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SUMMARY OF RECENT DESIGN STUDIES OF ADVANCED ACOUSTIC-COMPOSITE NACELLES

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16. Abstract

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The results of these studies indicate that the use of advanced composite materials offer significant potential weight and cost savings and will result in reduced fuel consumption and noise when applied to nacelles. The most promising concept for realizing all of these benefits was a long duct, mixed flow acoustic composite nacelle with advanced acoustic liners.

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SUMMARY

This report summarizes the results of recent NASA sponsored studies of advanced acoustic-composite nacelles. Conceptual nacelle designs for current wide-bodied transports and for advanced technology transports, intended for operational use in the mid 1980's, were studied by Lockheed-California Company and the Douglas Aircraft Company. These studies were conducted with the objective of achieving significant reductions in community noise and/or fuel consumption with minimum penalties in airplane weights, cost, and operating expense.

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INTRODUCTION

Results of recent studies of the application of advanced technologies to long range commercial CTOL jet transport aircraft (references 1 through 6) indicate that significant weight, cost, and performance penalties will be incurred when propulsion systems are designed to low noise requirements. This is true for either advanced propulsion-system installations or for existing installations because in either case, acoustic lining, rings, or splitters, alone or in combination, will be required for noise attenuation external to the engine. Because the weight, cost, and performance penalties adversely impact commercial airplane economics, a need exists to reduce these penalties. Design studies were conducted by the Lockheed-California Company and the Douglas Aircraft Company to evaluate various nacelle concepts for reducing or offsetting these penalties, and the results of the studies are presented in references 7 and 8.

Two separate and distinct time periods were considered for the studies. The first assumed nominally a 1980 time frame for certification of a new version of a current wide-body transport which could incorporate an advanced acoustic composite nacelle. The second assumed nominally a 1985 time frame (or later) for certification of an advanced technology transport which would be an all new airplane, including appropriate application of advanced composites to the nacelle. For the wide-body transports, most of the composite nacelle component designs were based on replacement of existing components and entailed a minimum amount of redesign. For the advanced technology transport, all new designs were evolved which could take better advantage of the characteristics and properties of advanced composites. The levels of technology employed assumed that those concepts which had already attained some proof-of-concept through existing or recent research, or for which technology was nearly in-hand would be available for the wide-body transport airplane. For the advanced technology transport airplane, it was assumed that more advanced concepts as well as some improvements in material would be available. Therefore, as the results obtained for the wide-body transport airplane are indicative of the advanced technology transport airplane, only the results from the wide-body studies are summarized in this paper.

NACELLE CONFIGURATIONS

The broad objectives of the studies summarized in this paper was to define nacelle designs for a current wide-body transport aircraft which could: (a) achieve a significant reduction in community noise with minimum penalty in aircraft weight, cost, and operating expense, or (b) could achieve a reduction in aircraft weight, cost, and operating expense with no increase in community noise. Lockheed elected to design for low community noise with minimum penalties while Douglas elected to improve weight, cost, and performance with no increase in community noise. The effects of the various nacelle concepts were evaluated by comparing the performance, weight, and cost impact on an aircraft using the specific concept relative to a baseline airplane of known characteristics.

Lockheed Concepts

Baseline.- The Lockheed L-1011, powered by the Rolls-Royce R.B. 211-22B, was used as a reference for the Lockheed study. The baseline nacelle is shown in figure 1. The inlet, fan duct, and tail cone are treated for noise suppression using honeycomb panels with perforated face sheets. This baseline nacelle utilizes a 15-degree aftbody, a recent performance improvement over the original design.

Advanced Concepts.- Lockheed's noise goals were based on the existence of a noise floor which is a noise level created by the airframe and by jet noise and below which reduction of engine-generated noise is not productive. Shown in figure 2 are sketches of the configurations evaluated to achieve these noise goals. The baseline nacelle is included for visual reference. In configuration 1A, the inlet and fan duct are lengthened to accommodate the required acoustic liner length. The changes to the inlet and duct effectively suppress the fan noise; however, this configuration radiates excessive tailpipe noise.

Configuration 1B incorporates the same inlet and fan duct as 1A, but the tailpipe is lengthened to accommodate additional treatment and also incorporates six acoustically treated radial splitters. This arrangement was quite effective but does not attain the noise goals desired. Therefore, in configuration 1C, the radial splitters in the tailpipe (configuration 1B) have been replaced with an acoustically treated ring. This configuration achieves the desired noise reduction. In the three advanced configurations just described, the approach was to lengthen the inlet to obtain the required noise reduction. A near sonic inlet, configuration IIA, was also considered. This configuration is considerably longer, heavier, and more complex than the other configurations. The long inlets, long fan ducts, and the extensive treatment required in the tailpipes of the configurations that achieve the desired noise reduction contribute to additional nacelle drag and losses in the propulsion system. Observing that these components are nearly as large and as heavy as the components of a mixed-flow nozzle, and that the specific fuel consumption improvement attainable by the use of mixed flow might offset the losses of the long duct, configuration IIB was considered. This configuration retains the long inlet, but the tailpipe treatment is replaced with a nozzle to mix the fan and the core flows. The fan duct is extended to cover the nozzle and to produce the required mixing lengths and nozzle areas. This extended fan duct provides adequate opportunity to treat the fan noise and the core noise emanating from the tailpipe.

Configuration III is a minimum fuel concept which subordinates noise reduction to minimizing fuel consumption by using the standard length inlet and omitting any acoustic treatment that is not as smooth as a hardwall duct. The high-resistance facings used in the cool ducts are smooth and, therefore, have little drag penalty, but the mixer and nozzle treatments in the hot regions require perforates, and these perforates are replaced by hard walls for the minimum fuel configuration.

Douglas Concepts

<u>Baseline</u>.- The Douglas DC-10-30 powered by the General Electric CF6-50 was used as a reference for the Douglas study. The details of the baseline nacelle are shown in figure 3. The major nacelle components are identified and, as indicated by the dashed lines, incorporates substantial areas of acoustic treatment. However, only part of the treatment is of current technology composite construction.

<u>Advanced Concepts</u>.- Shown in figure 4 are the four short-duct, separate-flow nacelles evaluated and the long-duct, mixed-flow nacelle evaluated. Configuration 1 is the baseline nacelle as installed on the current production airplanes. Configuration 1A incorporates composites within the baseline aerodynamic contours to reduce weight. Configuration 1B represents an improvement to the performance and reliability of the basic separate flow system by shortening the core nozzle and deletion of the core reverser.

Configuration 1C was identical to 1A except for the addition of acoustic splitters in the fan duct. All of the short duct nacelles have identical nose cowl aerodynamic parameters and most of the flow path lines and aerodynamic contours are also the same.

As indicated in figure 4, an additional nacelle was studied. This is a long duct configuration which takes advantage of the inherent performance improvement available from the addition of a thermal mixer to the basic CF6-50C engine cycle. Prior to this study, Douglas and General Electric had evaluated a metal long-duct, mixed-flow nacelle and concluded that the reduction in fuel consumption achieved by the mixed-flow nacelle was counterbalanced by the increase in weight and attendant operating costs. With the introduction, in this study, of composites, and additional design refinements, the prospects of realizing the benefits of the mixed-flow nacelle, (i.e. reduced weights, cost, fuel consumption) were improved.

RESULTS AND DISCUSSION

The results of the two studies are summarized in tables 1 and 2. The configurations are characterized by predicted noise levels obtained on takeoff and approach at FAR Part 36 measuring conditions and evaluated in terms of nacelle weight per aircraft and cost per nacelle relative to the baseline nacelle. The configurations are also rated in terms of percent change in the mission fuel.

Lockheed

As stated previously, the Lockheed approach was to reduce the radiated engine noise to a level near those of the aircraft aerodynamic and jet noise with minimum penalties. The results of this approach, that is, maximum noise reduction, is shown in table 1. The application of advanced composite materials to the baseline nacelles results in a relative weight of 0.85 with a 0.3 percent reduction in mission fuel. This is a good indication of the impact of nacelle weight on performance. Configurations IA through IC (figure 2) indicate the impact of increasing length of the inlet and fan ducts and the addition of acoustically treated rings and splitters to obtain the various levels of radiated noise. The relative weights of these configurations varied from the order of 1.29 to 1.41 with percent increases in fuel consumption from 1.7 to 2.3. Comparing the relative weight and fuel consumption of these configurations accounts for only about 0.1 to 0.2 percent of this change. The rest of the 1.7 to 2.3 percent change in mission fuel is due to the internal losses, that is, increase in SFC, due to the acoustic requirements. Configuration IIA evaluates the trade between the long inlet with rings and a near sonic inlet. The noise reduction is obtained but weight and fuel penalties are excessive. When the weight penalties and fuel consumption penalties of the above configurations are considered, it is obvious that an improvement in installed performance of the propulsion system is required in order to accomplish these noise levels. The mixed-flow nozzle offers such an improvement. Configuration IIB evaluates the effect of mixed flow and the use of composite material. Additional noise reduction was obtained with this configuration and, with composite materials, a 0.3 percent improvement in mission fuel consumption, relative to the baseline, was obtained. Configuration III is an optimized or minimum fuel consumption configuration which has somewhat less noise reduction than configuration IIB but has a 1.0 percent reduction in mission fuel.

Douglas

The Douglas approach was to define a configuration that could reduce fuel consumption with no increase in noise. The Douglas results are summarized in table 2. Configuration IA indicates the benefits of advanced composite materials applied to the baseline configuration (figure 4). The relative weight (0.882) and the percent change in mission fuel, 0.30 percent reduction, were similar to the improvements indicated by Lockheed for their baseline configuration. Other changes to the baseline configuration described in figure 4 for configurations IB and IC reduced weight and fuel consumption as indicated in table 2. Douglas and their subcontractor, General Electric, felt that the improved performance of mixed-flow nozzles should be investigated. Configuration IIA, utilizing mixed flow and advanced composites, indicates a reduction of 4.75 percent in mission fuel and a relative weight of 0.842. Configuration IIB is the same as IIA except it is manufactured using current metal technology. It can be seen that relative weight increased to 1.13 and the large fuel saving of IIA is now reduced to a 1.70 percent saving. The relative costs of the Douglas configurations is also included in table 2. It can be seen that the relative cost of configuration IIA is 0.77 compared to configuration IIB relative cost of 1.13.

CONCLUDING REMARKS

Conceptual design studies have been conducted by the Lockheed-California Company and the Douglas Aircraft Company. These design studies were conducted to assess the impact of incorporating advanced technologies in the nacelles of a current wide-bodied transport and an advanced technology transport. The studies evaluated the improvements possible in areas of fuel consumption, flyover noise levels, airplane weights, manufacturing costs, and airplane operating costs. Short and long-duct nacelles were evaluated. Nacelle concepts using advanced acoustic liners, annular splitters, radial splitters, translating centerbody inlets, and mixed-flow nozzles were considered in the studies. The results warrant the following comments:

1. The advanced acoustic composite nacelles defined in these studies provided noise levels on the order of 10 EPNdB below FAR Part 36 requirements or obtained reductions in mission fuel consumption up to 4.8 percent.

2. Substantial fuel savings resulted from flow mixing on CF-6 as well as from the improved aerodynamics of the long-duct, mixed-flow nacelle.

3. The benefits attributable to the use of advanced composite materials include: reduced nacelle and wing weight; use of more advanced acoustic treatment designs; reduced manufacturing costs, especially for more complex geometry of advanced acoustic treatment designs; and improved durability in the high acoustic fields of the engine as compared with metal nacelles.

4. The reduction in fuel consumption achieved by an all metal long-duct, mixed-flow nacelle is counterbalanced by the increase in weight and attendant operating cost and, therefore, does not result in an airplane economic improvement. However, a composite long-duct, mixed-flow nacelle can achieve reductions in fuel consumption without increase in weight and operating cost.

REFERENCES

1. Boeing Commercial Airplane Company: Study of the Application of Advanced Technology to Long-Range Transport Aircraft. NASA CR-112092 and 112093. May 1972.

2. Lockheed-Georgia Company: Study of the Application of Advanced Technologies to Long-Range Transport Aircraft. NASA CR-112088 and 112089. May 1972.

3. Convair Aerospace Division, General Dynamics Corporation: Study of the Application of Advanced Technologies to Long-Range Transport Aircraft. NASA CR-112090 and 112091. May 1972.

4. General Electric Company: Propulsion System Studies for an Advanced High Subsonic Long Range Jet Commercial Transport Aircraft. NASA CR-121016. November 1972.

5. Brines, Gerald L.: Studies for Determining the Optimum Propulsion System Characteristics for Use in a Long-Range Transport Aircraft. NASA CR-120950. July 1972.

6. NASA Acoustically Treated Nacelle Programs, NASA SP-220, October 1969.

7. Goodall, R. G.; and Painter, G. W.: Conceptual Design Study of Advanced Acoustic-Composite Nacelles. NASA CR-132649. May 1975.

8. Nordstrom, Kenneth E.; Marsh, Alan H.; and Sargisson, Donald F.: Conceptual Design Study of Advanced Acoustic-Composite Nacelles. NASA CR-132703. July 1975.

CONCEPT	MATERIAL	ΔNOISE RE FAR 36, EPNdB		RELATIVE WEIGHT	ΔMISSION FUEL, %	RELATIVE COST
		TAKEOFF	APPROACH			
I	METAL	-9	-4	1.000	0	1.000
I	COMP	-9	-4	0.852	-0.3	0.852
IA	METAL	-10	-5	1.289	1.7	1.289
IA	COMP	-10	-5	1.215	1.5	1.215
IB	METAL	-11	-9	1.355	2.1	1.355
IB	COMP	-11	-9	1.292	2.0	1.292
[illegible]	METAL	-11	-10	1.408	2.3	1.408
IC	COMP	-11	-10	1.345	2.2	1.345
IIA	METAL	-11	-11	1.532	3.2	1.532
IIA	COMP	-11	-11	1.442	3.0	1.442
IIB	METAL	-12	-9	1.390	0.1	1.390
IIB	COMP	-12	-9	1.190	-0.3	1.190
III	COMP	-11	-6	1.082	-1.0	1.082

TABLE 1. - SUMMARY OF LOCKHEED RESULTS

CONCEPT	MATERIAL	NOISE RE FAR 36, EPNdB		RELATIVE WEIGHT	ΔMISSION FUEL, %	RELATIVE COST
		TAKEOFF	APPROACH			
I	METAL	-4	0	1.000	0	1.000
IA	COMP	-5	-3	0.882	-0.30	0.884
IB	COMP	-5	-2	0.769	-1.32	0.743
IC	COMP	-5	-3	0.932	-0.17	0.896
IIA	COMP	-8	-3	0.842	-4.75	0.770
IIB	METAL	-8	-3	1.128	-1.70	1.129

TABLE 2. - SUMMARY OF DOUGLAS RESULTS

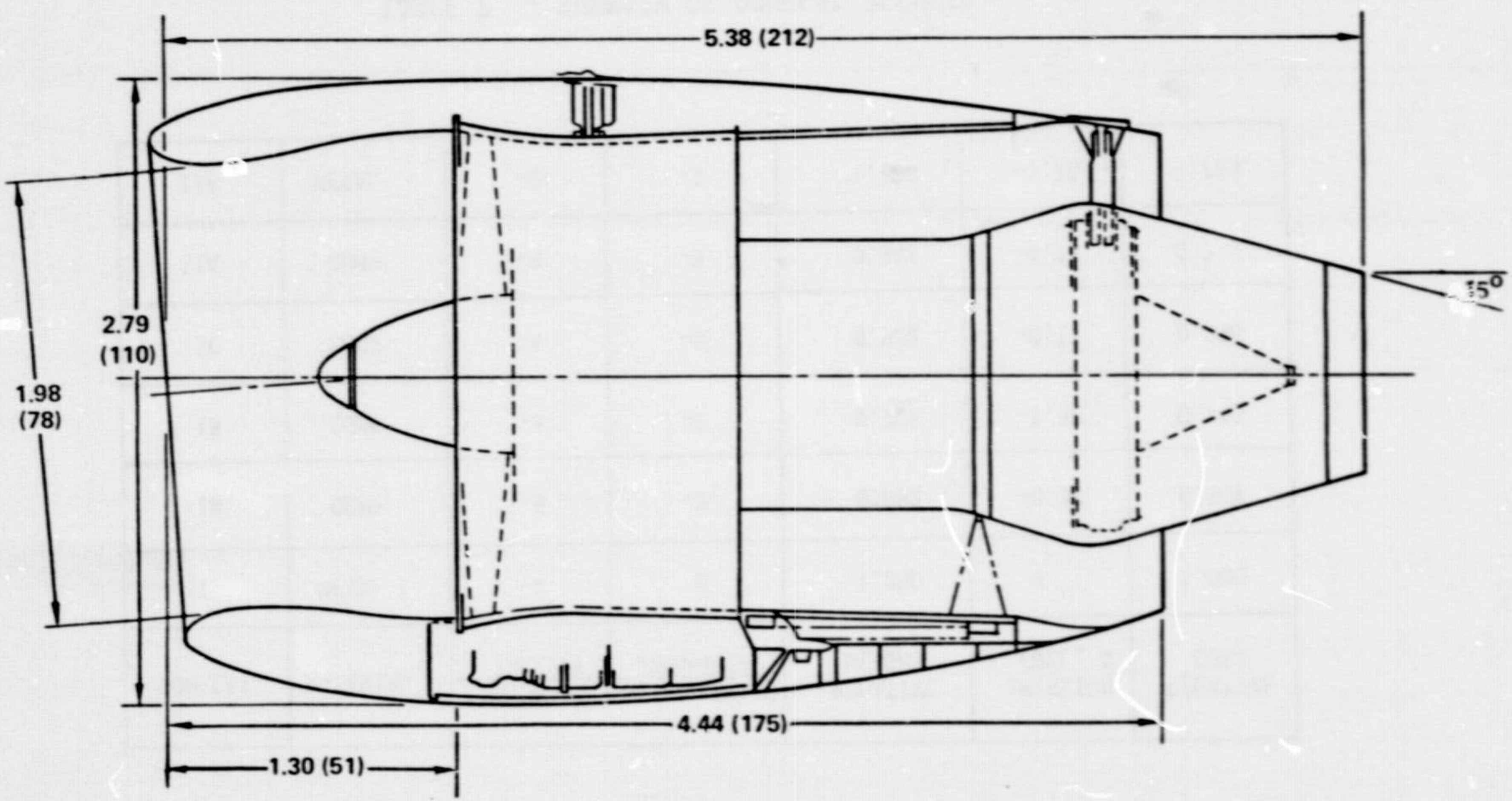

FIGURE 1 - LOCKHEED BASELINE NACELLE L-1011

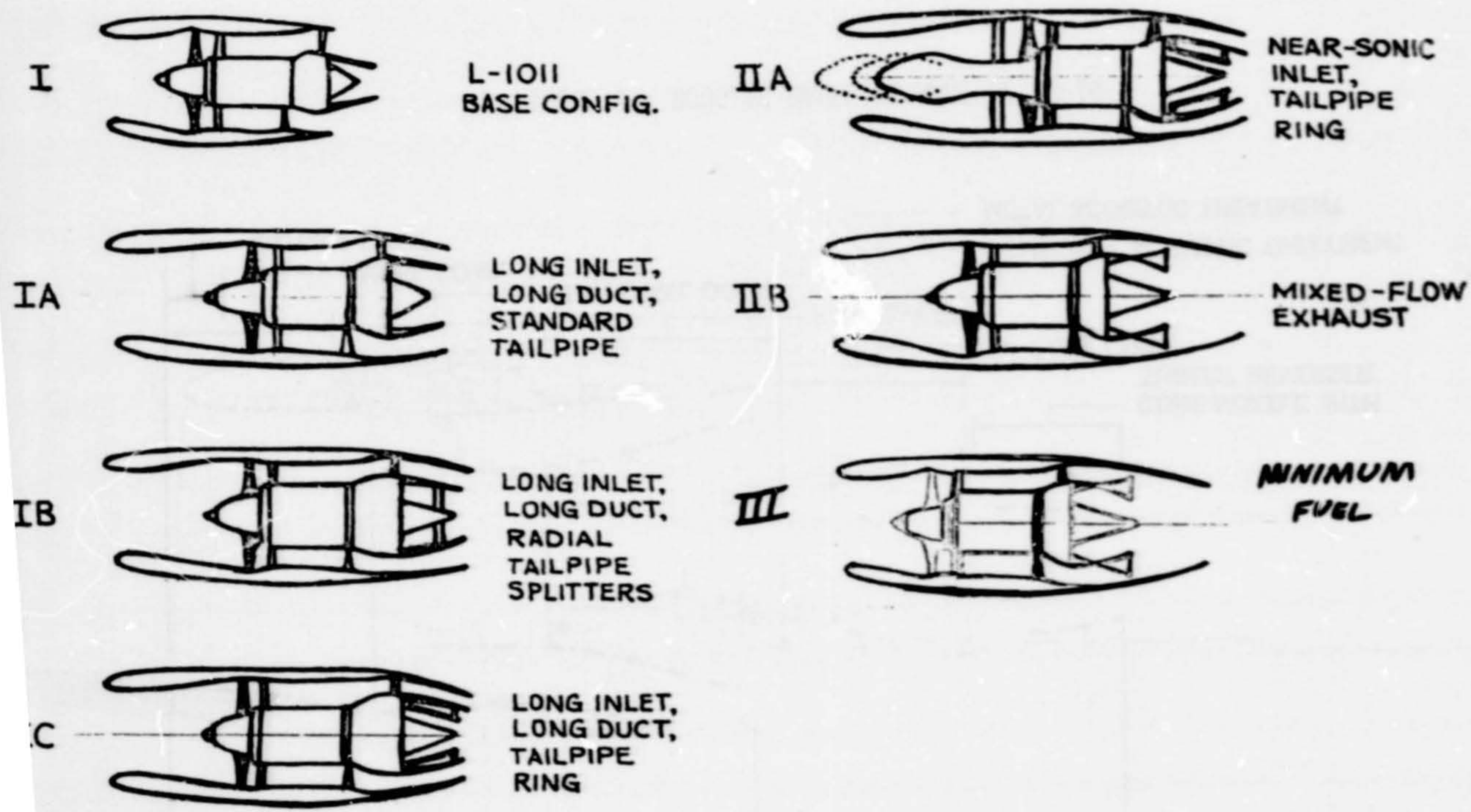

FIGURE 2. - LOCKHEED STUDY CONFIGURATIONS FOR WIDE BODY TRANSPORT

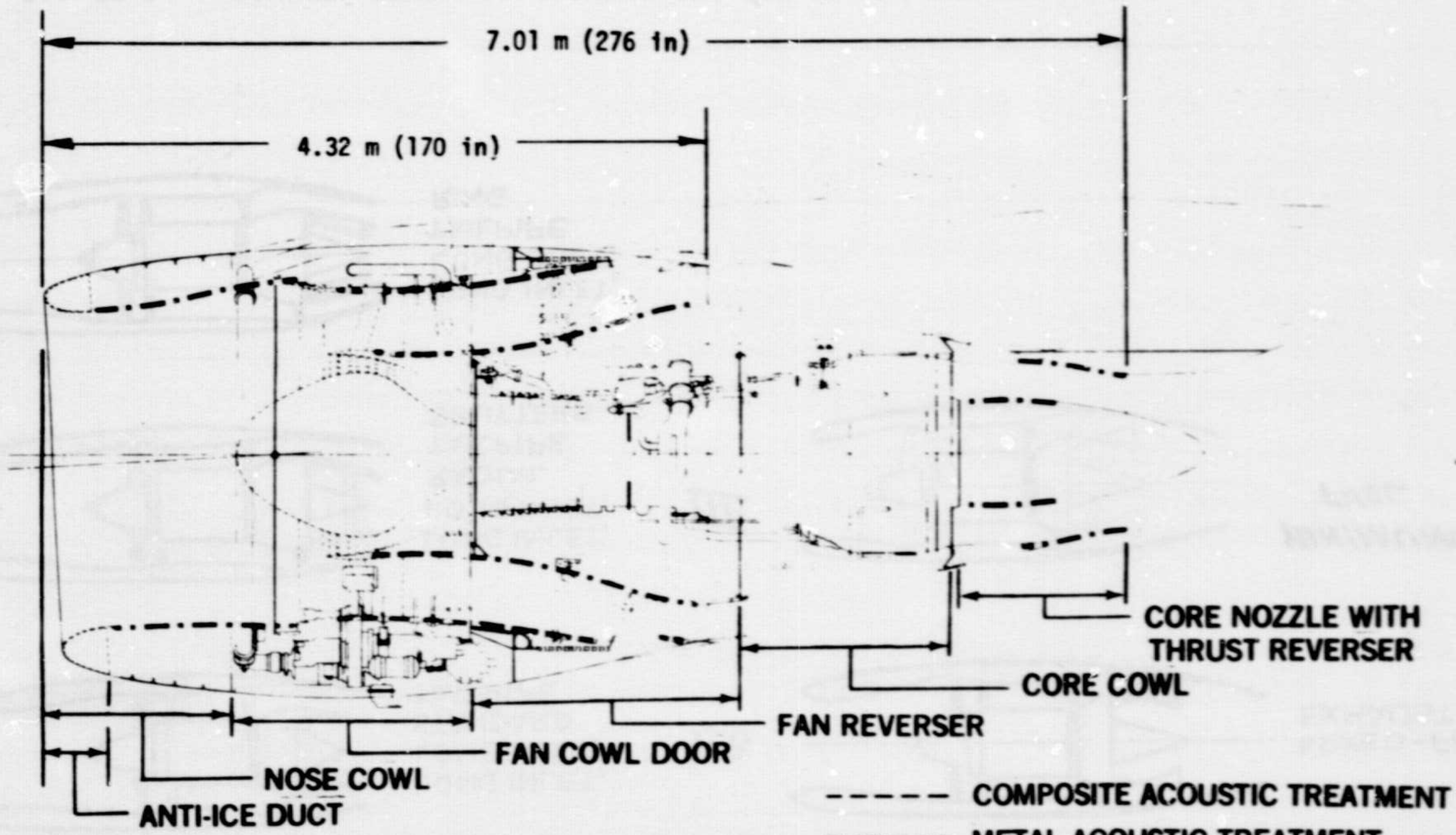

FIGURE 3 - DOUGLAS BASELINE NACELLE DC-10

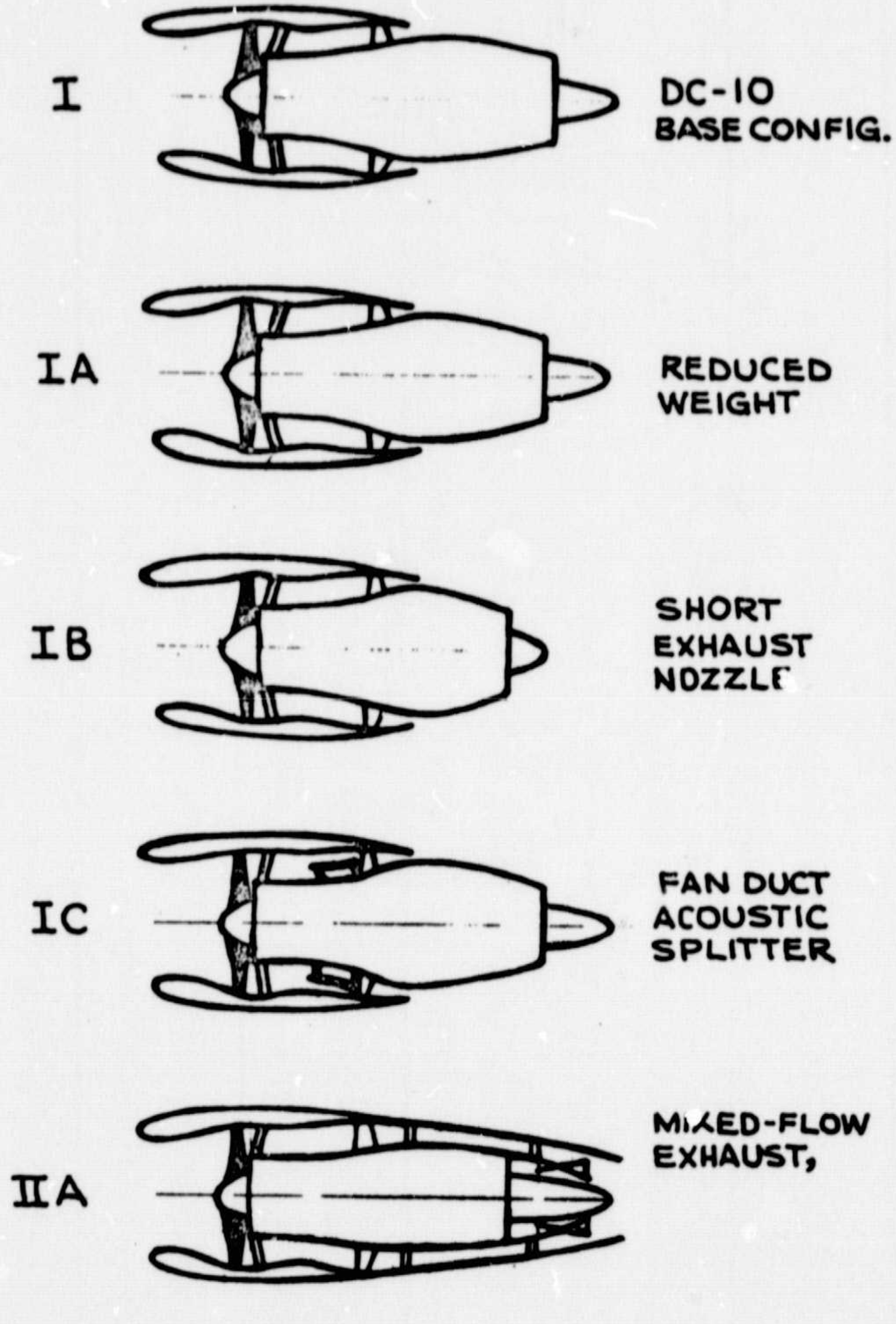

FIGURE 4. - DOUGLAS STUDY CONFIGURATIONS FOR WIDE BODY TRANSPORT