on environmental impact minimization research.

I. Introduction

NASA's aeronautical propulsion research and technology program began in a modest way during the 1930's in the original NACA research center at Langley Field, but in the early 1940's it was shifted to the new Lewis Flight Propulsion Laboratory--now NASA's Lewis Research Center--which had been built for that purpose at Cleveland, Ohio. Research in certain areas of propulsion is also conducted by the Langley Research Center, the Ames Research Center at Moffett Field, California, the Flight Research Center at Edwards Air Force Base, California, and by the Jet Propulsion Laboratory at Pasadena, California.

In the early years of NACA, all NACA's research was conducted within its own laboratories. Today the program is a combination of in-house research, research contracted to industrial firms, and research through NASA grants at many universities. This arrangement effectively multiplies NASA's in-house capacity in both facilities and personnel, and in many instances provides opportunities for alternative, competitive research approaches which would otherwise not be possible. The industrial participation also facilitates technology transfer from laboratory to practice.

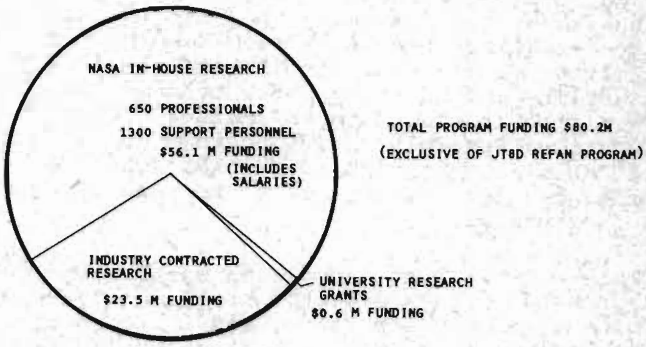


FIGURE 1. NASA AERONAUTICAL PROPULSION - RESEARCH AND TECHNOLOGY RESOURCES, FY 1974.

Figure 1 indicates the approximate distribution of the aeronautical propulsion program resources for Fiscal Year 1974 which ended June 30th. Almost two thousand NASA employees, of whom about 650 are professionals, were involved last year, and the total resources allocated were about $80 million*, of which seventy percent was spent on NASA personnel salaries, research equipment and in-house services. The aeronautical propulsion program is approximately twenty-five percent of NASA's total research in aeronautics.

II. Research Motivation

Aeronautical propulsion research and technology programs are all related to one or more basic motivations as shown in Figure 2.

- INCREASE PERFORMANCE
- IMPROVE FUNCTIONAL USEFULNESS
- REDUCE COSTS
- CONSERVE RESOURCES
- REDUCE ENVIRONMENTAL IMPACT

FIGURE 2. MOTIVATION FOR PROPULSION RESEARCH AND TECHNOLOGY

*Exclusive of JT8D Refan Program not shown as research and technology.

A few words about each of these motivations is in order.

Performance Improvement. The traditional motivator of propulsion research is the basic desire for more and better propulsion capabilities with less weight, volume and fuel consumption. Thrust to-weight-ratio and specific fuel consumption are two familiar figures of merit for performance.

Functional Usefulness. Some members of the propulsion community refer to this as the "-ilities" because it includes producibility, maintainability, durability, reliability and possibly a few others. It is difficult to attain and maintain high functional usefulness in modern systems, yet this is essential if the advantages of higher performance are to be realized and justified.

Costs. Developing propulsion systems for increased performance and functional usefulness is very expensive, and the cost of propulsion has become a formidable figure of merit for modern civil and military systems. Development and unit costs are important but even more so are the total costs of ownership and use, or life cycle costs. Cost reduction in this larger sense must underlie and influence every other research objective.

Resource Conservation. There is a growing need for conserving and prolonging the use of critical materials and depletable resources, and for identifying suitable future substitutes and alternatives. The most publicized example today is the fossil fuel situation. Increasing world demands for petroleum have brought a clear future requirement for eventually deriving hydrocarbon fuels from alternative sources including oil shale and coal. It should be noted also that the effects of increased fuel costs may well change our thinking about the significance of the traditional criteria and figures of merit for propulsion performance, functional usefulness and system costs.

Environmental Impact. The world has come to realize that the impact of aircraft noise and exhaust pollution on our sensibilities and environment can be substantial and must be reduced to acceptable levels. Accordingly, noise and exhaust emission limiting standards have been promulgated in many countries, with more stringent requirements for the future under consideration in many places.

The available technology to reduce noise and exhaust pollution levels adds weight, complexity and cost to the system, and may reduce both performance and functional usefulness. Major improvements in both noise and exhaust pollution reduction technology are required.

III. Program Scope and some Highlights

Figure 3 lists the many areas in which aeronautical research is being conducted within the NASA program.

FUNDAMENTALS AND COMPONENTS	PROPULSION SYSTEMS	ENVIRONMENTAL IMPACT
INLETS AND DIFFUSERS	INLET/ENGINE/NOZZLE/ AIRFRAME/CONTROL INTERACTIONS AND TRANSIENT RESPONSE.	JET NOISE AND SUPPRESSION
NOZZLES	INTEGRATED DIGITAL ELECTROMECHANICAL CONTROLS.	JET/SURFACE INTERACTION NOISE
FANS AND COMPRESSORS	DISTORTION EFFECTS	MACHINERY NOISE
COMBUSTORS AND AUGMENTORS	ALTITUDE EFFECTS	COMBUSTION AND CORE NOISE
TURBINES	AEROELASTIC PHENOMENA	DUCT ACOUSTICS
SEALS	TECHNOLOGY FOR LOW COST SYSTEMS.	PROPELLER NOISE
BEARINGS	SUPERSONIC CRUISE PROPULSION SYSTEMS.	NEAR-SONIC AND HYBRID INLETS
POWER TRANSMISSION	VARIABLE CYCLE SYSTEMS	NOISE SUPPRESSION MATERIALS
DIGITAL CONTROLS	LIFT FAN SYSTEMS	ATMOSPHERIC AND GROUND SURFACE ACOUSTIC EFFECTS.
COMPOSITE MATERIALS	ENERGV CONSERVATIVE SYSTEMS.	MOVING SOURCE NOISE EFFECTS
HIGH TEMPERATURE ALLOYS	ENERGY CONSERVATIVE DESIGN MODIFICATIONS.	NOISE FOOTPRINT PREDICTION
FAILURE MECHANISMS AND LIFE PREDICTION.	QUIET ENGINE FOR CTOL	CLEAN COMBUSTORS FOR GAS TURBINES.
FLUID DYNAMICS	STOL PROPULSION SYSTEMS	LOW EMISSION INTERNAL COMBUSTION ENGINES.
SHOCK/BOUNDARY LAYER INTERACTION.	QUIET, CLEAN SHORT HAUL EXPERIMENTAL ENGINE (QCSEE).	EXHAUST EMISSION/ATMOSPHERIC INTERACTIONS MODELLING.
HEAT TRANSFER	HYDROGEN FUELED HYPERSONIC SCRAMJETS.	KINETICS, REACTION RATES AND TRANSPORT.
MIXING	ALTERNATIVE HYDROCARBON JET FUELS FROM SHALE AND COAL.	ATMOSPHERIC MIXING MODELLING
COMBUSTION		AIRCRAFT EMISSION MEASUREMENTS

FIGURE 3. NASA AERONAUTICAL PROPULSION RESEARCH AND TECHNOLOGY AREAS

Time will not permit discussion of most of these areas here. Therefore, only a few of the program highlights, recent accomplishments and plans will be described to provide some indication of program status and emphasis. Because of the great current interest in research to reduce aircraft environmental impact, more of the topics to be discussed are from this area of the program rather than from the more frequently reported areas of detailed component and system technology, despite the fact that two thirds of our resources are devoted to these latter areas.

Advanced Multi-stage Axial Flow Compressor. Studies performed recently explored the technology requirements for new engines for advanced commercial aircraft which might come into service in the mid 1980's. These engines were found to benefit from very high pressure ratios, of the order of 40 to 1 overall, and 20 to 1 across the high pressure compressor. Modern compressors require about 13 stages to reach this pressure ratio, with average stage pressure ratios of about 1.25. Research results by NASA and engine manufacturers lead us to believe that it may be possible to achieve 20 to 1 with a six stage compressor, with average stage pressure ratios about 1.65.

NASA has therefore initiated a technology program to demonstrate the performance of a single spool compressor of overall pressure ratio of approximately 20 to 1. Studies will first be conducted to determine the required performance characteristics in as few as six stages, then an experimental program will be undertaken to explore the potential of the most promising designs. The resulting technology base will reduce the risk, time and cost of development programs leading to new transport engines since it is well known that the compressor is the pacing item in advanced engine development programs.

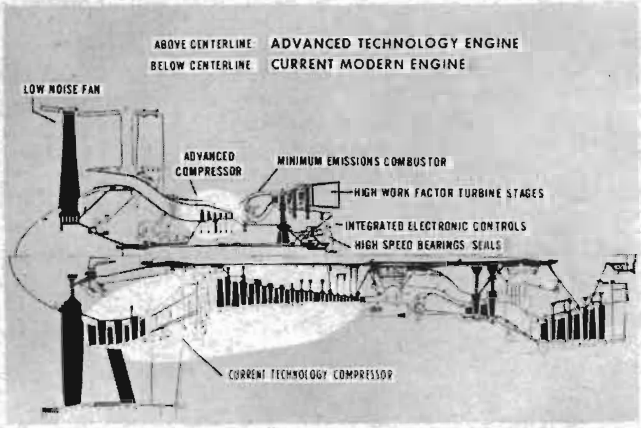


FIGURE 4. EFFECTS OF USE OF ADVANCED COMPONENTS ON REDUCING ENGINE SIZE.

Figure 4 shows the remarkable reduction in engine size which may result from incorporating an advanced multi-stage axial flow compressor and components of equivalent advanced technology level being investigated in other parts of NASA's programs for combustors, turbines, mechanical components and controls. The engine cross-section above the horizontal centerline in the figure is one concept of such an advanced engine, while the cross-section below the centerline is representative of current high bypass ratio engines in service. Compressor size comparison is highlighted in the figure.

Full Scale Engine Research Program. Full scale engine research is an essential ingredient in a balanced propulsion research program, for this reveals the real-life interactions and complex systems phenomena which are impossible to anticipate or simulate properly in component research programs. The Propulsion Systems Laboratory (PSL) at Lewis is the heart of this major research activity. It consists of four test cells capable of providing direct-connect engine air flow and altitude exhaust pressure simulations. Figure 5 shows NASA's CTOL Quiet Engine being installed in one of PSL's two 24 foot diameter cells.

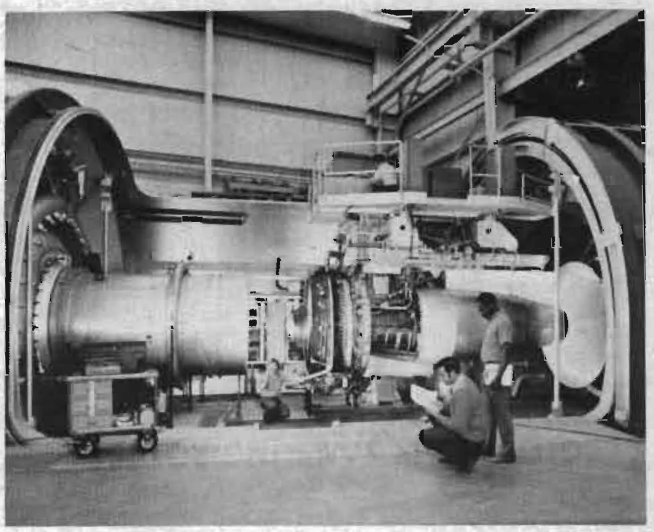


FIGURE 5. NASA QUIET ENGINE IN PSL

The PSL facilities have been used extensively to investigate effects of flow distortion using special dynamic distortion generation devices. Our research continues to seek greater insight into ways to best characterize dynamic distortion properties and to predict engine behavior. Companion to this work are programs to improve the dynamic control of propulsion systems to minimize compressor stall and inlet unstart under transient operating conditions. Both PSL and the Lewis 10 x 10 supersonic wind tunnel are employed in this work as well as flight research at the Flight Research Center.

This year NASA and the U.S. Air Force jointly began a long range, full scale engine research program using advanced development hardware. In this program the Air Force provides engines to NASA, and the NASA conducts investigations of mutual interest, providing the required engine instrumentation and data analysis. The intent is to pursue long range research goals rather than to concentrate on solution of current development problems, which are best handled at the Air Force Arnold Engineering Development Center and at the engine contractors' facilities.

The first engine in the joint program is a Pratt and Whitney F-100, which was delivered to NASA in April 1974. The test program is currently in progress in PSL. Research objectives are studies of fan blade/disc aeroelastic phenomena over a broad spectrum of engine operations. Later phases of the program will extend this investigation to the high pressure compressor, and also study engine dynamics and control phenomena through synthesis and evaluation of control concepts applicable to combined engine-inlet systems.

The second engine to be included in this program will be the J85-21, and the research program is being formulated at this time. Initial objectives will relate to compressor stage performance and overall matching.

Alternative Hydrocarbon Jet Fuels Program. NASA's program is aimed at coping with diminishing domestic oil resources by preparing for the eventual use of synthetic jet engine fuels derived from oil shale, coal, and from currently unacceptable derivatives of petroleum such as aromatics and high boiling point fractions. Coal and oil shale deposits exist in large quantity, and are natural choices for alternative sources of hydrocarbon fuels.

The United States Department of the Interior has for many years conducted research on extraction of oil from shale, and has also performed extensive research on coal liquefaction processes. It is not NASA's purpose to perform research in these areas, i.e., in refining or in related chemical engineering research. Instead, the program objectives are those shown in Figure 6.

OBJECTIVES*

- DETERMINE EFFECTS OF POTENTIAL ALTERNATIVE HYDROCARBON FUELS ON ENGINES AND PROPULSION SYSTEMS.
- DETERMINE ENGINE AND PROPULSION SYSTEM DESIGN CHANGES IF ANY REQUIRED BY ALTERNATIVE FUELS, AND TRADE-OFFS FOR PRESENT AND FUTURE SYSTEMS.
- DETERMINE SPECIFICATIONS FOR "OPTIMUM" ALTERNATIVE JET FUELS, CONSIDERING TECHNICAL IMPACT, COST, ENERGY EFFICIENCY AND AVAILABILITY.

*NOTE: ALL OBJECTIVES ARE JOINTLY PURSUED WITH MILITARY SERVICES AND CIVIL ORGANIZATIONS.

FIGURE 6. ALTERNATIVE HYDROCARBON JET FUEL PROGRAM.

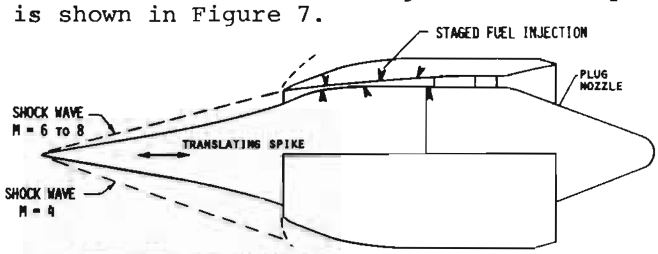
Presently, a jointly funded NASA/USAF program is underway in which an oil refinery is performing a refinery and fuel production survey in addition to acquiring small quantities of products refined from coal and oil shale for characterization studies to determine the many properties of interest.

NASA in-house research at Lewis will investigate the effects of these potential alternative fuels on combustors, turbines and other critical fuel system components, and study the relationship of these effects to fuel compositions and characteristics. Additional industrial contract research will extend this work to various engines and propulsion systems, evaluating performance, pollution, durability and other effects which may exist. The total program span is estimated to cover an eight year period ending around 1982. Present forecasts predict some commercial availability of jet fuel derived from shale oil in the early 1980's.

Just a brief reference will be made here to hydrogen as an aircraft fuel. Hydrogen properties are well known, and its usefulness and suitability as a jet engine fuel has been amply demonstrated in several engine programs including flight demonstrations. The primary issues now have to do with aircraft configurations and systems; fuel production, handling, safety, logistics, and of course cost; and overall system economics. NASA is continuing to study the economics and technology of hydrogen as an aviation fuel, and is planning appropriate research programs for future implementation. However, the introduction of hydrogen fuel into the system is judged to be decades in the future, for reasons not solely related to its properties. Thus, our propulsion program priorities require that most attention be directed to the hydrocarbon fuel problems.

Hypersonic Research Engine. Although hypersonic propulsion research is only a small part of the program, it is representative of advanced research and technology conducted because of its long range potential rather than its near term application. NASA's hypersonic propulsion program, for which the Langley Research Center is the lead Center, is concerned solely with hydrogen fuel cooled scramjet concepts. The Mach number range of interest extends beyond Mach 10 for potential future application such as recoverable launch vehicles, military strike-reconnaissance vehicles and hypersonic transports. Present NASA facilities limit the research to about Mach Number 7 at the inlet.

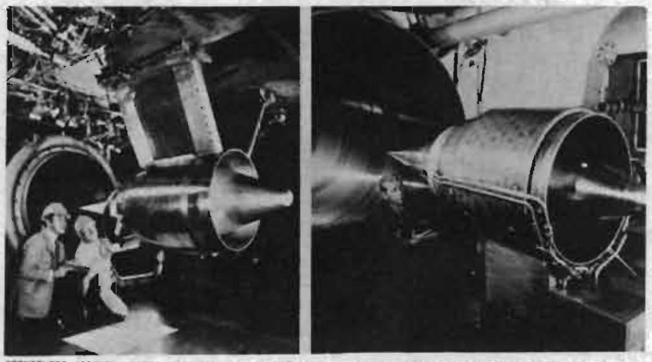
The Hypersonic Research Engine (HRE) program was initiated in 1967 at Langley. Major objectives were to establish component and systems technology for hydrogen fuel cooled scramjets which could also operate with subsonic combustion at the lower Mach numbers, and to investigate unexplored regions of flow, mixing, combustion and heat transfer. HRE was built to operate in the Mach 4 to 8 range. The concept is shown in Figure 7.



- SPIKE TRANSLATES - M = 6 TO 8 - SHOCK ON LIP
  FIXED - M = 4 TO 6
- SUPERSONIC COMBUSTION - M = 5 TO 8
- SUBSONIC COMBUSTION M = 4 TO 6
- COMBUSTOR GEOMETRY APPROXIMATELY 2-D

FIGURE 7. HYPERSONIC RESEARCH ENGINE CONCEPT

Two engines were built and tested. The first one, called the Structures Assembly Model (SAM) was built to develop and demonstrate flight-type components and fuel cooled structures, although it was not used to demonstrate actual combustion because of Langley's facility limitations. The second engine was designed as a water cooled engine for combustion and heat transfer research and was called the Aerothermodynamic Integration Model (AIM). Figure 8 shows both engines in their test facilities.



STRUCTURES ASSEMBLY MODEL (SAM) IN LANGLEY 8-FOOT HIGH TEMPERATURE STRUCTURES TUNNEL.

- MACH 7 STRUCTURAL TESTING OF THE HYDROGEN-COOLED, FLIGHT-WEIGHT HYPERSONIC RESEARCH ENGINE.
- THERMAL PERFORMANCE AND THERMAL FATIGUE DATA.
- 18-INCH DIAMETER AT COWL LIP - 86-IN. LONG.

AEROTHERMODYNAMIC INTEGRATION MODEL (AIM) IN LEWIS/PLUM BROOK HYPERSONIC TUNNEL FACILITY.

- MACH 5,6 AND 7 ENGINE PERFORMANCE TESTING OF THE WATER-COOLED, HEAVY-WALL HRE.
- HYDROGEN-FUELED SUBSONIC AND SUPERSONIC COMBUSTION PERFORMANCE DATA.
- 18-INCH DIAMETER AT COWL LIP - 86-IN. LONG.

FIGURE 8. NASA HYPERSONIC RESEARCH ENGINE PROJECT

The initial test program on SAM was completed in 1971 in Langley's High Temperature Structures Tunnel at Mach Number 7. SAM did demonstrate the adequacy of the basic component and structural designs and the complex fabrication techniques required for this kind of engine.

In April this year tests were completed on AIM, completing the HRE program. AIM tests were conducted in the Lewis Research Center's Hypersonic Test Facility at Plum Brook Station, at test Mach Numbers of 5, 6, and 7. The detailed test results from the AIM program are still being evaluated, but it appears that all test objectives were achieved. These basically were to study and demonstrate:

- o Supersonic Combustion
- o Supersonic - subsonic - supersonic combustion transition with staged fuel injection.
- o Effects of angle of attack and fuel/air (equivalence ratio) variations.
- o Heat transfer with combustion
- o Auto-ignition and kinetics

Although HRE was an axisymmetric, translating spike configuration, the basic information and systems technology achieved by both SAM and AIM will be useful in NASA's current and projected investigations of fixed geometry, modular "2D" integrated inlet/combustor/nozzle/airframe configurations of the type generally depicted in Figure 9.

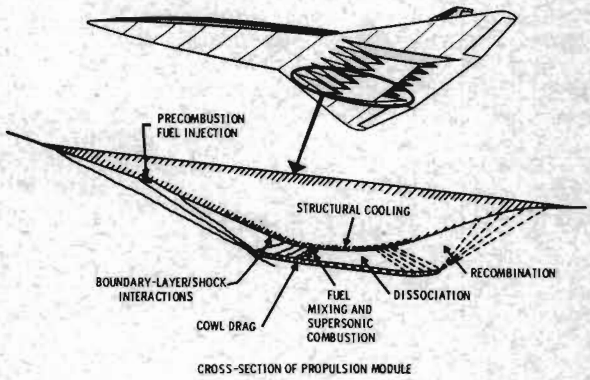


FIGURE 9. HYPERSONIC RAMJET PROPULSION RESEARCH

<u>Quiet, Clean Short-Haul Experimental Engine (QCSEE).</u> For many years NASA has explored the problems and potentials of STOL and VTOL aircraft. Recent emphasis has been placed on quiet and clean (low pollution) powered-lift systems which could be used effectively in commercial transport designs, particularly in future short-haul aircraft capable of operating economically and with environmental acceptability, using short runways near populous areas. New propulsion systems are key to success in this, and much effort has been expended on low noise fans for high bypass ratio engines to make this possible.

The QCSEE program is consolidating engine technology for these very quiet, clean, powered-lift short-haul aircraft, and is intended to demonstrate this technology with credible, full-scale experimental hardware. Major program emphasis is being placed on low propulsion system noise, reduction of undesirable exhaust emissions, maximum cycle efficiency with the core used, and high structural efficiency in the major engine components and nacelle. The demonstration goals are shown in Figure 10.

- NOISE: EQUIVALENT TO 90 EPNdB NOISE FOOTPRINT AREA LESS THAN ONE SQUARE MILE, FOR A 4-ENGINE SHORT-HAUL AIRCRAFT (APPROXIMATELY 3% OF 727 AIRCRAFT)
- POLLUTION:

CO	< 20	LBS/1000 LBS FUEL	(58 TYPICAL TODAY)
NO_x	< 10	" "	(42 " ")
H-C	< 4	" "	(15 " ")

- THRUST/WEIGHT: GREATER THAN 6:1 UNINSTALLED.
- COMPOSITE FAN BLADES, VARIABLE PITCH AND THRUST REVERSING.
- STRUCTURALLY INTEGRATED COMPOSITE NACELLE.
- INTEGRATED ELECTRONIC CONTROLS.

FIGURE 10. QCSEE TECHNOLOGY GOALS

Two QCSEE propulsion systems will be designed, fabricated and tested. The initial deliverable propulsion system will be an Under-the-Wing configuration appropriate to an externally blown-flap powered-lift aircraft. The second propulsion system will be a derivative of the first, appropriate to an Over-the-Wing configuration. The QCSEE will utilize the F-101 engine core being developed in the USAF B-1 aircraft program. This engine core will be mated with specially designed, quiet, low pressure ratio fans (1.27 for UTW and 1.34 for OTW at takeoff) and produce a very high bypass ratio engine of about 12 to 1. This very high bypass ratio has the potential for much greater fuel economy at the lower cruise speeds and altitudes applicable to future short-haul transports.

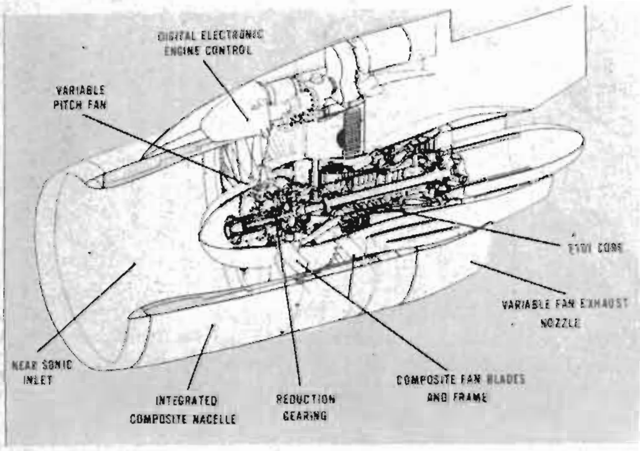
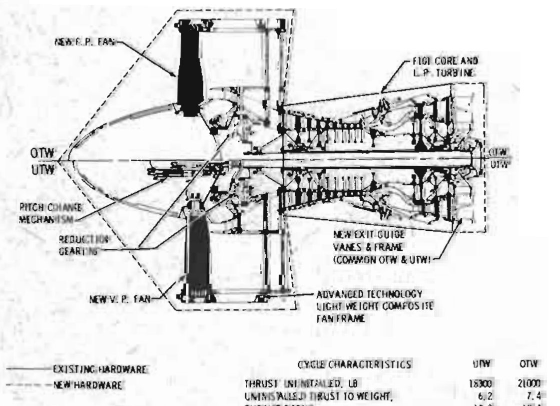


FIGURE 11. QCSEE UNDER-THE-WING ENGINE

Figure 11 indicates some of the advanced technology features to be incorporated in QCSEE which include variable pitch, composite fan blades which can also be used for thrust reversal; a lightweight, structurally integrated composite nacelle; a near-sonic inlet and integrated electronic controls. A geared fan drive will be used on the low spool. Figure 12 depicts some of the differences between UTW and OTW versions.



CYCLE CHARACTERISTICS	UTW	OTW
THRUST UNINSTALLED, LB	18300	21000
UNINSTALLED THRUST TO WEIGHT,	6.2	7.4
BYPASS RATIO	12.0	10.4
OVERALL PRESSURE RATIO	14.3	16.6

FIGURE 12. NASA/GE QCSEE CONFIGURATIONS

The experimental QCSEE propulsion systems will not be flown, but the hardware is being designed for flight except in specific areas where non-flight hardware can be used to save costs. Rotating parts and all items contributing to the acoustic and pollution characteristics of the system will be of flight design, weight, and construction.

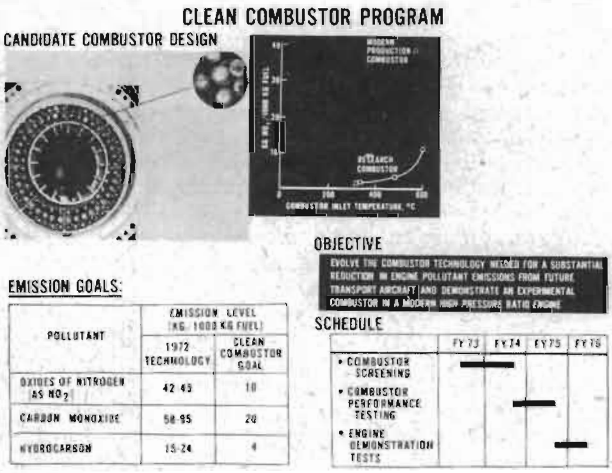
The program is currently in detail design phase and the final design review will be held during June 1975. The Under-the-Wing configuration will be completed and placed on test at the contractor's facility during May 1976, and the Over-the-Wing configuration about six months later. Subsequently, both propulsion systems will be delivered to NASA in late 1977 for an extensive evaluation of acoustic and propulsive performance, including installation on wing-flap systems.

<u>Engine Exhaust Pollution Reduction - Clean Combustors</u>. Aircraft pollutant emissions are of concern in two different situations. The first of these is in the vicinity of airports, for aircraft operating on the ground or at low altitudes during takeoff and approach. Although the mass of pollutant emissions that aircraft inject into the atmosphere is a small fraction of the amount injected by ground transportation and industrial sources, nevertheless the concentrations of aircraft pollutants in local areas may dominate other sources under some circumstances. Accordingly, the U.S. Environmental Protection Agency has promulgated regulations limiting certain emission products in new aircraft of all types after 1979, with even more stringent limits proposed for 1981.

The second situation of concern over aircraft exhaust emissions is the potential long term effect of high altitude emissions on the global environment, which has many ramifications including weather, food production, economics and human health. This concern relates to the continuous injection of aircraft exhaust products in the upper troposphere and in the stratosphere, which will increase as air transportation grows. No regulations exist today for aircraft emissions away from the airport environs, but it is clear that appropriate restraints would have to be accepted by aviation, through international agreements, if sufficient evidence accrues indicating any significant undesirable effects or ominous trends are occurring which can be attributed to continuous or increased high altitude operations.

NASA is conducting both in-house and contracted research on combustion fundamentals and combustor design technology to achieve acceptable emission levels for all types of aircraft engines. Much of this effort relates to engine conditions at ground idle, when combustion efficiency in conventional combustors is low, and when the maximum concentrations of carbon monoxide and unburned hydrocarbons are emitted. The second condition under research is that for high power settings at takeoff, when the production of oxides of nitrogen and visible smoke is greatest even though combustion efficiency is high. Unfortunately, the physical design of combustors and fuel injection systems for idle has different requirements than for high power conditions, and it has been difficult to find designs which do not sacrifice performance at one condition to improve it at the other.

Our largest research activity in this area is the Clean Combustor Program for large turbofan engines, being conducted for NASA by two major engine manufacturers. Figure 13 summarizes the objectives, the emission goals, and the program schedule.



POLLUTANT	EMISSION LEVEL (KG/1000 KG FUEL)	
	1972 TECHNOLOGY	CLEAN COMBUSTOR GOAL
OXIDES OF NITROGEN (AS NO_2)	42-45	10
CARBON MONOXIDE	58-95	20
HYDROCARBON	15-24	4

FIGURE 13. CLEAN COMBUSTOR PROGRAM

Other contract research is being conducted for the smaller gas turbine engine classes, and for the internal combustion engine types used by general aviation, which have a special class of problems.

Because of concern that emissions of nitrogen oxides in the upper troposphere and (for SSTs) in the stratosphere must be reduced, additional research is being undertaken to find practical ways to achieve reductions in NO_x levels more than an order of magnitude greater than in the NASA Clean Combustor Program now under way for the very large subsonic transport engines.

Global Air Sampling Program. Because the long term effects of high altitude aircraft emissions on atmospheric chemistry and the environment are now known, it is essential that realistic models to enable predictions be constructed and that data be obtained from both in situ and remote measurements and from laboratory experiments to guide and refine the models. A variety of NASA research and measurements projects are addressing many aspects of this objective.

One of these measurement programs is the Global Air Sampling Program, whose purpose is to measure concentrations of several atmospheric constituents in the upper troposphere and lower stratosphere for several years using commercial transport aircraft flying selected global routes. From these measurements it is hoped that statistically valid baseline data will be developed for atmospheric modelling studies. A second objective is to establish whether periodic or systematic changes and trends in various atmospheric constituents are occurring and to attempt to correlate any such changes with aircraft operations. Data of this sort, while having much broader uses, will also serve as an important guide for future engine emission reduction research and technology.

The GASP Program provides for the design and instllation of unattended sensors and data system packages in a number of Boeing 747 aircraft flying world airways. Five such installations are planned initially, with the first two going into service early in 1975 on United Airlines and Pan American World Airways.

FIGURE 14. GLOBAL AIR SAMPLING ROUTES

Figure 14 illustrates the routes of primary interest, including polar, equatorial and temperate zone routes.

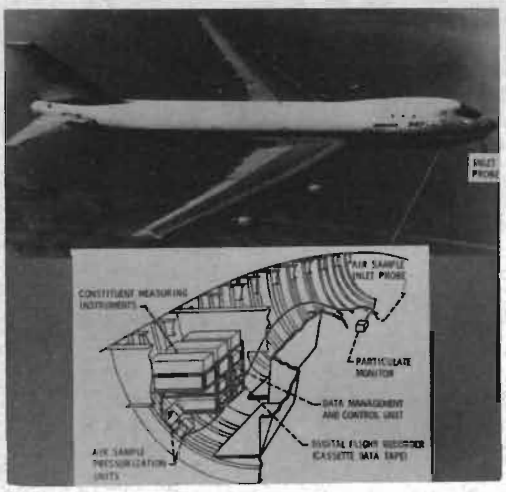


FIGURE 15. GLOBAL AIR SAMPLING PROGRAM B747 INSTRUMENT INSTALLATION

Figure 15 shows the GASP installation in a Boeing 747.

GLOBAL AIR SAMPLING PROGRAM MEASUREMENTS IN INITIAL AIRLINE INSTALLATIONS

ATMOSPHERIC CONSTITUENTS

CONSTITUENT	ESTIMATED CONCENTRATION	INSTRUMENT TECHNIQUE
OZONE	0.01 - 2.0 PPM	ULTRAVIOLET ABSORPTION
WATER VAPOR	3 - 10^3 PPM	ALUMINUM OXIDE HYGROMETER
CARBON MONOXIDE	0.05 - 0.2 PPM	DUAL ISOTOPE INFRARED ABSORPTION
PARTICLES:		
- NUMBER	10^{-2} - 10 / CM^3	LIGHT SCATTERING
- SIZE DISTRIBUTION	0.5 - 10 MICRONS	
- CHEMICAL COMPOSITION		FILTER/LAB ANALYSIS (FOR CARBON, SULFATES, AND NITRATES)
- MASS CONCENTRATION	0.05 - 5.0 MG/M^3	

RELATED MEASUREMENTS

LATITUDE	AIR TEMPERATURE	WIND SPEED
LONGITUDE	TRUE AIRSPEED	WIND DIRECTION
ALTITUDE	RATE OF CLIMB	TURBULENCE
HEADING	TIME AND DATE	PRESENCE OF CLOUDS

FIGURE 16. GLOBAL AIR SAMPLING PROGRAM MEASUREMENTS IN INITIAL AIRLINE INSTALLATIONS

Figure 16 lists the atmospheric constituents to be measured and correlated temporally with the related geographical and weather measurements indicated. Although only ozone, carbon monoxide, water vapor and particulates will be measured on the first installed packages, later modifications will include oxides of nitrogen, carbon dioxide, sulfur dioxide and hydrocarbons.

It should be noted that both upper tropospheric and lower stratospheric information will be obtained at various times of the year in different geographical regions due to seasonal variations of the tropopause.

Stratospheric Jet Wake Experiment. A second NASA flight measurement program of interest is the Stratospheric Jet Wake Experiment whose objective is to measure the hydrodynamic effects and atmospheric chemical reactions resulting from the actual engine exhaust of a supersonic airplane in the stratosphere.

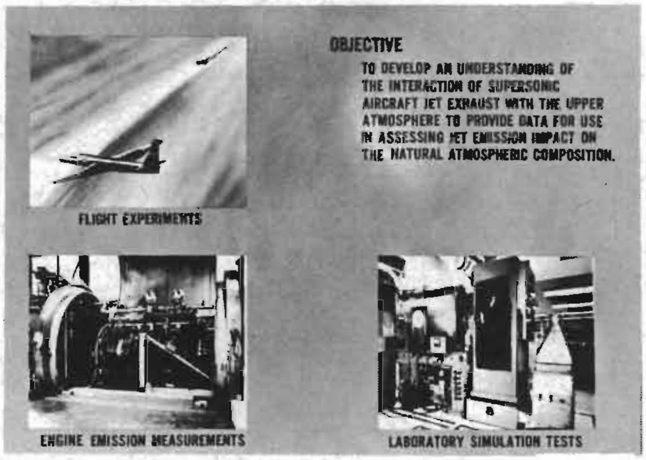


FIGURE 17. STRATOSPHERIC JET WAKE EXPERIMENT

The program is based on the use of an instrumented U-2 airplane probing the jet wake behind a supersonic YF-12 aircraft. As indicated in Figure 17, the YF-12 airplane's J-58 engine basic emissions levels were first measured under simulated altitude conditions in the PSL at Lewis, and laboratory tests were conducted to help anticipate some of the chemical reactions which might result in flight.

Initial high altitude flights with B-57F, F104 and YF-12 aircraft were made to develop flight procedures for detecting and intercepting jet wakes. It was found that visual detection could be assured by periodic, momentary YF-12 fuel dumping which formed a "dashed line" of 2-mile long segments of vapor condensates with 4-mile long spaces for measurement.

Exploration of the near-wake region (within one hour after passage of the YF-12) began in March this year. The instrumented U-2 successfully intercepted the YF-12 wake and measured particulates, nitric oxide and ozone. Measurements were made between 9 and 35 minutes after passage of the YF-12 flying at Mach number 2.4 at 64,000 ft. altitude (19.5 km). In addition to the in situ measurements, photographic records from ground-based cameras were also made to establish gross motions of the wake mixing region.

The wake measurement program will explore a range of operating conditions, and the region of measurements will be extended farther behind into the far-wake region to obtain data on longer term effects. It is planned now that the flight measurements program will extend through 1978.

IV. Concluding Remarks

Over the years NASA's propulsion research objectives have been broadened as new national goals and requirements have evolved. Today, in addition to the original objectives for propulsion performance increases, research seeks ways to improve the functional usefulness of propulsion systems while reducing costs and adverse environmental impact. The future will also see energy and other resource conservation requirements become increasingly important, even essential to the continued usefulness of air transportation. The inherently contradictory technical requirements of certain objectives we must all achieve in aeronautics continue to provide many challenges and opportunities for propulsion research and development. The author hopes that this brief overview of NASA's propulsion program, in highlighting some of the major activities of contemporary interest and concern, has also conveyed an indication of its total scope and breadth. Regrettably, many of the activities could only be described superficially or in passing.