NASA TECHNICAL NOTE

NASA TN D-6542
C.1

NASA TN D-6542

PERFORMANCE OF A MODULAR COMBUSTOR DESIGNED FOR A VTOL TIP-TURBINE LIFT FAN

by Nicholas R. Marchionna

Lewis Research Center
Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • NOVEMBER 1971

1. Report No. NASA TN D-6542	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PERFORMANCE OF A MODULAR COMBUSTOR DESIGNED FOR A VTOL TIP-TURBINE LIFT FAN		5. Report Date November 1971
		6. Performing Organization Code
7. Author(s) Nicholas R. Marchionna		8. Performing Organization Report No. E-6441
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		10. Work Unit No. 721-03
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

An array of 16 swirl-can modules was tested with liquid ASTM A-1 fuel in a 27.3-cm (10.75-in.) diameter circular duct at conditions simulating the design operating point of a combustor for a 44 482-N (10 000-lbf) thrust VTOL lift engine with an inlet air temperature of 589 K (600° F), an inlet total pressure of 77 N/cm^2 (111 psia), and a reference velocity of 50 m/sec (165 ft/sec). Performance of flat plate and conical flame holders were compared for combustion efficiency, total pressure loss, and pattern factor. At the design operating point requiring an exhaust gas temperature of 1055 K (1440° F), combustion efficiency was close to 100 percent for all models tested. The flat plate flame holders gave better exhaust gas temperature profile characteristics than the conical flame holders. With a burning length of 46 cm (18 in.), the pattern factor was 0.36 and the total-pressure loss was 5.1 percent.

17. Key Words (Suggested by Author(s)) VTOL combustor; Swirl can combustor; Combustion	18. Distribution Statement Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	19	$3.00

* For sale by the National Technical Information Service, Springfield, Virginia 22151

PERFORMANCE OF A MODULAR COMBUSTOR DESIGNED FOR A VTOL TIP-TURBINE LIFT FAN

by Nicholas R. Marchionna

Lewis Research Center

SUMMARY

A modular combustor array of 16 swirl-can modules was tested with liquid ASTM A-1 fuel in a circular duct with a diameter of 27.3 centimeters (10.75 in.) at the combustion plane. Combustors with both a conical and a flat plate flame holder design were tested and evaluated for combustion efficiency, total-pressure loss, and pattern factor. Combustion tests were conducted at an inlet air temperature of 589 K (600° F), an inlet total pressure of 77 N/cm^2 (111 psia), and reference velocity of 50 meters per second (165 ft/sec), simulating the design operating point for a 44 482-N (10 000-lbf) thrust VTOL lift engine.

Combustion efficiencies were close to 100 percent for all models tested at a combustor average exhaust gas temperature of 1055 K (1440° F).

Pattern factors decreased with increasing total pressure loss. For an exhaust duct length of 46 centimeters (18 in.), the conical flame holders produced a pattern factor of 0.45 with 5.6 percent total pressure loss and a pattern factor of 0.23 with 7.7 percent total-pressure loss. The flat-plate flame holders gave better exhaust-gas-temperature profile characteristics with a pattern factor of 0.36 at 5.1 percent total-pressure loss for the same conditions.

INTRODUCTION

The design of lift engine systems for V/STOL aircraft require special considerations. As presented in figure 1 from reference 1, some concepts envision an aircraft with clusters of lift fans that would only be used during the takeoff and landing portions of the aircraft mission. The lift fans must not only provide lift but also control for VTOL aircraft at this time. Since the operating time of these engines is short compared

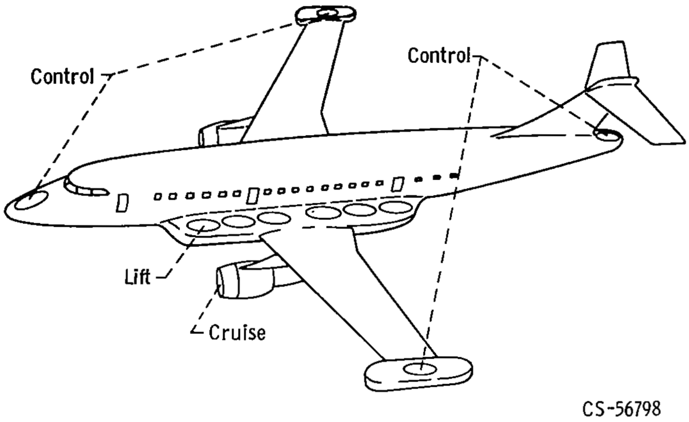
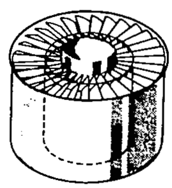
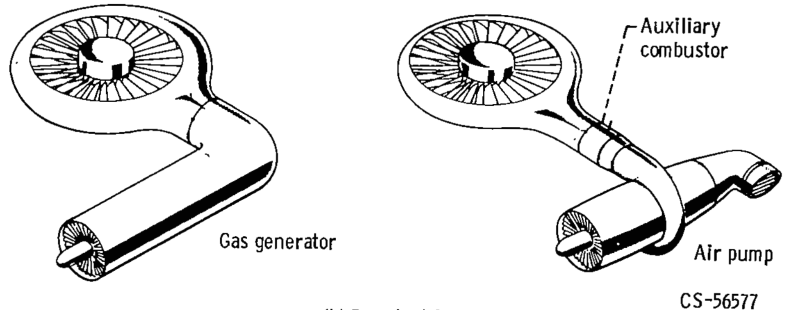


Figure 1. - VTOL propulsion functions.



(a) Integral drive.

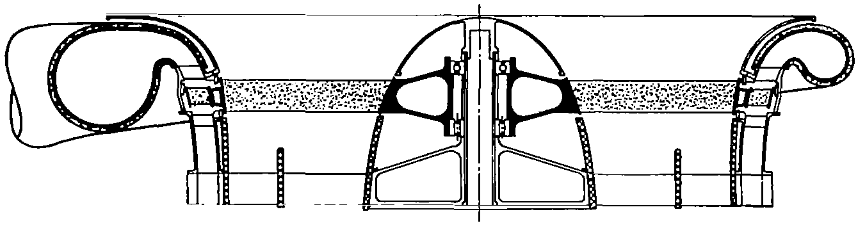


(b) Remote drive.

Figure 2. - Fan drive designs

with the operating time of the aircraft cruise engines, specific fuel consumption of the lift engines may be compromised for weight-saving features in the lift-engine system.

Figure 2 from reference 1 illustrates two basic methods of driving a lift fan: the integral drive method and the remote drive method. The integral drive fan is a self-contained engine. The two different remote drive fan designs shown in figure 2 are the gas generator design and the air pump design. Both remote drive designs supply gas at



CS-56574

Figure 3. - Remote drive lift fan.

elevated temperatures and pressures to the tip-turbine lift fan shown in cross section in figure 3 (from ref. 1). Hot gas enters a scroll which directs the gas around the fan and then passes it through turbine blades located on the tips of the fan blades.

In the air pump design shown in figure 2, air is bled from the compressor of the air pump engine and is heated further by an auxiliary combustor located in the duct between the air pump and the lift fan. The combustors investigated herein were designed for this application.

There are some special considerations required in design criteria for this type of combustor. The combustor should be light weight. One possible means to keep the weight low is to keep the heavier weight exhaust ducting as short as possible. Also it may be possible to eliminate the usual combustor liner if exhaust gas temperatures are not excessive. In many applications, the cross-sectional area of the combustor must be small to minimize drag. The requirement that the combustor be as small as possible implies high combustor reference velocities and a combustor design with a high heat release rate.

The usual requirement of minimizing exhaust gas hot spots (pattern factor) is important only if turning vanes are to be used at the inlet of the tip-turbine scroll. These vanes could be used to reduce the specific fuel consumption by lowering the total-pressure loss but may not be a firm requirement.

Another requirement that is usually considered in designing combustors for jet engines is altitude relight capability. Since the air pump provides the inlet conditions for the lift engine combustor and operation is required at only moderate altitudes, ignition and blowout are not considered a significant design problem for the combustor.

A new requirement that may be more significant is the pollution level from lift engines on a VTOL aircraft. Since a civilian aircraft by design would be used in high population density areas, the level of smoke and gaseous emissions will be important, especially during idle and the time of full thrust close to the airport.

Research has been directed toward development of a combustor composed of an array of combustor modules. In the past (refs. 2 to 4) this type of combustor has demonstrated the following performance features:

(1) High combustion efficiency

(2) Low total-pressure loss at high reference velocities

(3) Reduced smoke formation by premixing fuel and air in the carburetor.

A simplified combustor design was tested, similar to that proposed in reference 4. Both conical and flat plate flameholders were tested and evaluated for efficiency, total pressure loss, and pattern factor. An attempt was also made to correlate the tradeoff between total pressure loss and the pattern factor. No attempt was made to measure gaseous emissions.

UNITS

The U. S. customary system of units was used for primary measurements and calculations. In making the conversion to the SI system, consideration is given to implied accuracy and may result in rounding off the values expressed in SI units.

APPARATUS

Facility

The combustor test section was installed in a closed-duct test facility shown in figure 4. The facility is connected to the laboratory's air supply and exhaust systems. Air

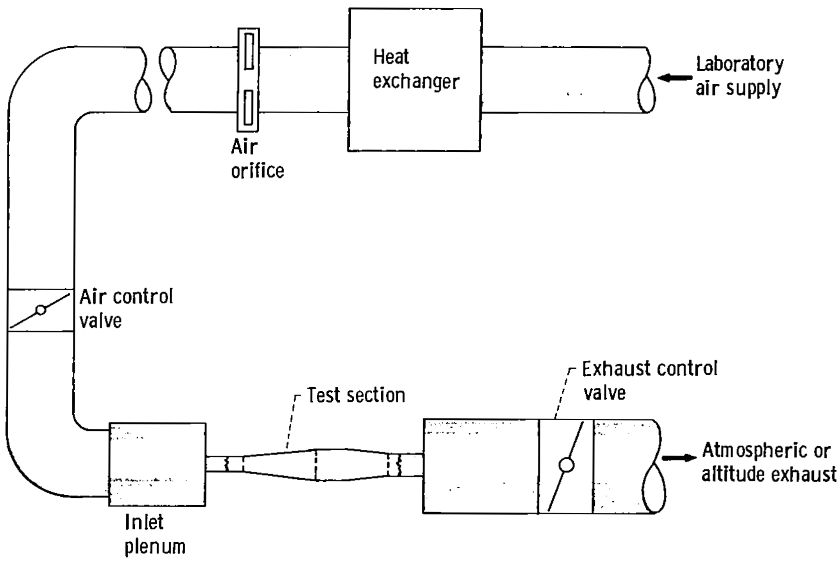


Figure 4. - Test facility.

at a pressure of 103 N/cm^2 (150 psia) was passed through a heat exchanger capable of heating the air to 589 K (600^o F). Air flow rates and combustor pressures were regulated by remotely controlled valves upstream and downstream of the test section.

Test Section

Combustor installation in the test section is shown schematically in figure 5. The test section is a circular duct simulating a possible configuration for a lift fan with a

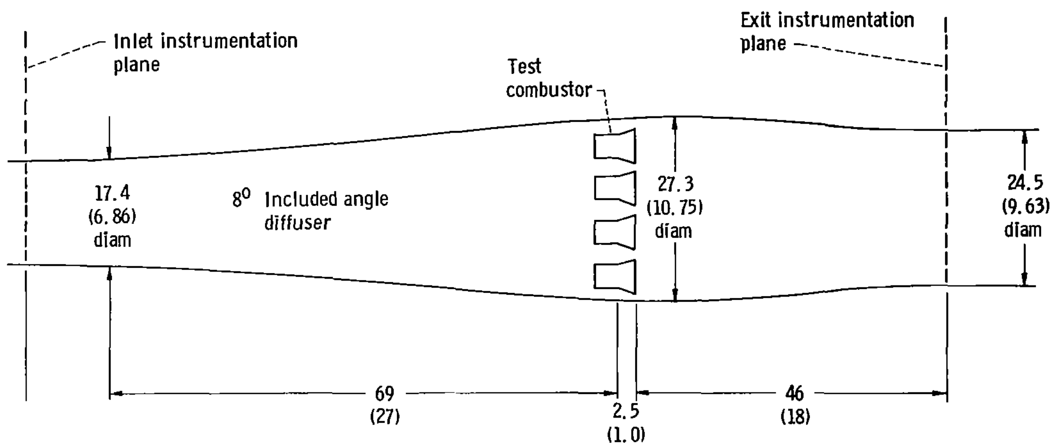


Figure 5. - Combustor installation in test section. (Dimensions are centimeters (in.).)

remote air pump. The test section has an 8^o included-angle diffuser for low-pressure loss. A test combustor was mounted on a 2.5-centimeter (1-in.) thick flange and inserted between the diffuser and exhaust nozzle. In addition to tests with the 45.7-centimeter (18-in.) exhaust nozzle shown in figure 5, tests were also conducted with an exhaust nozzle of 61 centimeters (24 in.). The duct diameter in the plane of the test combustor was 27.3 centimeters (10.75 in.).

Instrumentation

Inlet-air temperatures and exhaust gas temperatures were measured with fixed thermocouples at positions shown in figure 6. The nine thermocouples in the inlet and 40 in the exhaust section were located at centers of equal area in the duct. In addition,

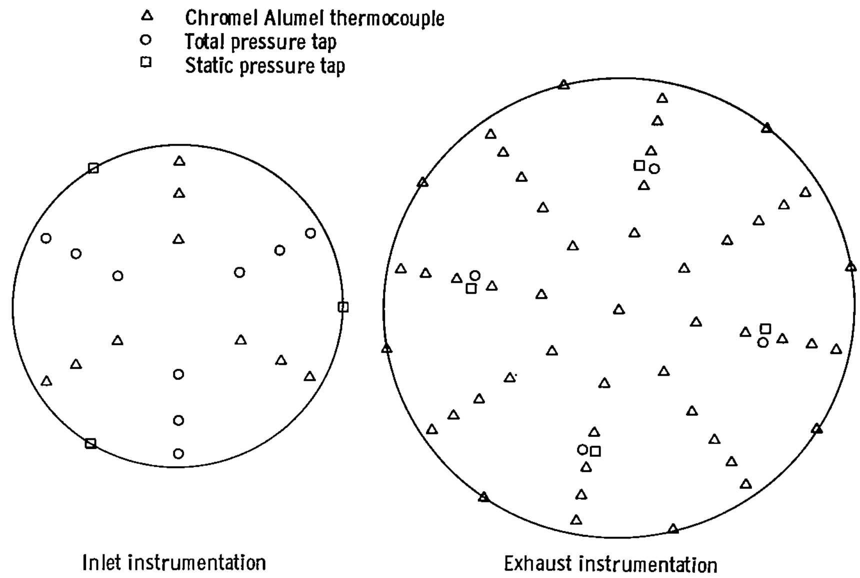


Figure 6. - Inlet and exhaust instrumentation (looking upstream).

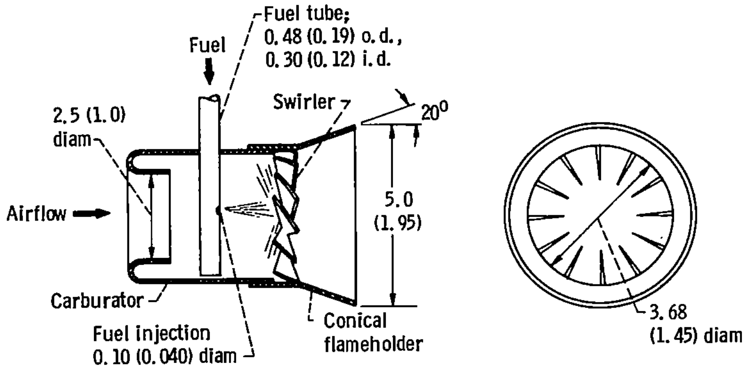
eight thermocouples were used to measure the exhaust duct wall temperature, and one thermocouple was used to measure the exhaust gas temperature in the center of the duct.

Data were processed in near-real time by the laboratory's central data processing system and an IBM 360 on-line computing program.

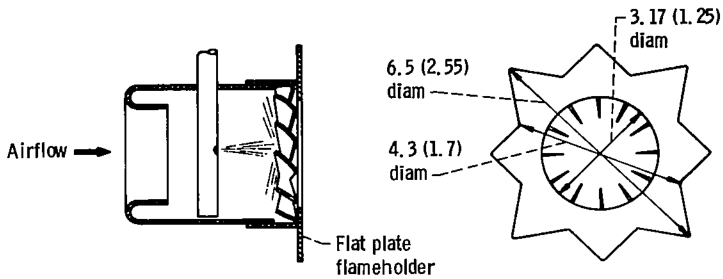
Test Combustors

The basic test combustor consisted of an array of 16 swirl-can modules. Two module designs were tested: one having a conical flame holder, and the other having a flat plate flame holder. These modules are sketched in figure 7. The modules use the same carburetor and swirler design. Fuel is injected on the upstream face of the swirler at approximately 26 meters per second (86 ft/sec), where it is partially atomized and provides some cooling of the swirler. This design results in more uniform distribution of fuel in the carburetor and a more uniform spray into the combustion zone than the previous designs using tangential fuel injection shown in reference 4.

A photograph of the initial design of the conical swirl-can combustor, model 1, is shown in figure 8. Fuel tubes from each module go into a manifold outside the combustor



(a) Conical module (model I).



(b) Flat-plate module (model II).

Figure 7. - Combustor module details. (Dimensions are in centimeters (in.).)

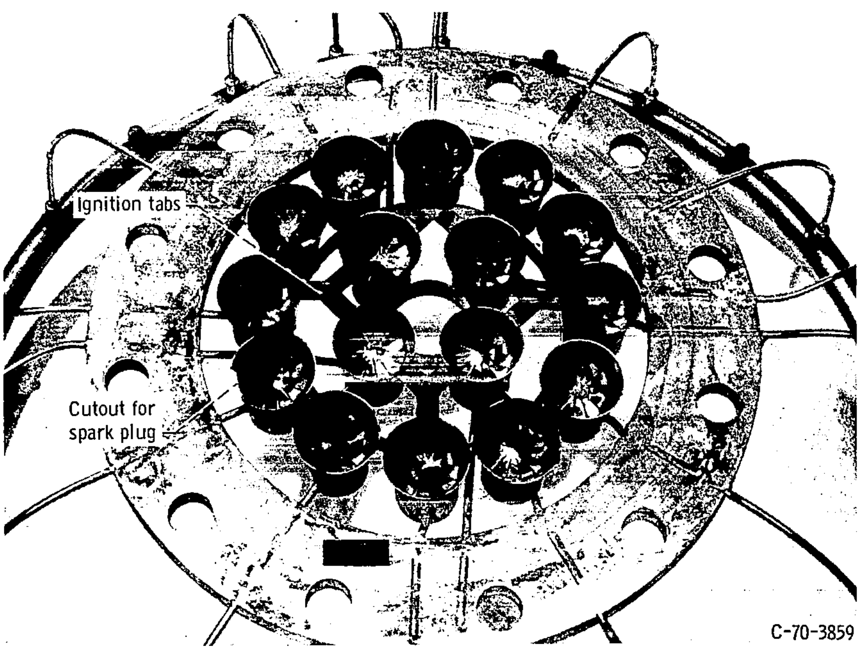


Figure 8. - Model I, conical swirl-can array, looking upstream.

wall. The modules are interconnected with tabs to provide ignition from the outer modules to the inner modules. The combustor was designed to have uniform blockage over the area of the duct. The choice of the number of modules was based on the desire to uniformly cover the large percentage of duct area close to the duct wall in order to provide a uniform exhaust gas temperature.

The flat plate modular combustor, model II, was constructed by cutting off the cones of the model I combustor and welding on the flat plates. The flat plates were used in other tests with swirl-can combustors and were designed to provide more perimeter for hot- and cold-gas streams to mix. The perimeter of the flat plate is 20.3 centimeters (8.0 in.) compared with 15.5 centimeters (6.1 in.) for the cone.

Additional tests were performed with modifications to the basic combustors. The combustors were modified by adding or removing blockage to the arrays. Modifications were aimed at improving the exhaust-gas-temperature distribution and finding the performance trade-off between total-pressure loss (blockage) and the uniformity of the exhaust-gas-temperature distribution. A list of the models and their description is presented in table I. Models I, IA, and IIA are shown in figures 8 to 10.

TABLE I. - TEST COMBUSTORS

Model	Figure	Description	Blockage, percent	Swirler vane angle	
				rad	deg
I	8	20° Conical flame holders	51.2	$\pi/6$	30
IA	9	Same as model I with blockage added to overall array	61.5	$\pi/6$ $\pi/9$	30 20
IB	--	Same as model IA with 24 outside blockage tabs removed	56.3	$\pi/9$	20
IC	--	Same as model IB with four inside blockage tabs removed	55.2	$\pi/9$	20
II	--	Flat-plate flame holders	50.9	$\pi/9$	20
IIA	10	Same as model II with cross added to center four modules	51.9	$\pi/9$	20

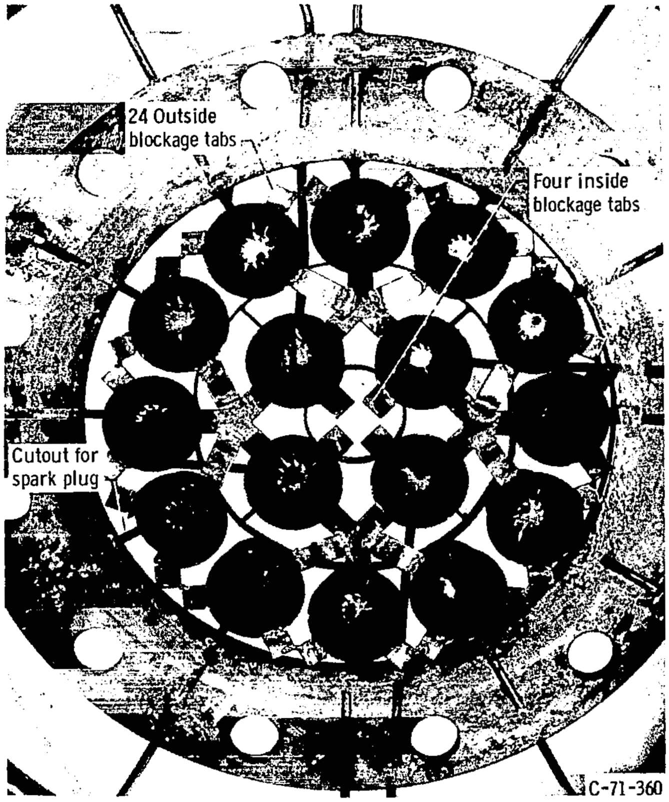


Figure 9. - Model IA combustor array.

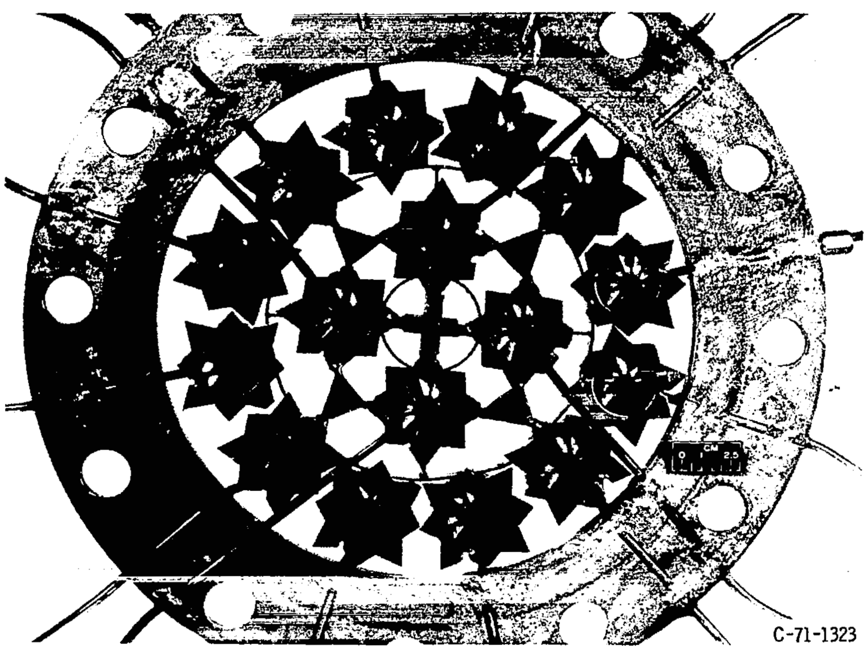


Figure 10. - Model IIA combustor array.

RESULTS AND DISCUSSION

Combustor Development

The combustors and their modifications were evaluated by comparing combustion efficiency, pressure loss, and exhaust-gas-temperature distribution at the test condition shown in table II. This condition represents the design operating point of a combustor for a 44 482-N (10 000-lbf) thrust lift fan as determined by unpublished cycle analysis.

TABLE II. - COMBUSTOR NOMINAL TEST CONDITION

Airflow rate, kg/sec (lbm/sec)	13 (29)
Inlet-air temperature, K ($^{\circ}F$)	589 (600)
Inlet air pressure, atm	8
Exhaust gas temperature, K ($^{\circ}F$)	1055 (1440)
Diffuser inlet Mach number	0.261
Reference velocity[a], m/sec (ft/sec)	50 (165)
Fuel-air ratio	0.0125

[a]Reference velocity is based on the mass flow rate, maximum area in the duct, and isentropic conditions related to the diffuser inlet.

Combustion efficiency. - Combustion efficiency was defined as the ratio of actual temperature rise to theoretical temperature rise. The average exit temperature used for efficiency calculations was based on the average of the 40 thermocouples in the exit plane.

Combustion efficiency was close to 100 percent at the design operating point for all models tested as shown in figures 11 to 13. A decrease in combustion efficiency with decreasing fuel-air ratio was observed as a function of blockage and swirler open area. This has been found to occur in other tests of swirl-can modular combustors (ref. 2). Poor efficiency at low fuel-air ratios can be improved by increasing the local fuel-air ratio in the region just downstream of the individual modules. This can be accomplished by reducing the swirler open area so that less air passes through the module at the same pressure drop or by reducing the pressure drop across the swirler (i.e., reducing the blockage in the combustion plane). Figure 11 shows the effect of swirler open area on combustion efficiency for the model 1A combustor for various fuel-air ratios around the design operating point. The swirler blades were closed down from $\pi/6$ radians (30°) to $\pi/9$ radians (20°) to produce a change in flow discharge coefficient C_DA from 1.62 to 1.42 square centimeters (0.25 to 0.22 in.^{2}). The flow discharge coefficients were determined from airflow calibrations of the module. A significant increase in combus-

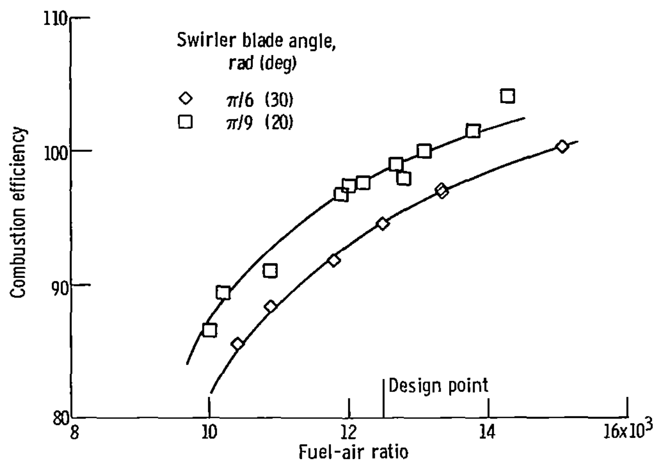


Figure 11. - Effect of swirler open area on combustion efficiency. Model IA combustor, design operating point.

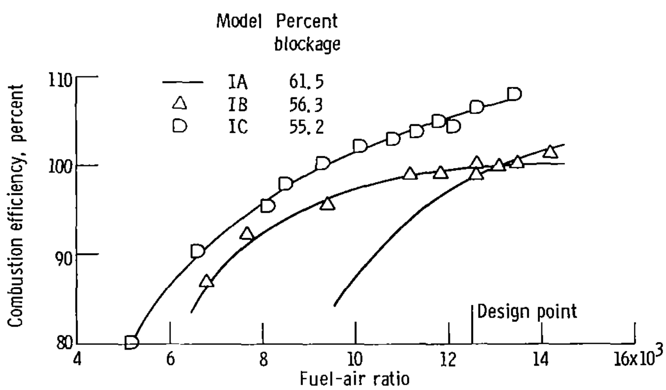


Figure 12. - Effect of blockage on combustor efficiency. Design operating point; swirler angle, $\pi/9$ radians (20°).

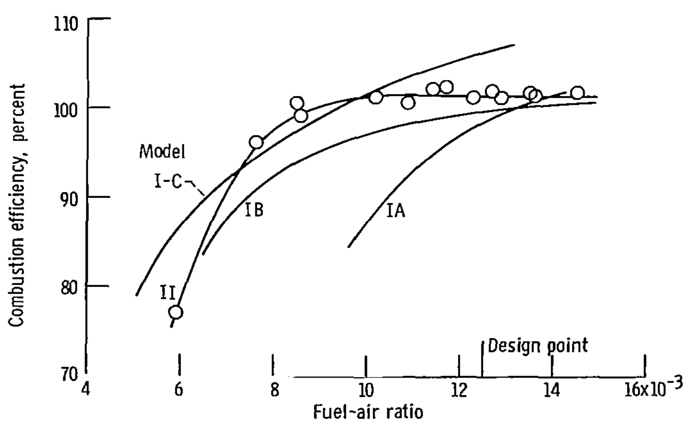


Figure 13. - Combustion efficiency for model II combustor compared with models IA, IB, and IC; design operating point.

tion efficiency at the lean fuel-air ratios occurs when the blockage in the combustor plane is reduced (pressure drop is decreased). Figure 12 shows the combustion efficiency for the model IA, IB, and IC combustors, which had blockages of 61.5, 56.3, and 55.2 percent, respectively. These models had the same swirler open area but different values of total pressure loss. The values of efficiency above 100 percent for the model IC combustor are attributed to an above average number of thermocouples being located in the high temperature region of a large temperature gradient peculiar to that model.

Since tests with the conical flame holder exhibited improved lean performance with reduced swirler open area, the flat plate flame holder was designed with a smaller inner exit diameter in the flat plate to further reduce the airflow through the swirler. The efficiency curves for the model II combustor is shown in figure 13, together with the efficiency curves for the model IA, IB, and IC combustors from figure 12 for comparison. The lean efficiency performance of the model II and IC combustors were similar. Both combustors had the same swirler vane angle and approximately the same blockage.

Total pressure loss. - Combustor total-pressure loss $\Delta P/P$ includes the diffuser pressure loss and is defined by the following expression:

$$\frac{\Delta P}{P} = \frac{\text{Average diffuser inlet total pressure - Average combustor exit total pressure}}{\text{Average diffuser inlet total pressure}}$$

Figure 14 shows the effect of the combustor blocked area on total-pressure loss at the

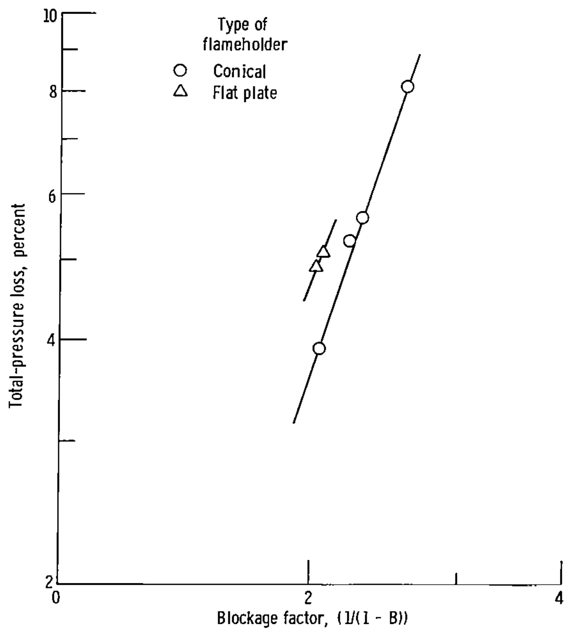


Figure 14. - Total pressure loss as function of blocked area for conical and flat-plate modular combustors at the design operating point.

design operating point. In the incompressible range, the air velocity past the array V_L is related to the reference velocity V_R by the blockage:

$$\frac{V_L}{V_R} = \frac{1}{1 - B}$$

where B is the fraction of blocked area. A larger value of pressure loss was recorded for the flat-plate combustors than for the conical combustors for the same fraction of blocked area. This is attributed to the larger sudden contraction loss for the flat plate form.

Effective use of increased pressure loss across the combustion plane effects increased turbulence. Turbulence mixes the hot- and cold-gas streams in a modular combustor. Thus, total-pressure loss has a strong effect on the exhaust-gas-temperature distribution.

Combustor exhaust-gas-temperature distribution. - To describe the combustor exhaust-gas-temperature distribution quality, a parameter referred to as the pattern factor was used. The pattern factor is defined by the expression:

$$\text{Pattern factor} = \frac{T_{max} - T_{av}}{\Delta T}$$

where T_{max} is the highest local combustor exit temperature, T_{av} is the average combustor exit temperature, and ΔT is the combustor temperature rise.

The average temperature at each radial position can be described by the normalized radial profile, defined by

$$\text{Normalized radial profile} = \frac{\overline{T}_R - T_{av}}{\Delta T}$$

where $\overline{T}_R$ is the average temperature at a constant radius.

Figure 15 shows the relation between the pattern factor and total-pressure loss for the models tested. The solid symbols indicate testing with a 61-centimeter (24-in.) long exhaust section. The open symbols indicate testing with a 46-centimeter (18-in.) long exhaust section. The pattern factor decreases with increasing pressure loss due to the increase in turbulence and quicker mixing. The effect of mixing length can be seen by comparing the pattern factor the model IA combustor tested at the 61 centimeter (24 in.) length (pattern factor = 0.15) and at the 46-centimeter (18-in.) length (pattern

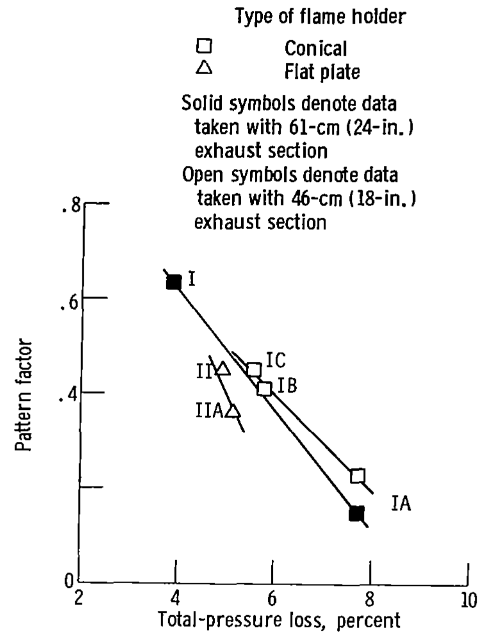


Figure 15. - Pattern factor as function of total-pressure loss for combustors tested at design operating conditions.

factor = 0.23). The high value pattern factor of 0.63 for the model I combustor is attributed to low turbulence associated with the low pressure loss for that design.

The flat plate combustors exhibited better pattern factor values than the conical combustors. The conical flame holders produced a pattern factor of 0.45 with a 5.6 percent total-pressure loss, while the flat plate flame holders had a pattern factor of 0.45 with only a 4.9 percent total-pressure loss. Pattern factor for the model IIA combustor was 0.36 at a total-pressure loss of 5.1 percent.

The exhaust-gas-temperature distribution of a modular combustor is highly dependent on the distribution of the open area and blockage. Since one of the design objectives was to design a combustor that would not require a liner, air had to be allowed to flow along the periphery of the combustor wall for cooling. An annular passage of 0.35-centimeter (0.14-in.) around a 27.3-centimeter (10.75-in.) diameter duct accounts for 5 percent of the duct area. For a combustor with 50 percent blockage, a gap of this size would allow 10 percent of the air to flow along the walls. Any flow separation or low mass flow along the walls of the diffuser could cause very high temperatures to occur downstream of the combustion plane along the walls. To ensure that the walls would not exceed the average exhaust gas temperature, the lip of the cones for the model I combustor were positioned 0.90 centimeter (0.35 in.) from the combustor housing.

The normalized radial profiles for the models I, IA, and IIA combustors are presented in figure 16. The normalized radial temperature profile for the model I com-

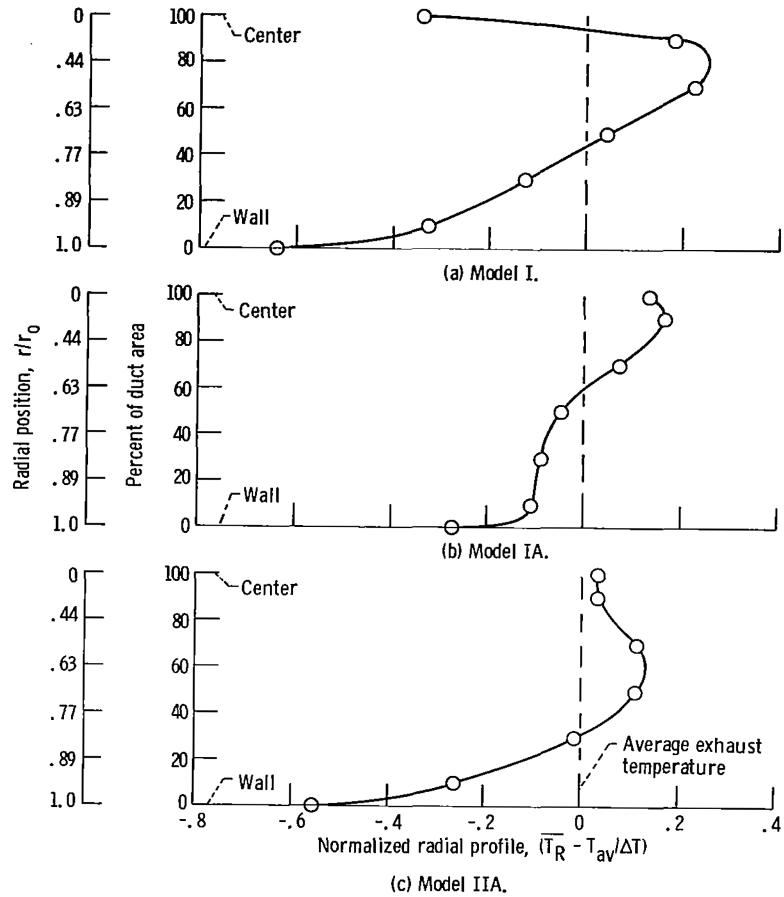


Figure 16. - Normalized radial profiles at design operating point.

bustor (fig. 16(a)) shows that the temperature is below the mean duct temperature near the walls, crosses the mean at about 43 percent into the duct area, and reaches a maximum at about 80 percent of the duct area, measured from the wall. By increasing the blockage near the walls the radial temperature gradient becomes less severe. Figure 16(b) shows the normalized radial profile for the model 1A combustor which had 61.5 percent blockage more evenly distributed. The temperature has increased near the walls, but is still below the mean duct temperature from the wall to 60 percent of the duct area. The radial average still peaks at approximately 90 percent into the duct area, measured from the wall.

The flat-plate combustors radial profile temperature gradient was better than that for the conical combustors. Figure 16(c) shows the normalized radial temperature profile for model IIA. The temperatures near the wall are still below average but the mean duct temperature is reached within 30 percent of the area from the wall. The peak in the radial profile occurs about 60 percent into the duct area from the wall. Since the fuel injection points for all models were the same and the blockage was evenly distributed, these results seem to indicate that the flat-plate flame holders provide more complete mixing than the conical flame holders.

Model IIA Performance Characteristics

Detailed performance data of the model IIA combustor are presented in figure 17 for what is believed to be the best configuration tested for an application to a VTOL auxiliary combustor. Data were taken over a range of fuel-air ratios for reference velocities of 41, 50, and 59 meters per second (135, 165, and 195 ft/sec) with an inlet air temperature of approximately 577 K (580° F) and diffuser inlet total pressure of 77 N/cm^2 (111 psia). Figure 17(a) shows the variation of combustion efficiency with fuel-air ratio. Only a small decrease in combustion efficiency from 100 percent is noticeable at the highest reference velocity tested. Figure 17(b) shows that changes in reference velocity had little effect on the pattern factor over a range of fuel-air ratios the maximum pattern factor was 0.36. Figure 17(c) shows the relation between pressure loss and diffuser inlet Mach number for this combustor at an exhaust to inlet temperature ratio of 1.8. The total-pressure loss at the design operating condition was 5.1 percent.

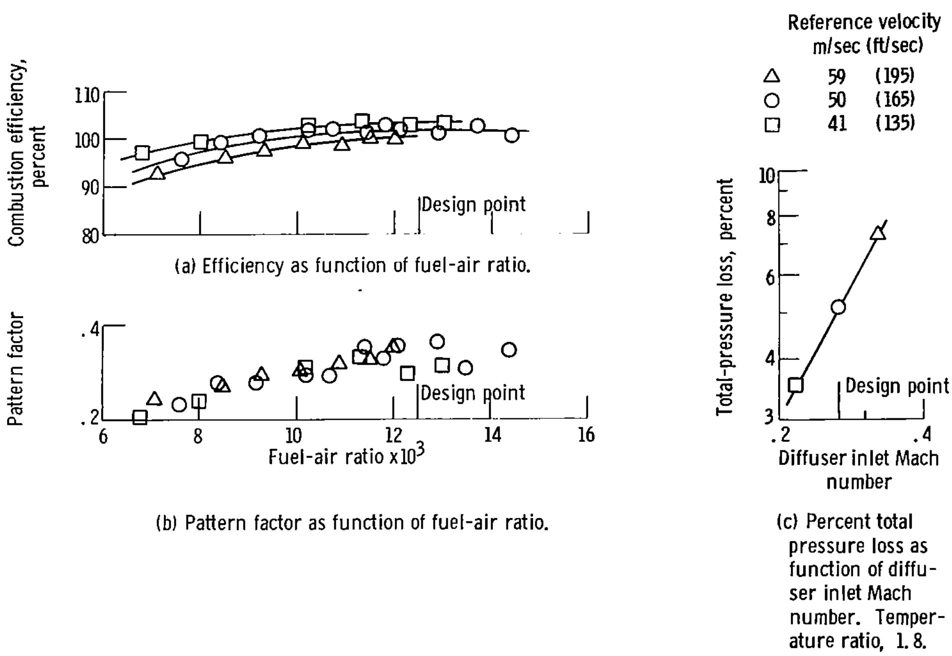


Figure 17. - Model IIA performance characteristics. Diffuser inlet pressure, 111 psia (77 N/cm^2); inlet temperature 577 K (580° F).

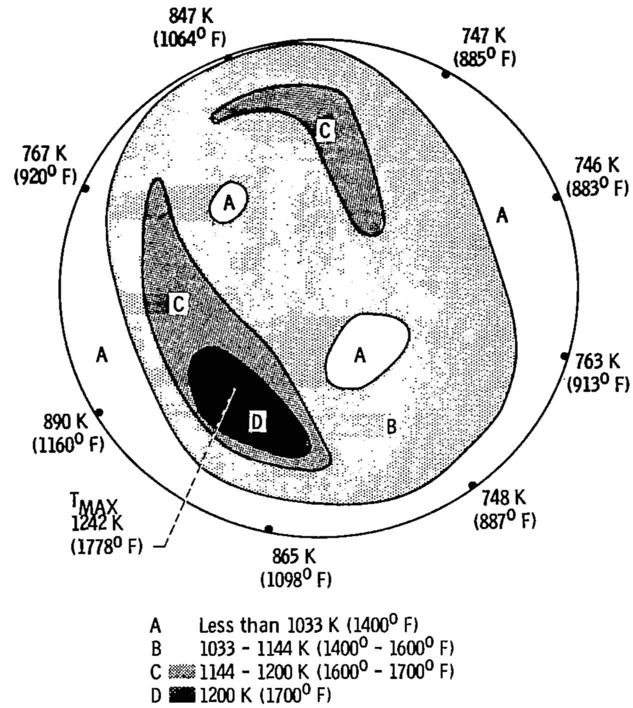


Figure 18. - Model IIA exit temperature map. Average exhaust gas temperature, 1066 K (1461° F); average wall temperature, 797 K (976° F).

A contour map of the exhaust gas temperature for the model IIA combustor at the design operating point is shown in figure 18. All measured wall temperatures were below the average exhaust gas temperature. The average wall temperature was 797 K (976° F) when the average exhaust gas temperature was 1055 K (1440° F). No combustor liner was required at this condition but could easily be adapted to the design if desired.

SUMMARY OF RESULTS

An array of 16 swirl-can modules was tested at conditions simulating operation of an auxiliary combustor for a VTOL lift fan. Two module designs were tested, one having a conical flame holder, and the other having a flat-plate flame holder. The combustor was mounted in a duct with a diameter of 27.3 centimeters (10.75 in.) at the combustion plane. Tests simulating a design operating point with an inlet-air temperature of 589 K (600° F), inlet total pressure of 77 N/cm^2 (111 psia), and reference velocity of 50 meters per second (165 ft/sec) were conducted. Some off-design tests were conducted with the best configuration. The two designs were compared with respect to efficiency, pressure loss, and pattern factor. The tests indicated the following significant results:

1. Combustion efficiency of 100 percent was obtainable at the design operating point requiring an average exhaust gas temperature of 1055 K (1440° F).

2. A trade-off exists between combustor pressure loss and pattern factor. For an exhaust duct length of 46 centimeters (18 in.), the conical flame holders had a pattern factor of 0.45 with a pressure loss of 5.5 percent and a pattern factor of 0.23 with a pressure loss of 7.7 percent.

3. The combustors with flat plate flame holders produced better exhaust-gas-temperature profile parameters at the same exhaust-duct length than the combustors with the conical flame holders. A pattern factor of 0.45 was recorded with a pressure loss of only 4.9 percent, and a pattern factor of 0.36 was recorded with a pressure loss of 5.1 percent.

4. Combustor wall temperatures were found to be below the average exhaust-gas temperature. A combustor liner was not required for the design operating point condition but could easily be adapted to this design if desired.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, July 20, 1971,
721-03.

REFERENCES

1. Anon.: Aircraft Propulsion. NASA SP-259, 1971.
2. Niedzwiecki, Richard W.; and Moyer, Harry M.: Performance of a 48-Module Swirl-Can Turbojet Combustor Segment at High Temperatures Using ASTM-A1 Fuel. NASA TN D-5597, 1969.
3. Butze, Helmut F.; Trout, Arthur M.; and Moyer, Harry M.: Performance of Swirl-Can Turbojet Combustors at Simulated Supersonic Combustor-Inlet Conditions. NASA TN D-4996, 1969.
4. Niedzwiecki, Richard M.: Preliminary Tests of a Simplified Modular Turbojet Combustor. NASA TN D-5688, 1970.

NASA-Langley, 1971 —— 33 E-6441

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546