NASA OVERVIEW

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INTRODUCTION

This review as outlined in figure 1 will be a summary of effort at Ames Research Center in researching performance and application of thrusting augmentors. It represents the major portion of the NASA-wide effort in recent years. Ames got started in 1965 when a large-scale testing program on STOL application, which was sponsored jointly with the Canadian Government, was initiated. The investigation has culminated in the publication of references 1 and 2 and the continuing study of the augmentor wing at forward speed which is presently still funded by the Canadians. The early part of this effort resulted in using the augmentor wing in the NASA Research Aircraft C8A which is still being flown. More description of this effort is documented in references 3 through 6 including Ames in-house research. Specific application to VTOL was initiated with a joint Air Force NASA program in 1972 and resulted in Ames 7- by 10-Foot Wind-Tunnel tests, some of which are reported in reference 7, and a report by NASA currently in preparation. Support of research in the application of thrusting ejectors to V/STOL will continue until maximum installed performance has been achieved.

OBJECTIVES

The objectives of this effort have and will continue to be those listed in figure 2. In all studies, there is a concentrated effort to understand configuration effects on performance resulting in a general parametric description of thrust augmentors for effective application to STOL and V/STOL. Everyone tries to obtain as much theoretical as empirical data to apply to this objective but, at present, the latter is by far more abundant than pertinent theoretical results. All the objectives in figure 2 are very much related but must support the principal objective of application or "Key Design Considerations" which, in our current target, are not only high uninstalled performance or large thrust augmentation numbers in the laboratory but assuring that these numbers come from configurations which can be packaged into V/STOL aircraft — "fighter" or otherwise.

TEST FACILITIES

To study installed performance, Ames will rely on several test facilities which take both small- and large-scale models for static and wind-tunnel tests. An installation in the Ames 7- by 10-Foot Wind Tunnel is shown in figure 3.

The configuration is the Air Force design — reference 7 in a semispan model which yield both static and wind-on data. Figure 4 shows the Ames 11-foot wind-tunnel test section with a semispan model of the deHavilland "Cruise Augmentor." This installation allowed study of the performance of the augmentor wing at high subsonic speeds. The Large-Scale Static Test Stand is shown in figure 5 with the Ames wind tunnels shown in the background. An additional building is now being located to the right of the stand but will not interfere with operation of the test stand. Figure 6 shows the de Havilland fuselage-mounted ejector model in the 40- by 80-foot wind tunnel. For this model the ejector is powered by a J-97. More will be said about the configuration and the test results by a later speaker. An updated data reduction system and a high pressure air supply is being added to the latter two facilities.

An additional facility, the 80- by 120-foot wind tunnel will be ready for use in three years and should be included in plans for developmental testing. It will share power systems with an "overhauled" 40 by 80 foot wind tunnel and will be a through-flow no-return part of the complex extending out the right (toward the northwest) of the 40- by 80-foot wind tunnel shown in figure 5. Also seen in figure 5, a large full-scale model or aircraft can be tested on the test stand, put on a trailer and transported to the 40 by 80 or 80 by 120 foot wind tunnel over a very short distance.

EJECTOR PERFORMANCE EVALUATION

Through testing both at small- and large-scale numbers on augmentor performance are summarized in figure 7. This collection of data has been shown previously and parts of it published last year in reference 8. The gross augmentation is defined as the ratio of total actual thrust to the actual thrust of primary nozzle. For evaluating the primary thrust, this actual or measured value must often be derived from the thrust based on isentropic expansion from the nozzles using correction factors representative of nozzle efficiency. The mixing length is the average distance from the primary nozzles to the end of the diffuser and is nondimensionalized by the average nozzle width $\bar{t}$. (Total nozzle area divided by ejector throat length.) The lower performance ejectors are either STOL application for low entrainment or were poorly optimized.

It is certainly possible that both the values for the XFV-12A and the de Havilland model (fuselage ejector) can be or already has been further optimized. The use of $\ell/\bar{t}$ as a parameter in the figure was an arbitrary choice but was used for many years as a means of "collapsing" data for slotted and simple lobed nozzles to the faired lines. The spread in performance for given mixing lengths illustrates the effects of both types of entrainment and mixing as well as ejector configuration differences.

The challenge in sorting out the differences in ejector performance shown in figure 7 must be met by evaluating some of and more than the parameters listed in figures 8, 9, and 10 which have been separated into geometric, performance, and operating definition, respectively. For geometry, one can organize these into nozzle, shroud or diffuser, and general configuration.

What is, obviously, absent is the type or specific design or "scheme" such as whether or not the configuration promotes strictly turbulent mixing or is the entrainment accomplished through shear alone. For each ejector configuration, the performance evaluated, using some or all of the parameters listed in figure 9, must be documented for as many of the geometric parameters as possible. Tests must be made at the operating conditions (parameters) in figure 10. A primary problem in the experimental study of the potential of a given ejector concept is not just the complexity of the hardware required but the amount and sophistication of the instrumentation needed to document this performance and operation.

INVESTIGATIONS AT LARGE SCALE

Many of the operating or test conditions can be obtained only by installing the ejector in an aircraft configuration and testing it both statically and at airspeed. It seems essential to investigate installation effects with a particular ejector configuration even though the isolated ejector is still not completely optimized in order to insure that all performance parameters have been evaluated properly. To do this, a significant amount of basic research using smaller models (cold or hot air supply) and analytical development should be continued vigorously, however, large-scale testing is a valuable tool in evaluating installation effects.

Current experimental and theoretical programs are being carried out on the V/STOL fighter configuration shown in figures 11 and 12. The NASA XV-12A static tests are complete and some of the results will be discussed here. The wind-tunnel tests on a large-scale model of the wing root or fuselage-mounted ejectors (installation shown in fig. 6) were completed in February and will be discussed in this workshop by Mr. D. C. Whittley. Installation of the short diffuser or Alperin ejector will be studied using the fighter design shown in figure 12.

It is intended that this be a parallel program with large-scale tests on a RALS plus deflector nozzle configuration. This latter program will be initiated next February with test in Ames 40- by 80-Foot Wind Tunnel on the STOL configuration having blowing over a deflected flap plus spanwise blowing. All of these models will be powered by J-97's. As shown in figure 12 an alternate configuration might be the combination of an ejector with the VEO or vectored direct thrust in the rear.

A more detailed sketch of the ejector fighter configuration is shown in figure 13. Except for the strakes, it is a configuration that is meeting requirements of the Navy and Air Force supersonic fighter, particularly for subsonic high maneuverability needs. A strake is a natural spot to place the ejector but the ejector diffuser must be short, or, if not, diffuser scheme must be designed into the aircraft such that it can be retracted for cruise. For the latter option, a primary emphasis on the complete model tests will be one of integration into the aircraft mission both mechanically and aerodynamically. The program is being started with both NASA and Contractual work using isolated and small-scale ejector models. This will be followed by large-scale static tests (at the scale of the complete model) using the complete ejector propulsion system. And only after acceptable installed ejector performance is obtained statically will the complete model be tested.

CONCLUDING REMARKS

Ames Research Center will continue to take the lead in NASA's effort to explore several applications of the thrusting ejector. Figure 14 lists areas in future effort where research and development will be supported both in-house and contractually. It seems evident that the major application will be to the V/STOL fighter and our large-scale testing is currently organized on this basis. However, it is felt that other applications such as that of control thrustors, and augmenting circulatory lift in the STOL mode should be continually considered.

REFERENCES

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3. Whittley, D. C.; and Cook, W. L.: Comparison of Model and Flight Test Data for an Augmentor-Wing STOL Research Aircraft. Presented at the AGARD Flight Mechanics Symposium on "Flight/Ground Testing Facilities Correlations," June 9-12, 1975.

4. Farbridge, J. E.: The Transonic Multi-Foil Augmentor-Wing, AIAA Paper 77-606. Presented at 1977 AIAA/NASA Ames V/STOL Conference, 1977.

5. Aiken, Thomas N.: Aerodynamic and Noise Measurements on a Quasi-Two Dimensional Augmentor Wing Model with Lobe-Type Nozzles, NASA TM X-62,237, 1974.

6. Aiken, Thomas N.; Falarski, M. D.; and Koenig, David G.: Aerodynamic Characteristics of a Large-Scale Semispan Model with a Swept Wing and an Augmented Jet Flap with Hypermixing Nozzles, NASA TM X-73,236, 1979.

7. Brown, S. L.; and Murphy, R. D.: Design and Test of Ejector Thrust Augmentation Configurations Paper No. 19, AGARD CP-143, April 1974.

8. Aiken, Thomas N.: Thurst Augmentor Application for STOL and V/STOL, NASA TM X-73,241, 1977; also AIAA Paper 77-605, 1977.

- AMES RESEARCH CENTER OBJECTIVES
- TEST FACILITIES
- SUMMARY OF DEVELOPMENTS AND EJECTOR PERFORMANCE
- PARAMETERS
- V/STOL FIGHTER APPLICATION

Figure 1.- Outline of NASA overview.

- PARAMETRIC DESCRIPTION OF THRUST AUGMENTOR APPLICATION TO STOL AND V/STOL
- USE OF THEORETICAL AND EMPIRICAL DATA
- AIRCRAFT—AUGMENTOR INTEGRATION
- KEY DESIGN CONSIDERATIONS:
  - STOL TRANSPORTS
  - √ V/STOL FIGHTER

Figure 2.- Current objectives of thrust augmentor development at Ames Research Center.

Figure 3.- Ejector powered model in Ames 7- by 10-Foot Wind Tunnel.

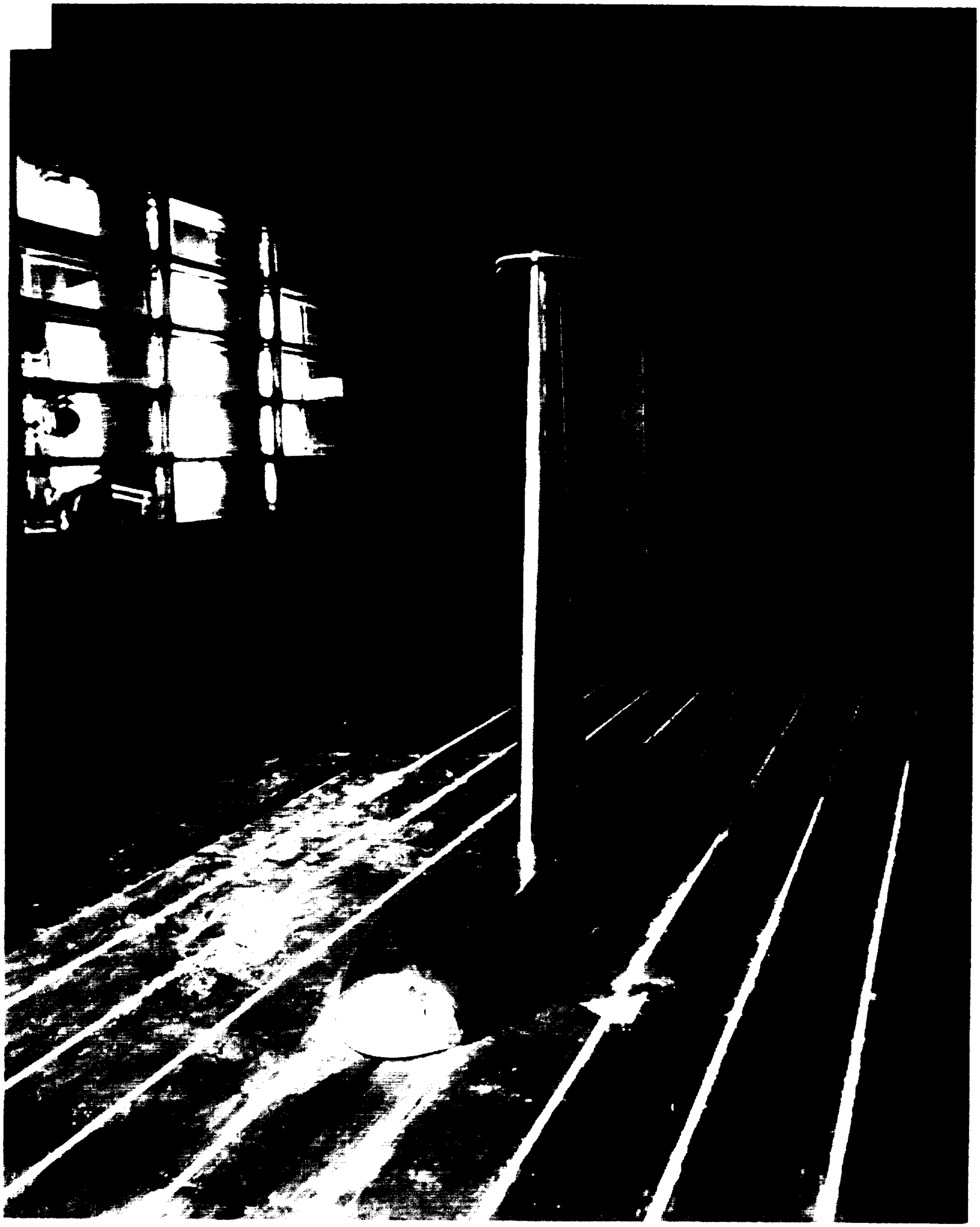

Figure 4.- de Havilland cruise model in Ames 11-Foot Wind Tunnel.

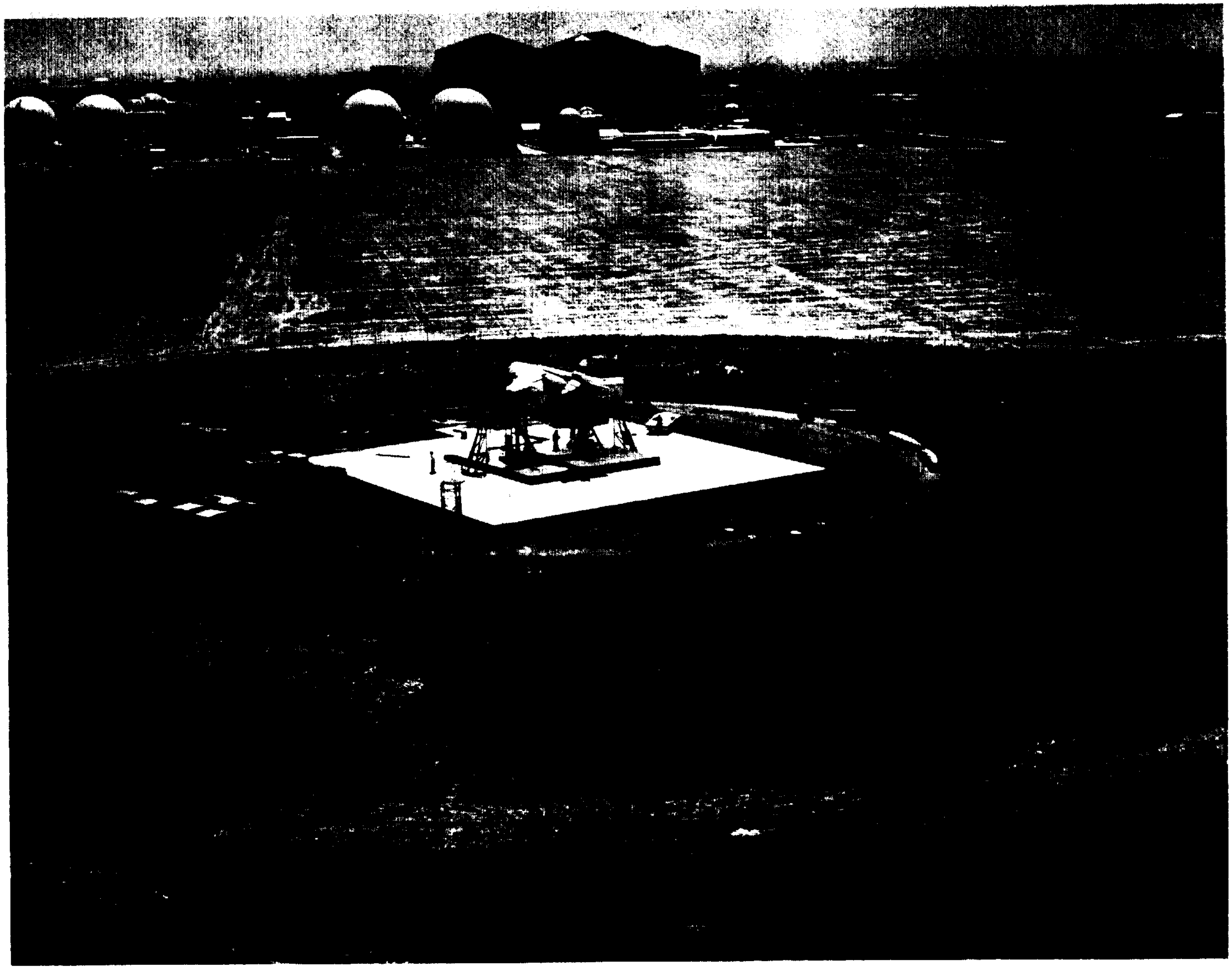

Figure 5.- AV-8B model in Ames Static Test Facility.

Figure 6.- de Havilland fuselage ejector model in Ames 40- by 80-Foot Wind Tunnel.

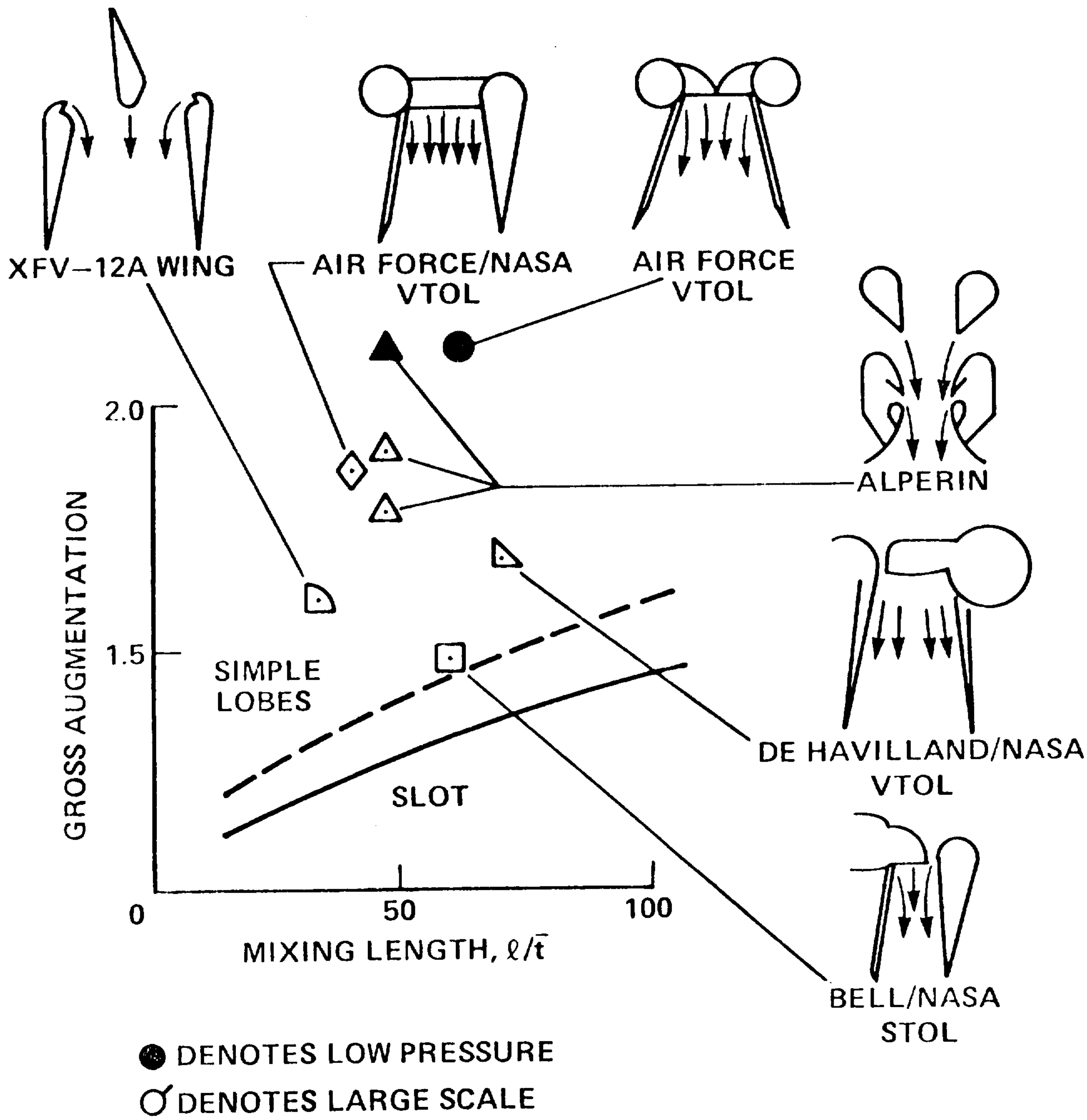

Figure 7.- Thrust augmentor performance.

DUCT AREA RATIO	A_d/A_n
THROAT AREA RATIO	A_t/A_n
DIFFUSER AREA RATIO	A_e/A_t
EXIT AREA RATIO	A_e/A_n
MIXING LENGTH	$\ell/\bar{t}$
NOZZEL TYPE	
NOZZEL ASPECT RATIO, NAR	h/t
NOZZEL PITCH, NP	p/t
TURNING ANGLE, θ_T	
VENTILATION	
AUGMENTOR ASPECT RATIO	

Figure 8.- Thrust augmentor geometry parameters.

DUCT PRESSURE LOSS, $\Delta P/P$	$(P_{IN}-P_{OUT})/P_{IN}$
NOZZEL VELOCITY COEFFICIENT, C_V	$(T/m_n V_{JI})$ SHROUD OFF
TURNING EFFICIENCY, η_T	T/T_{OT}
CIRCULATION LIFT COEFFICENT, C_{L_i}	$C_L - C_{L\ POWER\ OFF}$
GROSS AUGMENTATION, ϕ_G	$T_{SHROUD\ ON}/T_{SHROUD\ OFF}$
ISENTROPIC AUGMENTATION, ϕ_I	$(T/m_n V_{J_I})$ SHROUD ON
ENTERTAINMENT RATIO	m_S/m_n
NET AUGMENTATION, ϕ_N	$\theta_G-(m_S V_\infty)/T_{SHROUD\ OFF}$

Figure 9.- Thrust augmentor performance parameters.

DUCT MACH NUMBER, M_D	
NOZZEL PRESSURE RATIO, NPR	$(P_N)_{TOTAL}/P_\infty$
NOZZEL TEMPERATURE RATIO,	$(T_n)_{TOTAL}/T_\infty$
THRUST LOADING, T/S	$(T_n)_a/S$
VELOCITY RATIO, V_∞/V_J	$V_\infty/(V_{J_a}$ OR $V_{J_I})$
THRUST COEFFICIENT, C_J	$(T_n)_a/qS$

Figure 10.- Thrust augmentor operating parameters.

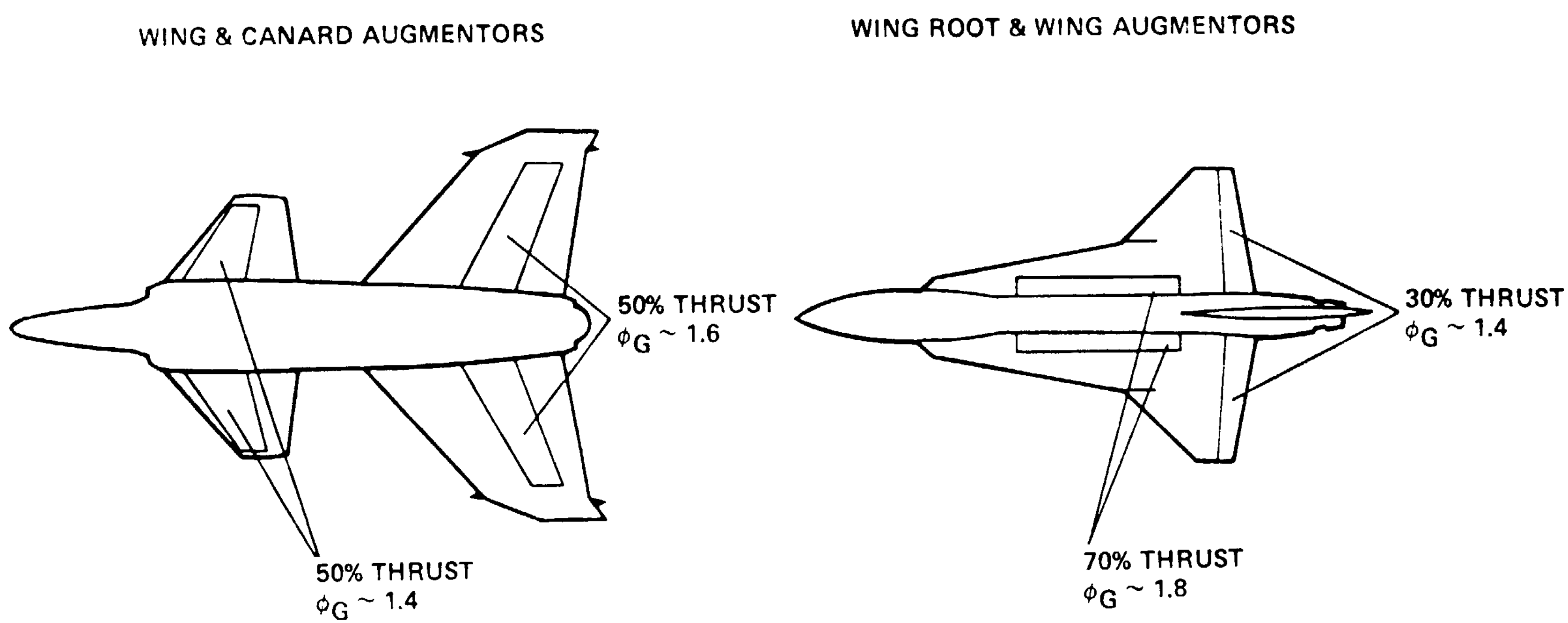

Figure 11.- V/STOL fighter-augmentor integration concepts.

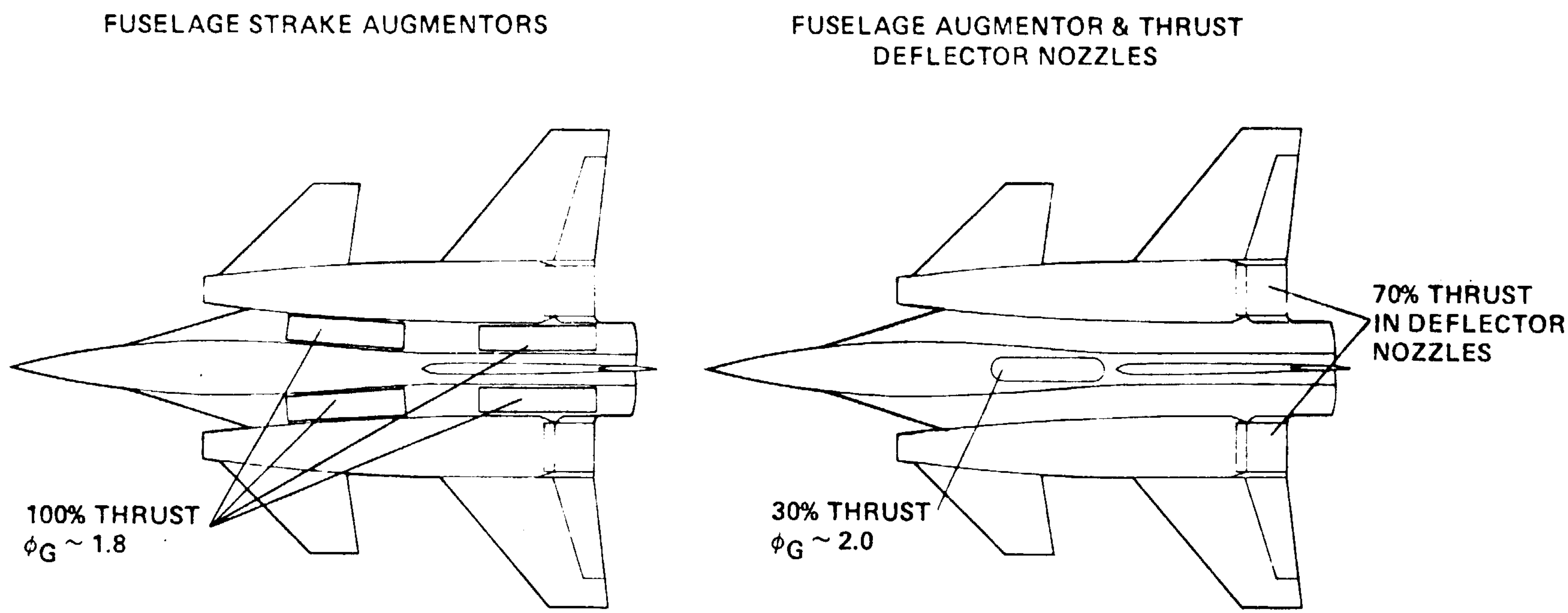

Figure 12.- V/STOL fighter-augmentor integration concepts.

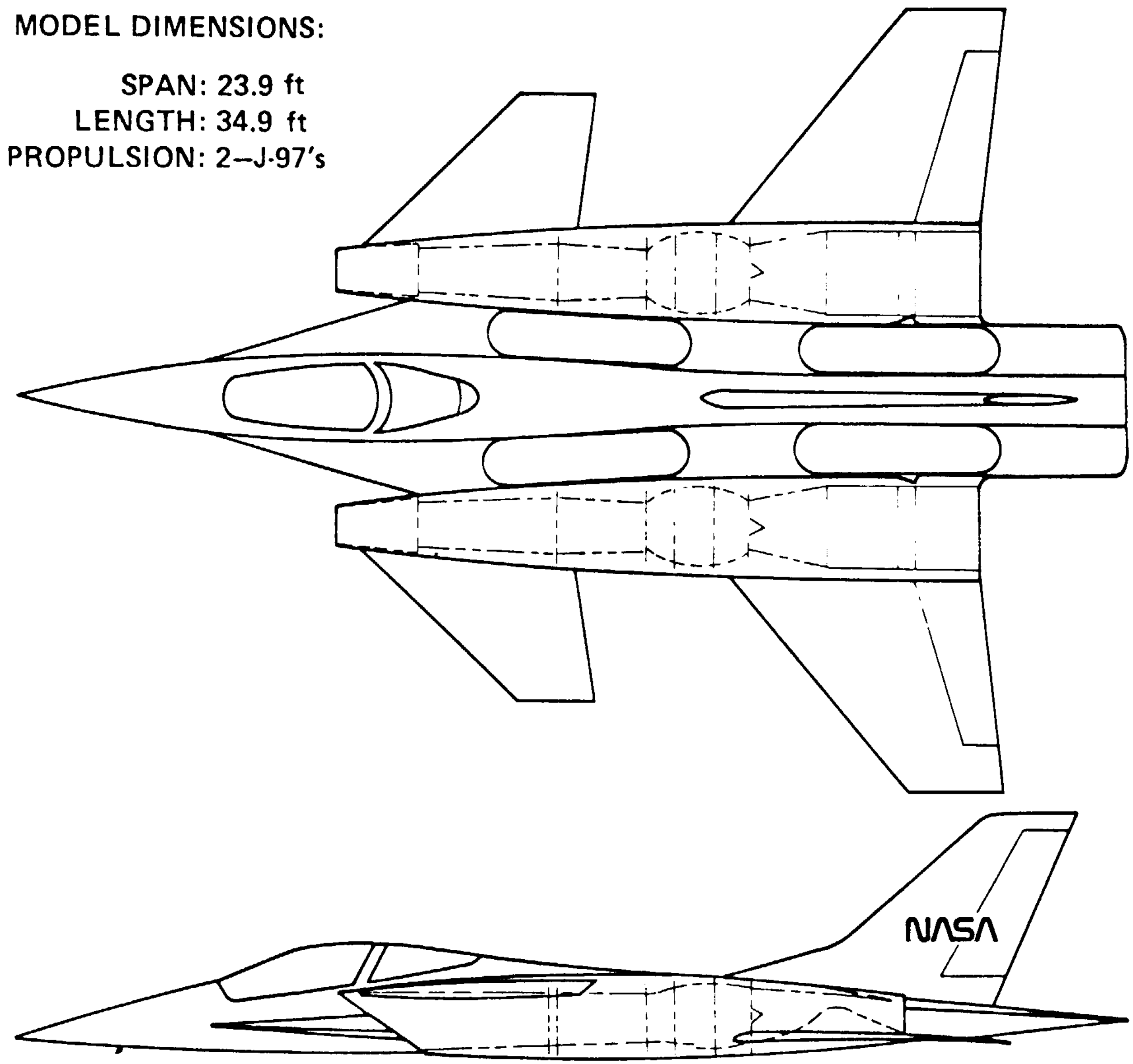

Figure 13.- Sketch of model under consideration for tests in the Ames 40- by 80-Foot Wind Tunnel.

- BASIC STUDIES—(EXPERIMENTAL)
  - SHORT DIFFUSER AUGMENTOR
  - FUSELAGE OR NACELLE MOUNTED
  - STOWAGE PROBLEMS
- THEORY DEVELOPMENT
- LARGE-SCALE V/STOL FIGHTER
  - FUSELAGE MOUNTED
  - NACELLE MOUNTED
- CONTROL THRUSTERS

Figure 14.- Areas of future effort in thrusting ejector research and development.