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ACOUSTIC FATIGUE: OVERVIEW OF ACTIVITIES AT NASA LANGLEY

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ABSTRACT

A number of new aircraft and spacecraft configurations are being considered for future development. These include high-speed turboprop aircraft, advanced vertical takeoff and landing fighter aircraft, and aerospace planes for hypersonic intercontinental cruise or flight to orbit and return. Review of the acoustic environment expected for these vehicles indicates levels high enough that acoustic fatigue must be considered. Unfortunately, the sonic fatigue design technology used for current aircraft may not be adequate for these future vehicles. This has resulted in renewed emphasis on acoustic fatigue research at the NASA Langley Research Center. The overall objective of the Langley program is to develop new methods and information for design of aerospace vehicles that will resist acoustic fatigue without excessive weight penalties.

The program includes definition of the acoustic loads acting on structures due to exhaust jets or boundary layers, and subsequent determination of the stresses within the structure due to these acoustic loads. Material fatigue associated with the high frequency structural stress reversal patterns resulting from acoustic loadings is considered to be an area requiring study, but no activity is currently underway.

INTRODUCTION

Sonic fatigue has been recognized as an important consideration for aerospace vehicles since the 1950's. Operational experiences of a variety of aircraft and spacecraft demonstrated that intense acoustic pressures can actually cause failure of lightweight structures such as skin panels, fuselage rings and stringers, and ribs in wing, flap, and tailplane structures(Ref.1). While these failures may not be catastrophic, the maintenance and repair costs may be considerable. During the 1950's and 1960's considerable research was done to both understand and develop design methods for acoustic fatigue.[2,3]

At the present time, a variety of new vehicle types are either under development or being considered for development, figure 1.[4] All of these vehicles feature increased performance in comparison with currently existing vehicles. Performance increases such as higher speed, greater maneuverability, larger payload, and increased efficiency can be expected to lead to new sonic fatigue problems associated with higher noise loading and lighter weight structures. The effects of extremely high temperatures, new structural materials, and new complex structural configurations must also be taken into account. The existing sonic fatigue technology is not expected to meet the needs of these emerging vehicles, therefore basic research in sonic fatigue has been given renewed emphasis.

This paper will present an overview of the current acoustic fatigue program at the NASA Langley Research Center. Estimation of the acoustic fatigue situation for future vehicles is discussed first to identify needed research areas. Then, current research on acoustic loads prediction and structural response is described, including example results,facilities used, and plans. Acoustic loads research is focused on supersonic heated jets and boundary layers. Structural response research is focused on 1) development of theoretical methods for predicting strain and modal response characteristics; 2) the effects of high temperature on structural response behavior; and 3) fiber-reinforced composite material structures.

SONIC FATIGUE ESTIMATION

The vehicles shown in figure 1 are in very early stages of development, therefore no direct information is available on the acoustic loadings, structural response, or fatigue lifetime. An indication of the potential acoustic fatigue problems can be obtained by use of acoustic data from existing similar aircraft, scaling laws, and available design guides.[3, 5, 6, 7]

Previous aircraft experience provides a guide to noise levels that may be expected to result in fatigue failures, figure 2.[1] The shaded bars indicate the noise levels at which acoustic fatigue failures were observed for various types of acoustic loadings. For levels in the range of 140 to 150 dB fatigue damage can occur after many cycles, and for levels of 180 dB or higher damage can occur after only short exposure. The noise pressure scale indicates that sound can exert significant forces, for example 170 dB of normally incident sound would exert about 144 pounds of force on a one foot square panel. The need for lighter weight structures on future aircraft suggests that they may experience fatigue at noise levels similar to those shown in figure 2.

Aerospace Plane

The aerospace plane concept focuses on two types of mission operation,[8] either sustained hypersonic cruise within the atmosphere, or space launch of payloads into orbit. In either case takeoff is horizontal from a runway and acceleration is rapid. Acoustic loadings should be considered for various phases of flight, including takeoff, ascent, cruise, reentry, and landing.

In the early stages of the takeoff roll the structure in the nearfield of the engine exhaust jet will experience noise levels between 160 and 170 dB. These levels are similar to those measured on the Shuttle and can be estimated from known empirical formulas and exhaust jet parameters. As the speed of the airplane increases, the relative speed between the jet and the freestream decreases so that the intensity of the jet noise sources is decreased. When the local flow speed becomes sonic, the disturbances from the jet cannot propagate upstream to the structure. The speed of Mach 1 is expected to be reached within minutes after takeoff, and then the jet noise loads are expected to become negligible.

A flight envelope for ascent or cruise operation is shown in figure 3.[8] Use of the data in figure 3 along with standard atmosphere characteristics leads to the conclusion that the aircraft will operate at dynamic pressure values on the order of 1000 to 2000 psf. Maximum fluctuating pressure loads on a structure under a boundary layer have been found to vary in proportion to the dynamic pressure; empirical relations that relate fluctuating pressures to dynamic pressure are given in figure 4. Estimates of acoustic loadings for various vehicle locations, figure 5, indicate levels that are well into the range where acoustic fatigue failures have been observed in the past.

Temperature is expected to be an important parameter when considering structural response and fatigue under aerospace plane flight conditions. Estimated temperatures, figure 6, are high over large areas of the vehicle structure, with large temperature gradients in some regions.[9] These temperatures may affect the acoustic fatigue problem in two ways. First, the structures and materials that are required for reusable high temperature operation are likely to be complex, figure 7,[10, 11, 12] and may be of the type for which little acoustic fatigue data is available. Second, temperature can influence the acoustic fatigue lifetime in several ways, figure 8, including thermal prestress or thermal buckling (which results in high stress "oil canning" or "snap-through" behavior) , and changes of material properties such as Young's modulus or the fatigue lifetime as expressed in the S-N diagram.

High Performance Fighters

One feature of increased performance for fighter aircraft is increased maneuverability, as exemplified by the Harrier VSTOL aircraft.[13] Thrust vectoring provides both vertical takeoff and landing capability, and greatly increased maneuverability in forward flight. Most designs feature engine exhaust locations that are forward on the fuselage such that the exhaust jets are directed either onto, or nearly onto, the aircraft structure, figure 9. Estimates indicate that, for some nozzle positions, most of the aircraft is immersed in a noise field with levels above 150 dB, with levels near the nozzle being significantly higher. The exhaust temperatures may exceed 1000° F in the region of the nozzle, and therefore the structure needs either high temperature capability or thermal protection devices.

Composite materials are finding increased usage in fighter aircraft.[14,15] Figure 10 indicates the areas where composites are used on the Harrier II aircraft. Reference 15 indicates that "...some 30% of the aircraft by weight is made up of composites." Design guides for graphite-epoxy composites are available,[16] and appear to be acceptable for current applications. New materials and configurations are still evolving, however, and new V/STOL aircraft of higher performance are under consideration,[17,18] indicating that a continuing program of acoustic fatigue study is desirable.

Advanced Turboprop Aircraft

New propeller configurations have been under development for some time for large passenger transport aircraft with the objective of saving fuel costs. These propeller blades have a swept-back shape that is intended to increase the aerodynamic performance and to decrease the noise generated. However the noise levels remain in the range where acoustic fatigue must be considered, especially for configurations having the propellers located near the fuselage, figure 11. There are two unique features of this situation. First is the tonal nature of the acoustic field, where the acoustic energy is concentrated at the propeller blade passage frequency (in the range 150 to 250 Hz) and harmonics of that frequency, and where the acoustic field is highly correlated over large areas of the structure. This noise field characteristic is especially sensitive to the relative dynamics of the structure and the noise, and must be treated with a different approach than those used for broad band jet or boundary layer noise. The second feature is the unusually long duration of the high noise levels. The propeller noise is highest at the highest tip speed, which occurs during the cruise phase of flight. The exposure time is much longer than usual (for most aircraft the high noise levels occur only during a relatively short time of takeoff and landing), and therefore requires special consideration.

ACOUSTIC LOADS RESEARCH

Boundary Layer Loads

With respect to the vehicle types shown in figure 1, new information on boundary layer loads is most important for the hypersonic (aerospace plane) vehicle. Most available boundary layer loads data are for speeds less than Mach 2.5, with the exception of some data for a maneuverable entry body taken in Mach 4 and Mach 8 wind tunnels.[7] The scatter in the high speed data is large, with overall levels currently estimated within 5 dB and spectrum levels within 10 dB. This uncertainty in levels is inadequate since use of the higher values would probably result in overdesigned structure, and use of lower values may lead to an unsafe design.

New information for the higher speed segments of the flight envelope, figure 3, may not be required because there are indications that fluctuating pressures decrease with Mach number above about Mach 6. When the entry and descent flight profiles are defined, the associated loads can be determined using the same methods as for ascent.

Experimental and theoretical research has been initiated for definition of the fluctuating boundary layer loads for super/hypersonic flight conditions. Experimental studies are focused on development of methods for measurement of fluctuating pressures at Mach numbers up to 6 for temperatures up to 1800° F. Test facilities being considered include the 8 foot high-temperature structures tunnel and a 7 inch wind tunnel. A key element is a transducer that can operate at the high temperature and at the high frequencies (several thousand Hertz) required for model studies. Theoretical studies are developing methods to account for the effects of factors such as velocity and temperature gradients on the measurements.

Jet and Plume Loads

Acoustic loadings due to engine exhaust jets are currently of most interest for the hypersonic vehicle and the high performance fighter configurations, figure 1. Because of the vehicle configurations, with the engine exit located relatively far forward on the fuselage, the exhaust flow impinges on a significant length of fuselage structure. The high performance of the vehicles results in exhaust flows with high velocities and high temperatures. In the vertical landing mode an ASTOVL aircraft, figure 9, may also be subjected to jet loadings due to the "reflection" of the downward-flowing engine exhausts from the landing surface.[14] Available information such as acoustic loadings from free jets,[19] and low speed impinging flows,[20] are not expected to be sufficient for these future aircraft conditions.

Research is underway on existing configurations, and has been proposed for definition of acoustic loads for configurations and jet conditions approaching the requirements of future vehicles. (Test facilities and instrumentation are not available for the actual temperatures that are expected.) Figure 12 illustrates a test to define the acoustic pressures and temperatures on a flat plate due to an impinging supersonic jet. The nozzle exit is 4 inches wide by 0.5 inches high, and it is designed to operate at exit velocities of Mach 1.35 and 2.0, and at temperatures from ambient to 1000° F. Preliminary results indicate that the jet flow is strongly influenced by the presence of the plate and that fluctuating pressure levels are high. The interaction of two supersonic jets is illustrated in figure 13.[21] The test configuration, shown at the upper left, is representative of currently operating aircraft. The unsuppressed jets, lower left, interact to form intense sound waves that propagate upstream, where they could impinge on structure. For this configuration the resonance was suppressed using a geometric modification of one of the nozzles, resulting in the load reduction shown at the right. The facility used for these tests has been used for a variety of studies and has been shown to give results in agreement with full scale results.[22] Modifications of this facility are planned in order to obtain temperatures and flow velocities that more closely represent those of future vehicles, figure 14.

For hypersonic vehicles combustion may be a significant source of acoustic loading on the engine and airframe structure. Theoretical and experimental research has been proposed for definition of the loads and for investigation of active combustion control.

STRUCTURAL RESPONSE RESEARCH

Dynamic Strain Prediction

The great variety of structural materials and configurations called for by future vehicles suggests that an empirical approach may be too costly and time consuming to provide the required acoustic fatigue data in a timely manner. Consequently, an alternate approach employing theoretical methods may be appropriate. A theoretical basis for stress prediction exists,[23] and the recent advances in analytical methods (such as finite elements) and computing power are causes for some optimism that renewed efforts could produce satisfactory, improved theoretical methods.

In a recent study,[24] some composite panels were subjected to normally incident acoustic waves and their acceleration and strain responses were measured and predicted. The test apparatus and results are illustrated in figure 15. Care was taken in setup and calibration of the horn and in mounting the panel in order to approach ideal test conditions. As illustrated at the lower left, very good agreement between measured and predicted panel acceleration was achieved. On the other hand, the measured strain was consistently less than the predicted strain, lower right, for the "iso" (aluminum) panel as well as for the three composite panels. This result appears to be in general agreement with previous attempts to predict strain for idealized panels (reference 25, for example). Recent theoretical efforts to improve the agreement have accounted for the boundary conditions in an improved way and have compared Ritz solutions with finite element solutions.[26] Satisfactory agreement has not yet been achieved, so additional theoretical and experimental efforts are expected.

Non-Linear Strain Response

Intense acoustic loadings can drive flat panels to such large deflections that non-linear in-plane forces become important. Development of theoretical methods for prediction of panel response when large amplitude non-linear effects are important has been initiated.[27] Some recent results showing non-linear effects for aluminum and composite panels are presented in figure 16.[28]

For this analysis the sound was normally incident, resulting in constant pressure over the surface of the plate. The frequency spectrum of this pressure was flat,consequently the forcing pressure magnitude on the plate vibration modes was the same for the three plates, even though the modal frequencies were different due to the different plate stiffnesses. The effective stiffness, D_{eff}, was determined from the modal vibration frequency of the plates. The method of equivalent linearization was used to solve the non-linear equation that resulted from the use of a single mode substitution in the non-linear plate equations. Both linear and non-linear analysis show that the composite panels have more strain than the aluminum panel. For the linear case the magnitudes of the differences can be explained using the mass values, stiffness values, and the approximate formula given at the lower right of the figure. The effect of nonlinearity is shown to depend on the particular composite layup, for example at the highest sound level the strain of the aluminum panel and of the 90/±45/0 composite panel are both reduced to about 45% of their linear values, but the 0/±45/90 composite panel is reduced to 37.5% of its linear value.

The analytical methods used for figure 16 have also been used to study the effect of non-linear damping on the large amplitude response of composite panels,[29] and to study the effects of transverse shear and plate thickness on panel response to acoustic excitation.[30]

Snap-Through of Buckled Plates

Acoustic excitation can also cause non-linear response behavior in panels that are naturally curved or are curved due to buckling. The non-linear response of panels that are buckled due to in-plane compression has been investigated,[31] and some of the results are illustrated in figure 17.

In this analysis, the out-of-plane displacement of a rectangular plate under in-plane compression is represented by a single mode. By including tensile energy due to large displacements, the non-linear force-displacement relation was obtained, figure 17. When the compressive edge shortening, u, is less than the critical value, u_c, the plate remains flat and the force-displacement curve is monotonically increasing. When $u>u_c$ the curve has a local maximum and a minimum, and therefore the two equilibrium positions A and B. When the vibratory motion about equilibrium position A becomes just sufficiently large, the displacement will "snap-through" to point C and the ensuing motion will take place about equilibrium position B, or snap-through towards A again.

The equivalent linearization technique is used to find the non-linear vibratory response of the buckled plate under random acoustic excitation,and results are shown at the right of the figure. The excitation level parameter (alpha) is nondimensionalized such that alpha = mean square displacement, q_{ms}, for linear response of a flat plate without compression. For a given excitation level, response increases with increasing in-plane compression until the buckled deflection is too large for snap-through on every cycle (persistent snap-through) and the snap-through occurs only intermittently. hhe figure also shows that as the excitation level increases, the point of maximum response corresponds to increased plate buckling, i.e. larger values of u/u_c. For alpha = 2, the maximum mean square displacement, (and therefore the maximum stress) is about 1.4 times the value with no compression; this increased stress could lead to reduced acoustic fatigue lifetime. Experimental study of snap-through behavior is currently planned.

Response at Elevated Temperature

The effects of elevated temperature are expected to be more important for future vehicles due the combination of longer duration exposure to both acoustic and thermal loads, larger areas of the structure that are exposed, and the need for lighter weight reusable structure. As indicated in figure 8, temperature can affect the structural response to acoustic loads through four mechanisms. Preparations are being made for experimental and theoretical study of these mechanisms. The "oil canning", or "snap-through" behavior of a thermally buckled panel might be expected to be similar to the behavior of a mechanically buckled panel, therefore the results described above could provide some guidance.

Figure 18 indicates some early theoretical results and some features of the planned tests. The initial study will use cantilever plates with moving base excitation, and will measure strain response at temperatures up to about 1000° F. This configuration will simplify the test hardware to avoid problems such as mechanical attachment of a shaker to a hot test panel, and will allow study of the effects of material property changes without the complicating effects of large prestress or buckling.

The lower left graph shows calculated stress and deflection due to a temperature gradient through the thickness of the plate. The stress arises because the boundary clamp prevents expansion of the plate in the Y direction, figure 18. The end deflection arises due to the greater expansion of the heated face of the plate compared to the relatively cooler back face. These effects can be minimized in the test setup, and the same analysis used for the more complex clamped-clamped boundary condition.

The lower right graph shows calculated vibratory strain due to the moving base. A Rayleigh-Ritz method for linear response to a white noise spectrum was used and the effects of thermal prestress and pre-deformation were not included. The figure shows that a reduction of Youngs modulus due to an increase of temperature results in an increase of the strain at the resonant frequency, and a decrease of the resonant frequency.

Testing at Elevated Temperature

Facilities and test methods for use at high temperature are not well developed, therefore new developments are needed. For example, there is a need to know the resonant frequencies, damping values, and strain response of panels at high temperature, (as well as at large amplitudes). An example of a method that is being studied is the Ibrahim Time Domain (ITD) method, figure 19.[33] This method is intended to measure structural properties while the structure is responding to a random input. The random response time history is sampled to obtain a decay curve, as indicated at the upper left. The decay curve is then analyzed to obtain the component resonant frequencies and damping values. In the study illustrated, results from the ITD method were compared with results from a standard impulse hammer test of four panels at room temperature. Damping ratio estimates using the ITD method are presented in the upper right as a function of acoustic excitation level.The values shown are somewhat lower than, but in reasonable agreement with the values of 0.029 to 0.046 obtained from the impulse tests. The lower right figure shows a comparison between the natural frequencies identified by the ITD and hammer test methods. As shown the agreement is excellent. Further studies of this method, as well as related methods,[34] appear warranted.

The Thermal Acoustic Fatigue Apparatus (TAFA), figure 20, was developed for testing of Space Shuttle thermal protection systems.[35,36,37] It uses two electro-pneumatic sound generators of 30 kW each to produce a progressive wave at levels up to 163 dB rms overall, and can accomodate test panels up to a maximum size of 6 by 6 feet. Electrical power of 500 kW is available at the test chamber for panel heating. The TAFA is currently being returned to service after an inactive period,and is being fitted with quartz heaters of several types for evaluation. Upgraded acoustic and electrical power capabilities may be required in order to produce the highest sound levels and heat flux values envisioned for future environments.

CONCLUDING REMARKS

This paper describes the current status of the acoustic loads and fatigue program at the NASA Langley Research Center. Estimates of the possible acoustic fatigue requirements of future ASTOVL and hypersonic aircraft are discussed, and research topics that are being studied are outlined. It appears that near term sonic fatigue technology requirements include understanding of the behavior of high temperature and composite structures, improved accuracy in analytical prediction of the strain response of structures, and development of acoustic and thermal test facilities that can produce the environments expected for future aerospace vehicles.

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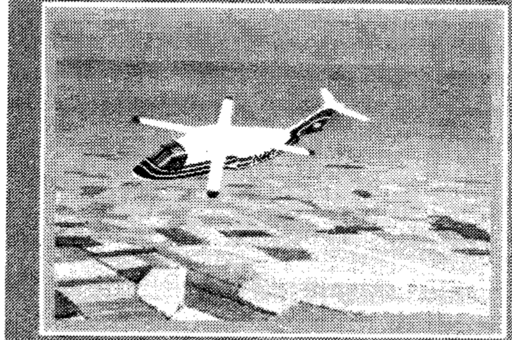
FUTURE AEROSPACE VEHICLES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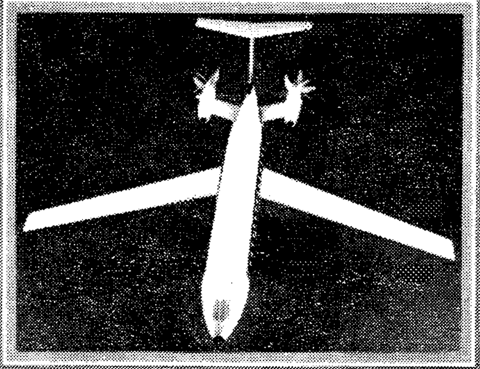
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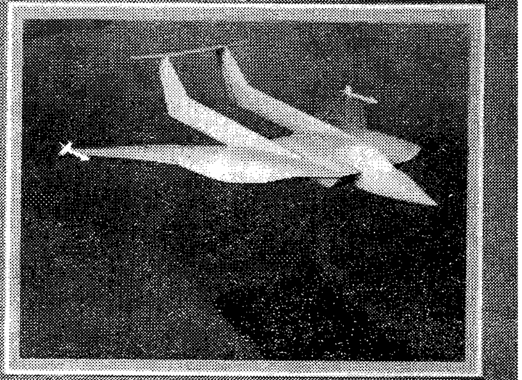
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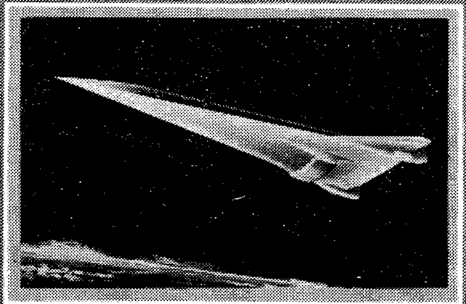
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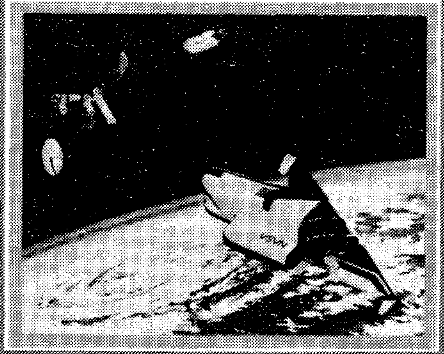
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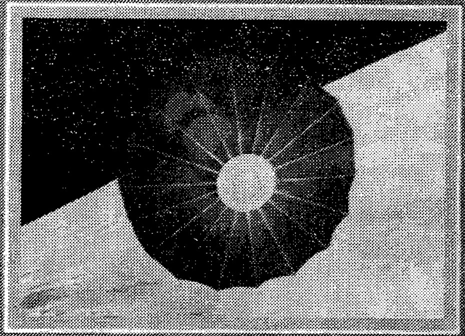

ORBITAL TRANSFER VEHICLE

Figure 1

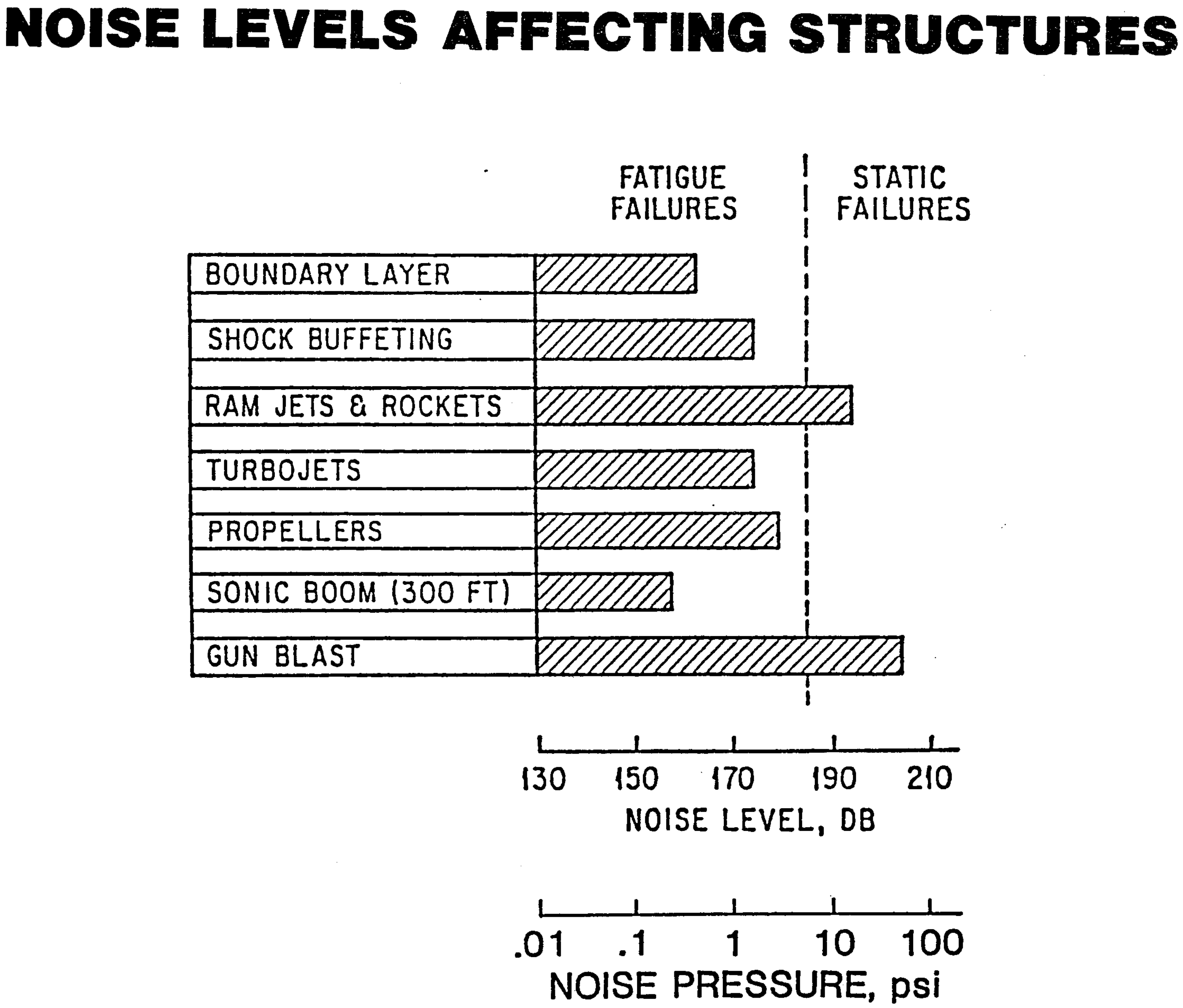

NOISE LEVELS AFFECTING STRUCTURES
FATIGUE FAILURES
STATIC FAILURES
BOUNDARY LAYER
SHOCK BUFFETING
RAM JETS & ROCKETS
TURBOJETS
PROPELLERS
SONIC BOOM (300 FT)
GUN BLAST
130
150
170
190
210
NOISE LEVEL, DB
.01
.1
1
10
100
NOISE PRESSURE, psi

Figure 2

FLIGHT ENVELOPE FOR EXPERIMENTAL HYPERSONIC VEHICLE

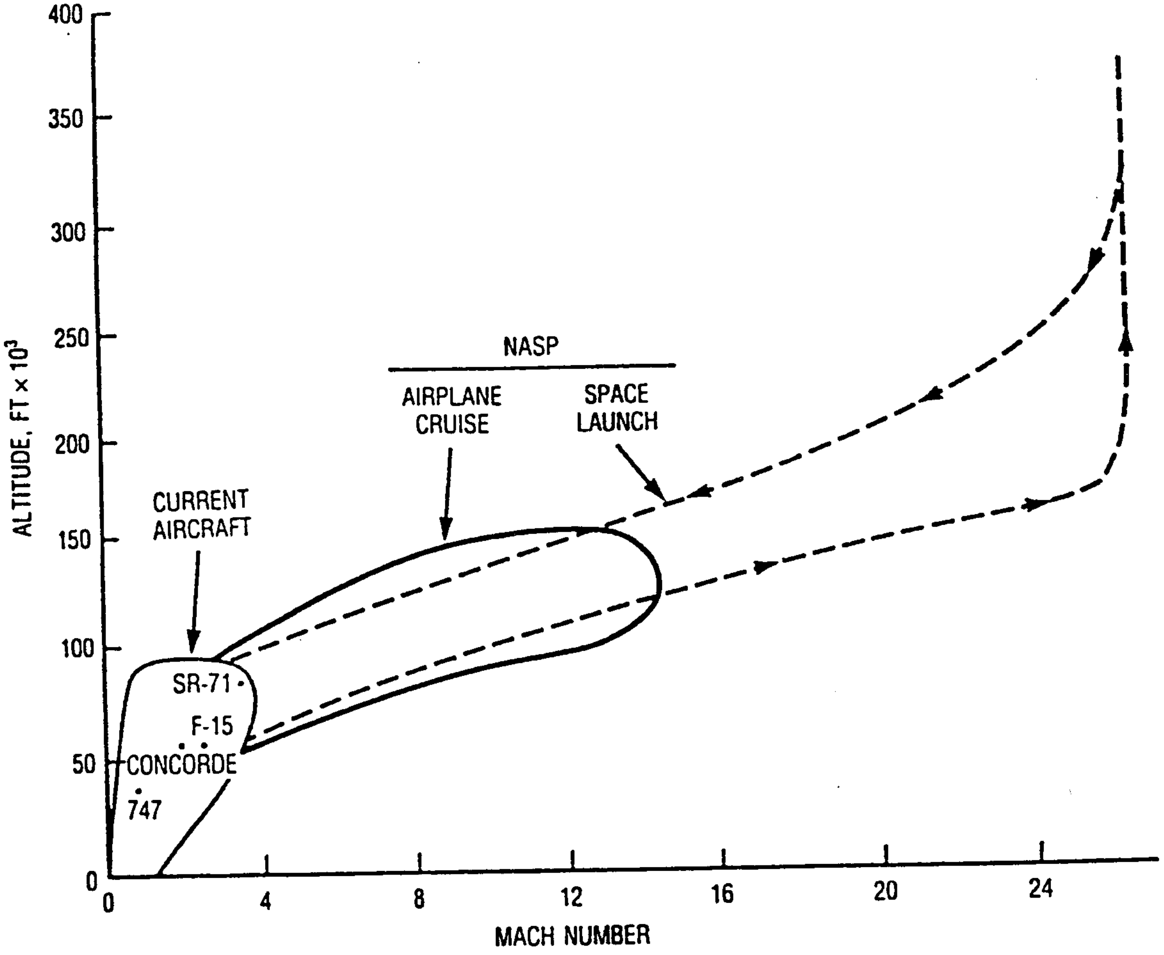


Figure 3

EMPIRICAL SCALING LAWS

Boundary Layer Loads

BL Type	RMS Pressure
Attached	$0.001\mathbf{Q}$
Separated	$0.020\mathbf{Q}$
Shock Interaction	$\frac{0.140\mathbf{Q}}{1+0.5M^2}$

Q=Free-stream Dynamic Pressure

Figure 4

GENERIC NASP DESIGN ENVIRONMENTS

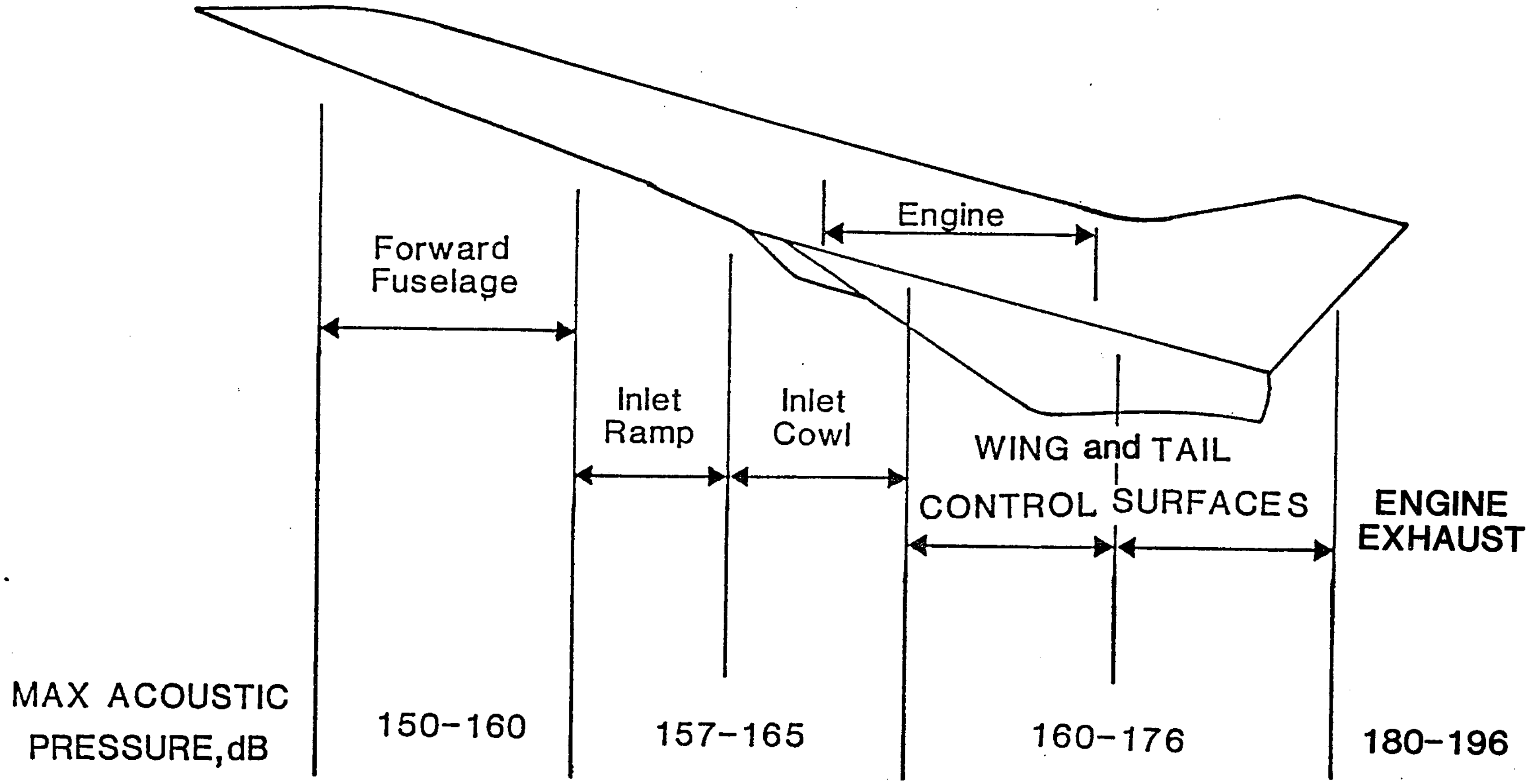


Figure 5

EQUILIBRIUM SURFACE TEMPERATURES

$M_\infty = 8$; $q = 2200$ psf

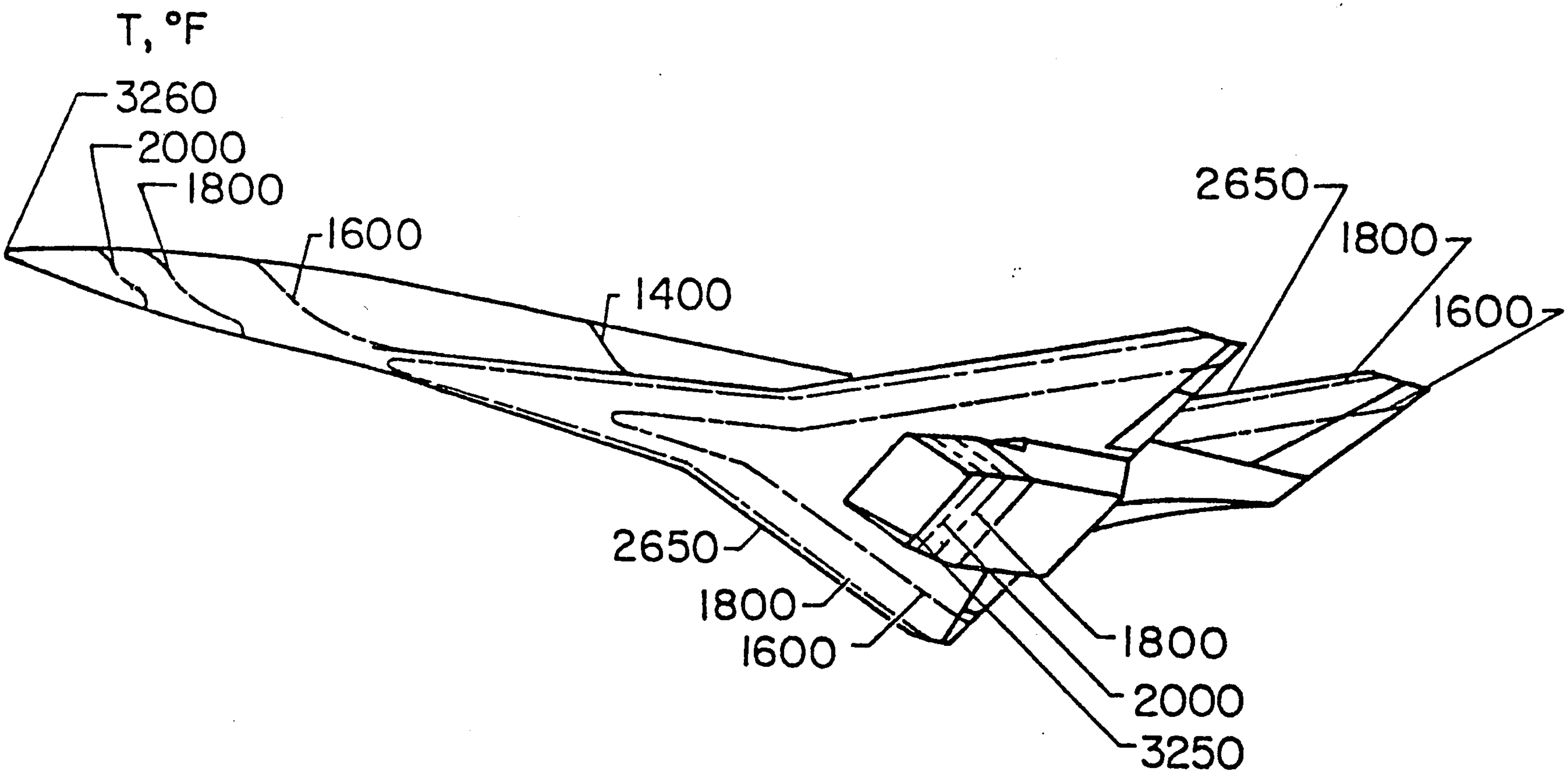
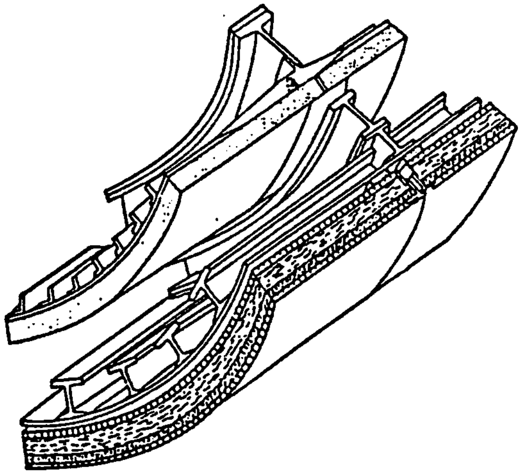
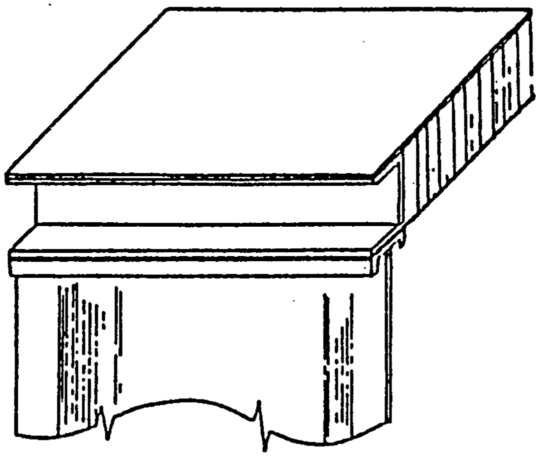


Figure 6

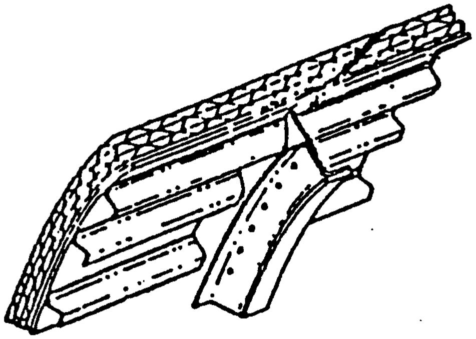
CANDIDATE STRUCTURAL CONCEPTS



SIDEWALL CONSTRUCTION



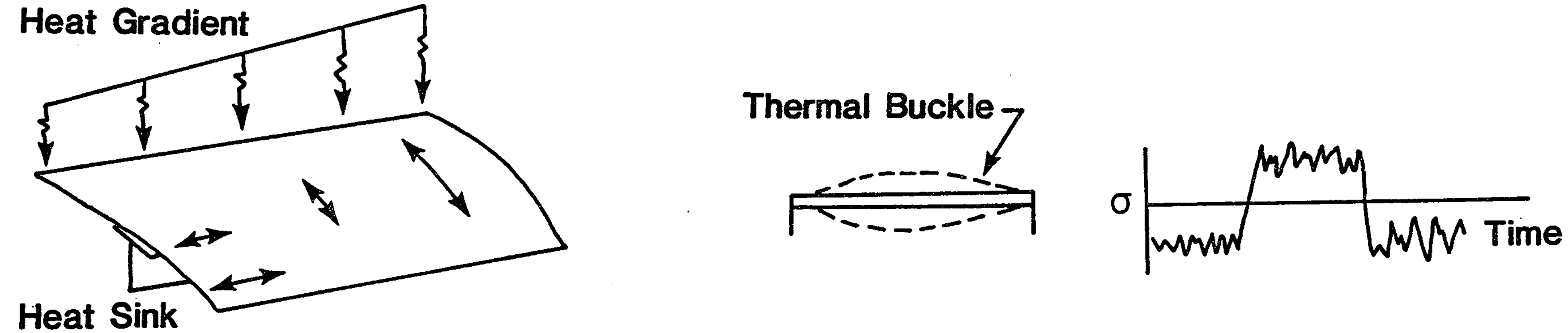
HONEYCOMB CORE SANDWICH



TITANIUM MULTIWALL

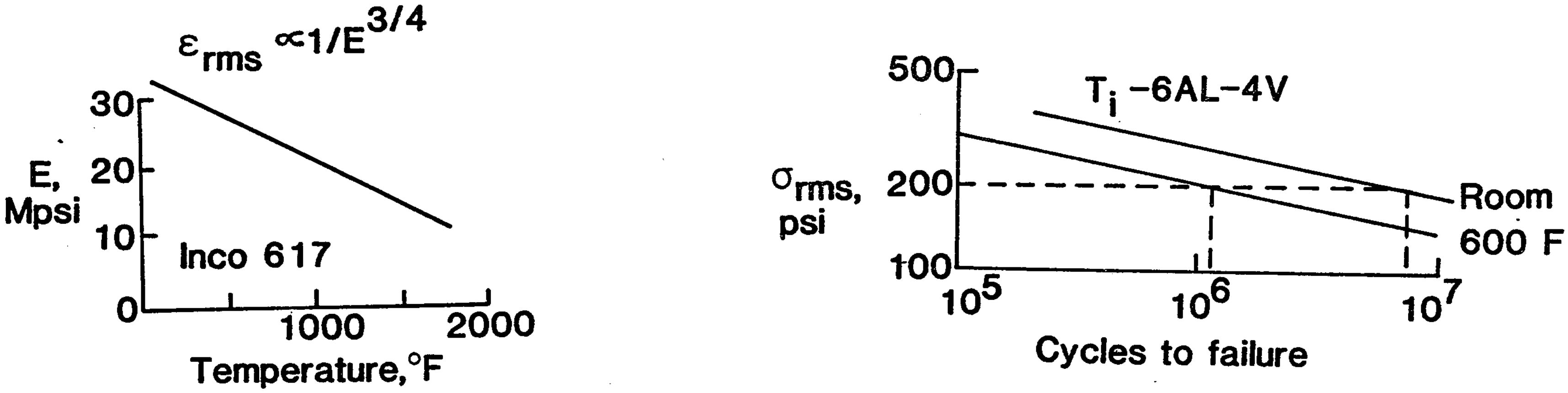
Figure 7

THERMAL INTERACTIONS WITH ACOUSTIC FATIGUE



THERMAL STRESS

SNAP-THROUGH



MATERIAL/DYNAMIC PROPERTIES

FATIGUE LIFE

Figure 8

VSTOL ENGINE CONFIGURATION

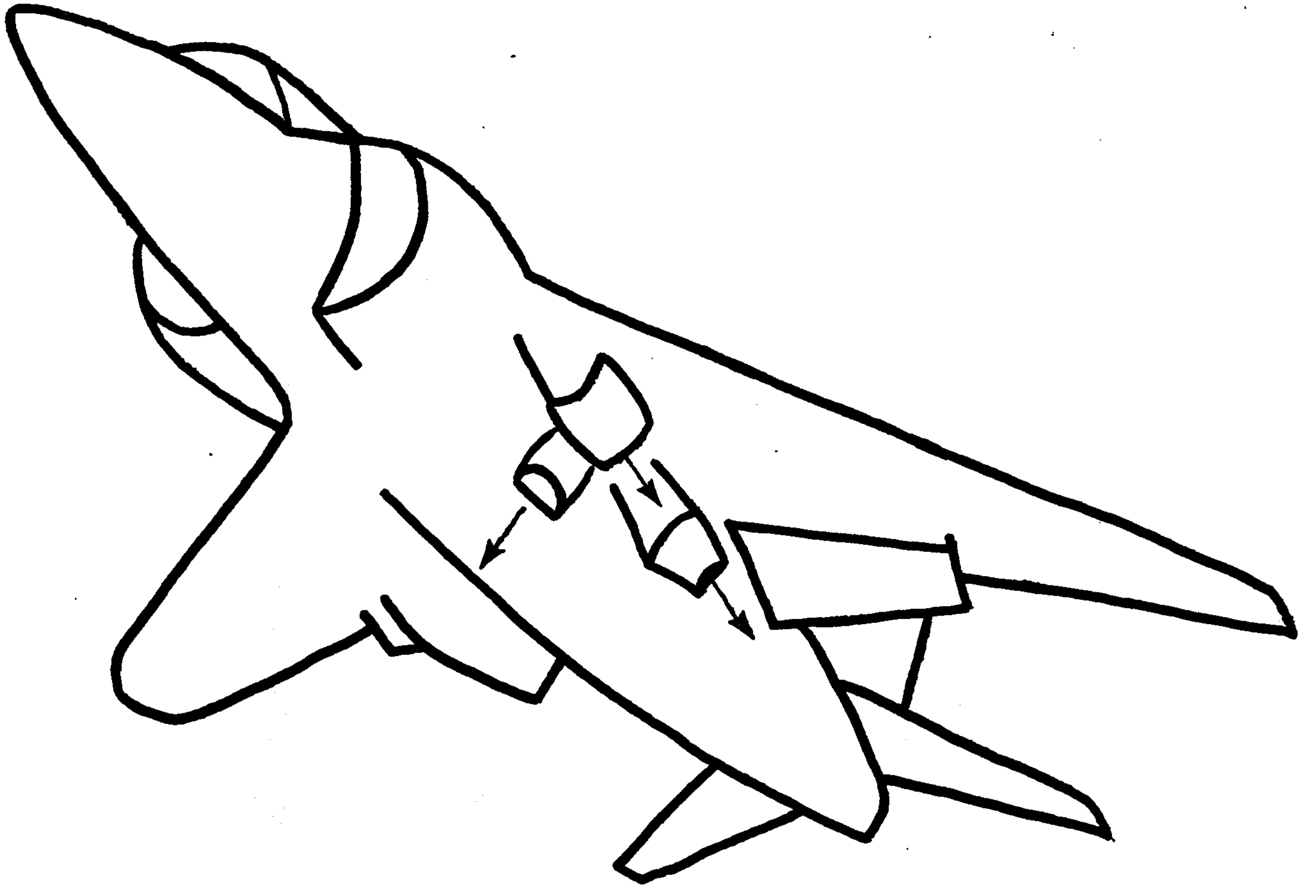
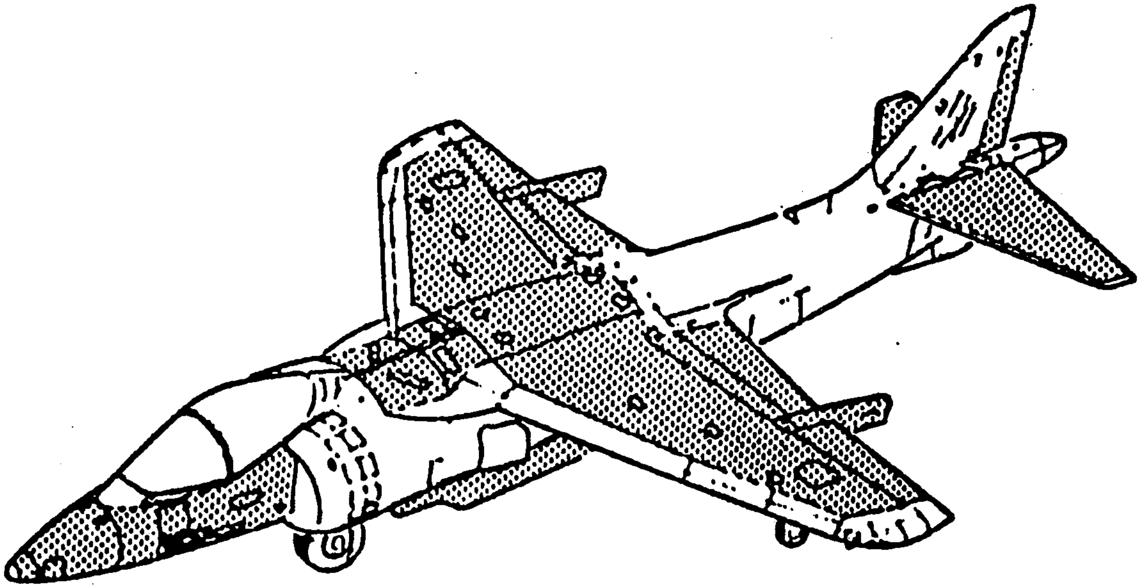


Figure 9

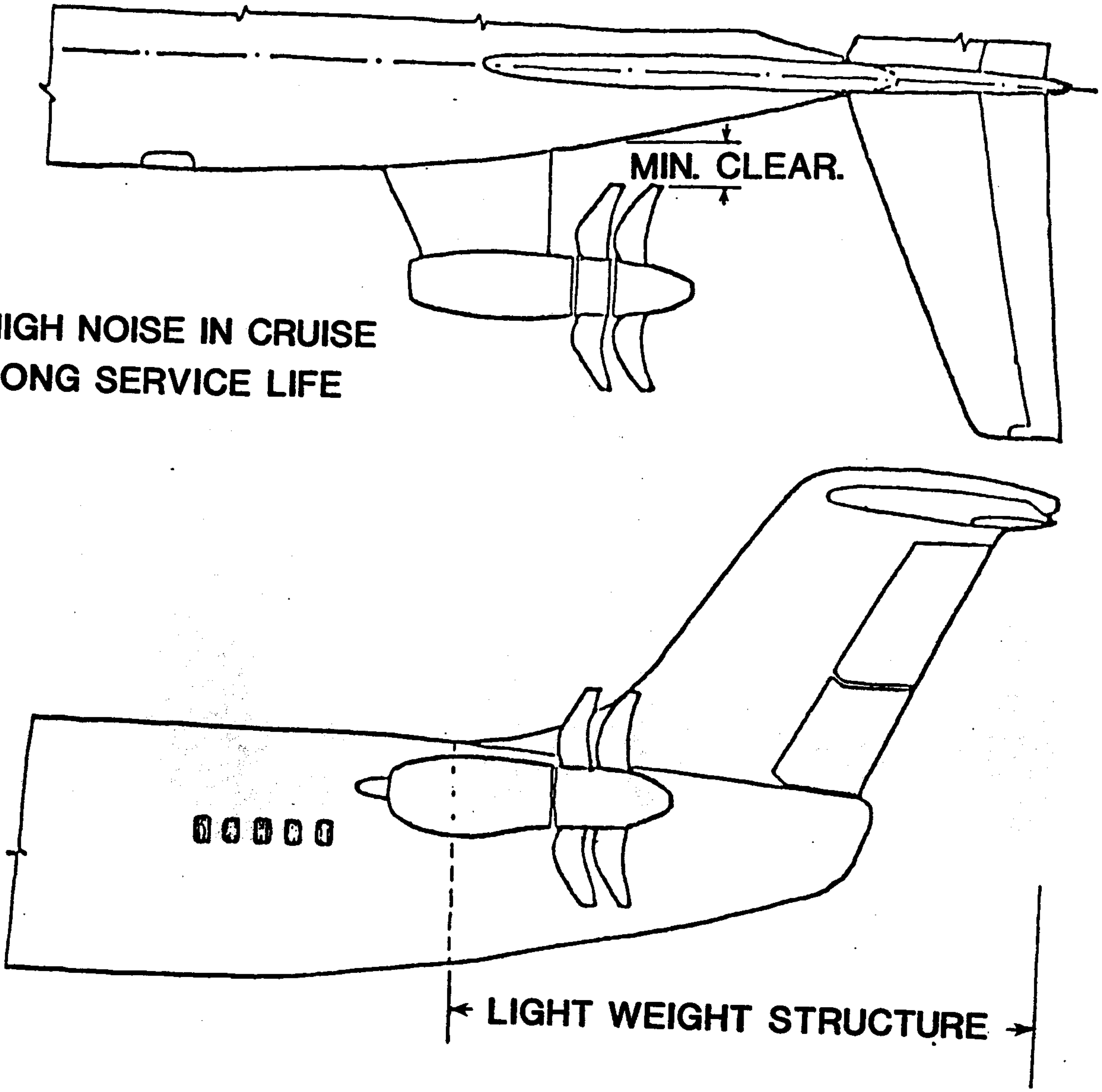
COMPOSITE PARTS OF FIGHTER AIRCRAFT



AV-8B HARRIER II

Figure 10

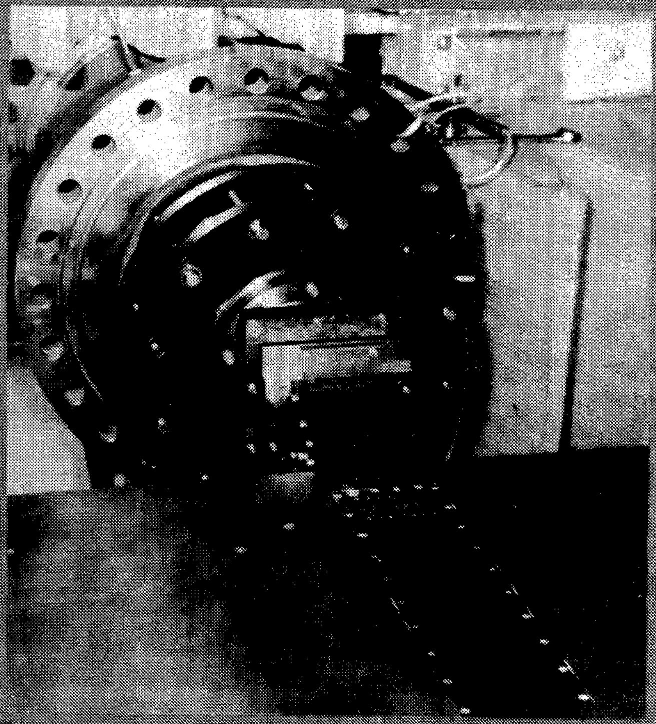
ADVANCED TURBOPROP SONIC FATIGUE CONSIDERATIONS



- HIGH NOISE IN CRUISE
- LONG SERVICE LIFE

Figure 11

SUPERSONIC JET PLUME/STRUCTURE INTERACTION



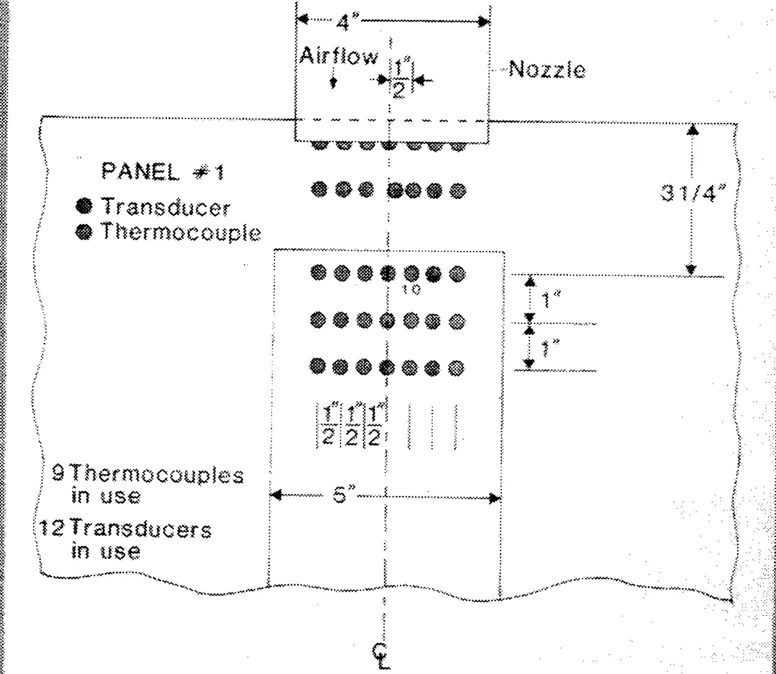


Figure 12

ORIGINAL PAGE IS
OF POOR QUALITY

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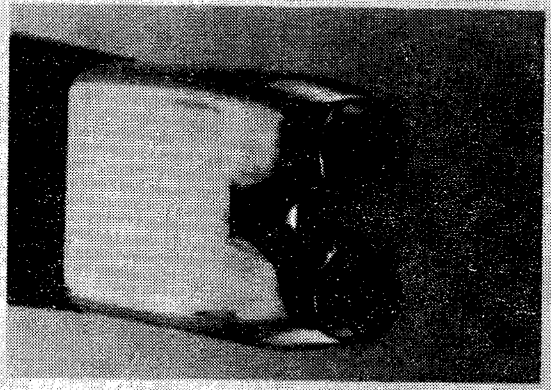
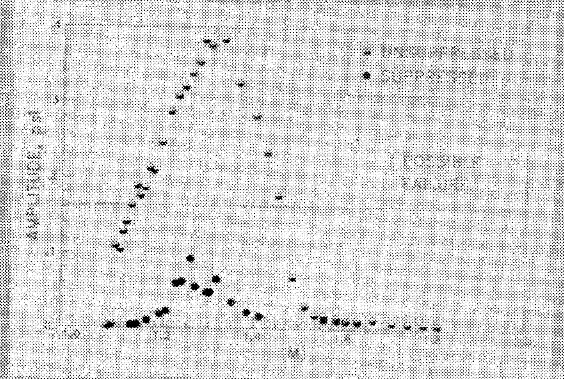
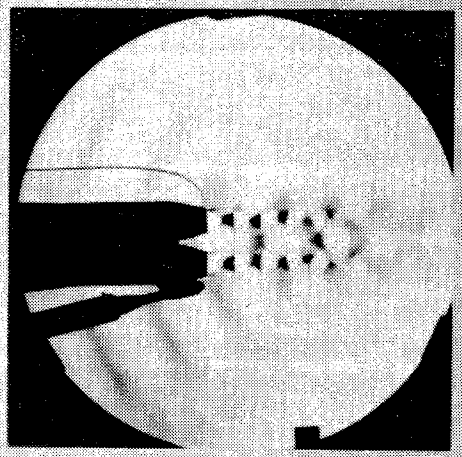
LOAD REDUCTION ASSOCIATED WITH TWIN SUPERSONIC PLUMES



Model (1/40 Scale)

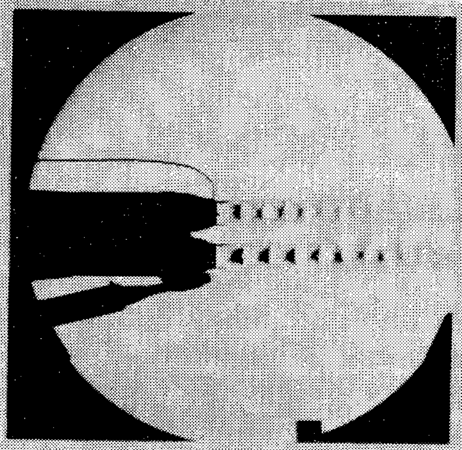


Magnitude of Load Reduction



Resonance Unsuppressed

$M_j = 1.3$



Resonance Suppressed

$M_j = 1.3$

Figure 13

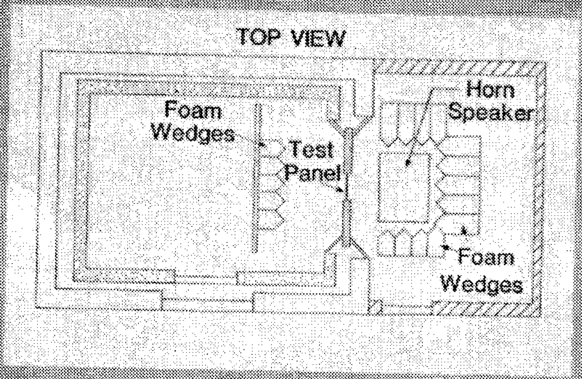
CAPABILITIES OF LANGLEY JET NOISE APPARATUS

	MACH NUMBER	TEMPERATURE
PRIMARY FLOW	2.0	1000°F 2500°F (WITH FUTURE PROPANE BURNER)
EXTERNAL FLOW	0.9 2.0 (PROJECTED)	AMBIENT (WITH AUXILARY HEAT TO AVOID CONDENSATION)

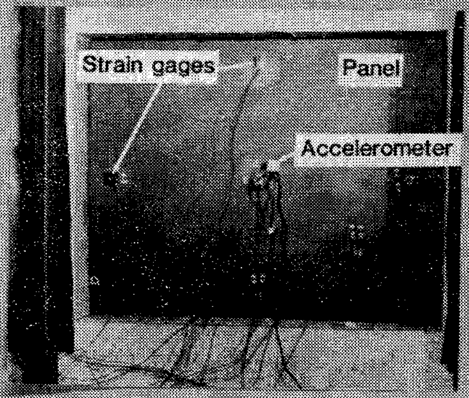
Figure 14

86-9281

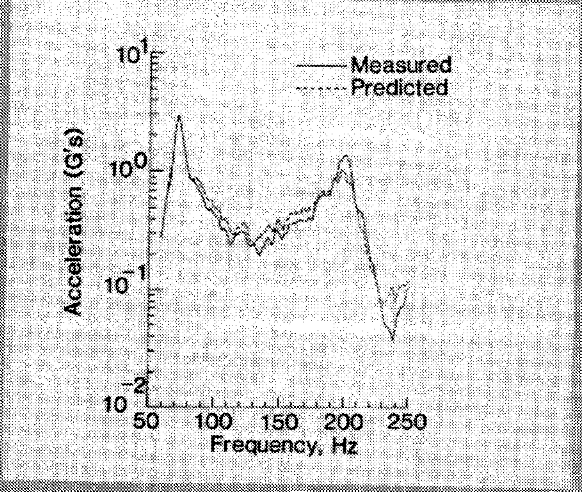
RESPONSE OF RECTANGULAR PANELS TO ACOUSTIC LOADING



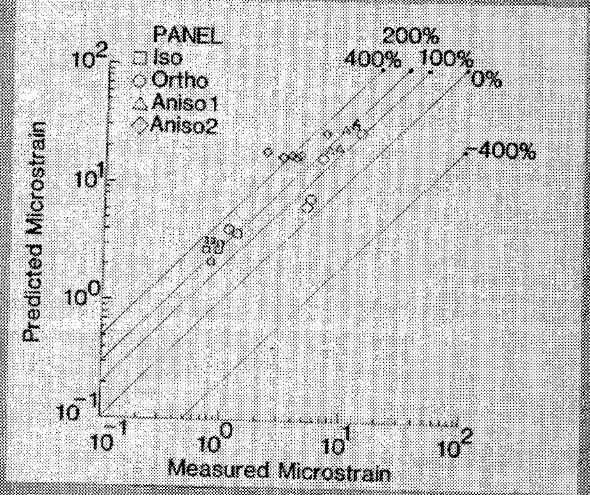
TEST APPARATUS DIAGRAM



TEST PANEL PHOTOGRAPH



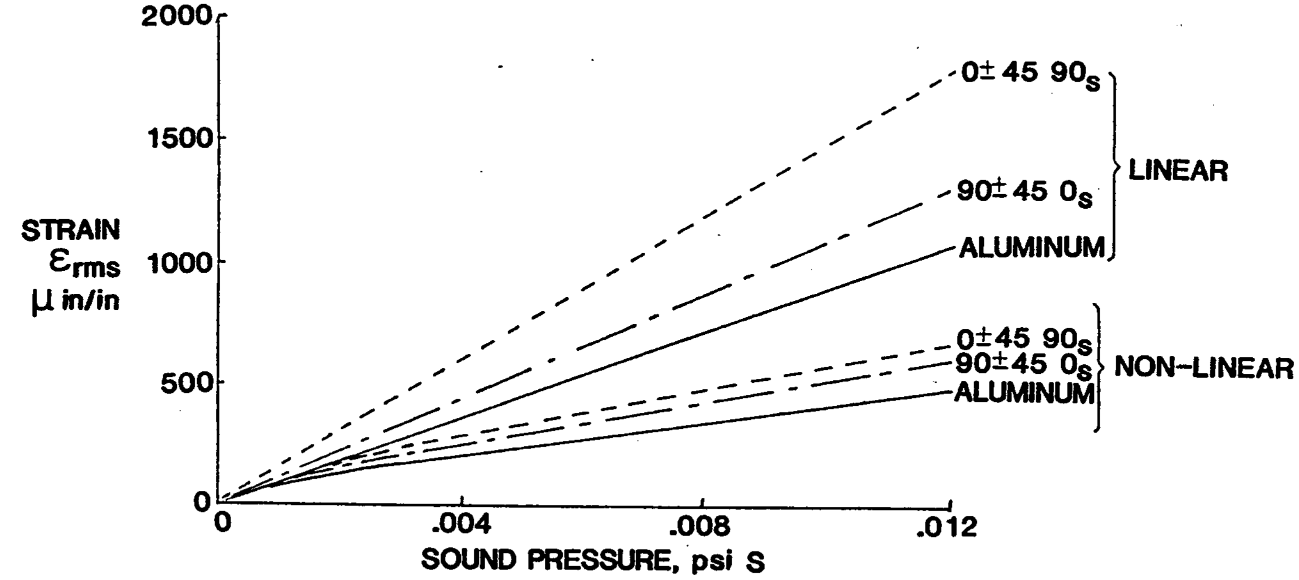
ACCELERATION SPECTRA

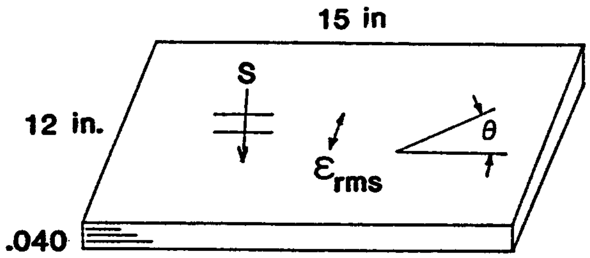


RMS STRAINS

Figure 15

PREDICTED STRAIN IN COMPOSITE PANELS DUE TO ACOUSTIC LOADS





$$\varepsilon_{rms} \sim S/[m\zeta^2 D^3_{EFF}]^{1/4}$$

	ALUMINUM	0±45 90	90±45 0
STIFFNESS D_{EFF}	62	43	64
MASS m	0.1	0.056	0.056
DAMPING ζ	0.023	0.02	0.02

Figure 16

SNAP-THROUGH OF BUCKLED PLATES UNDER ACOUSTIC EXCITATION

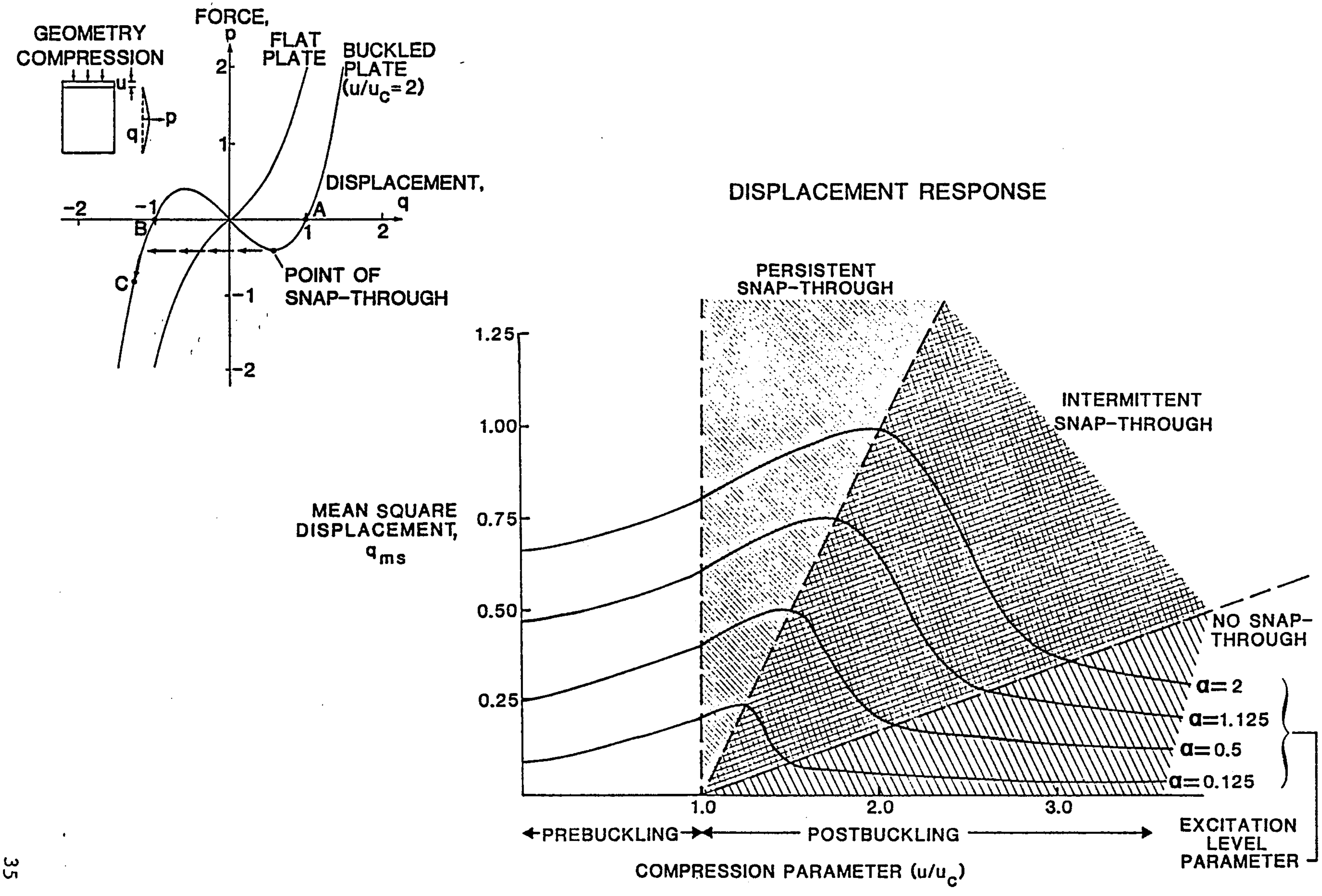
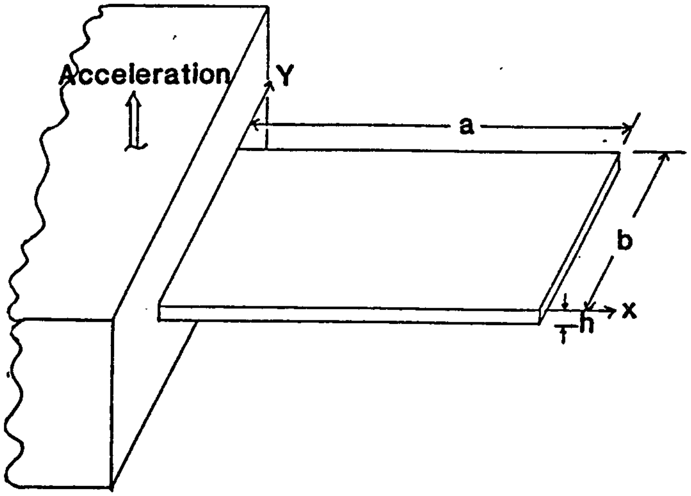
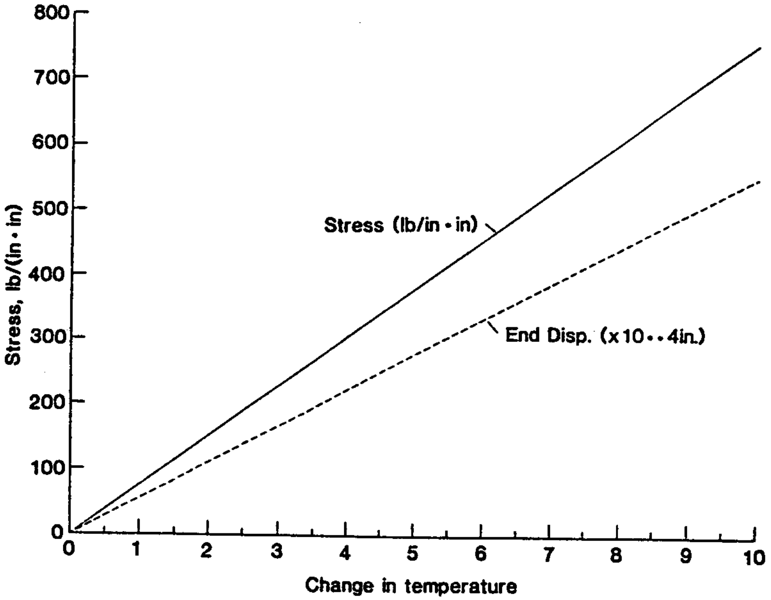


Figure 17

DYNAMIC STRAIN RESPONSE AT ELEVATED TEMPERATURE



- T≤1000°F
- ALUM, TITANIUM, INCONEL, GRAPH–EPOXY
- STRAIN, DAMPING, FREQUENCY
- CANTILEVER, CLAMPED–CLAMPED



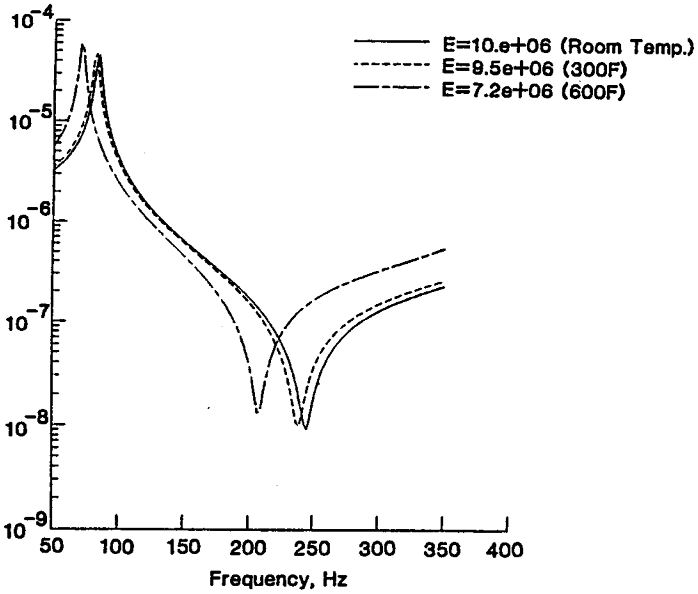


Figure 18

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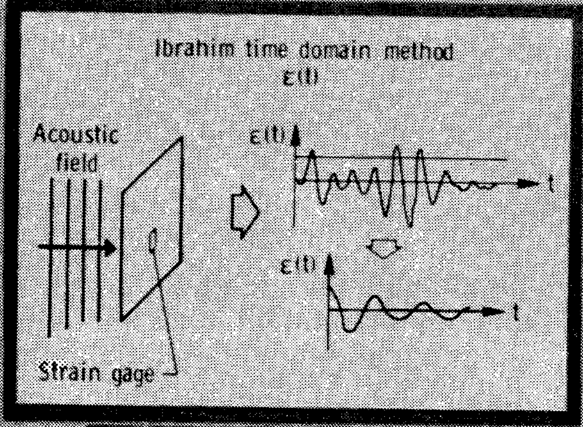
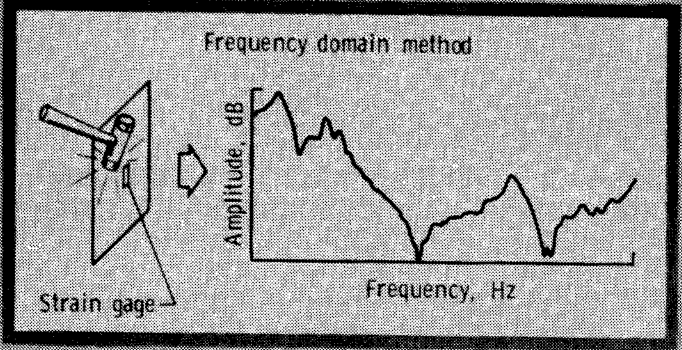
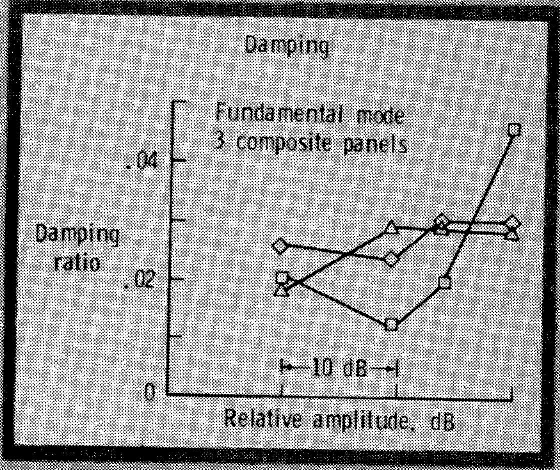
MODAL IDENTIFICATION METHOD FOR INTENSE ACOUSTIC LOADS


Ibrahim time domain method

Advantages of ITD

- High temperature applications
- Nonlinear applications
- Improved damping identification


Frequency domain method


Damping

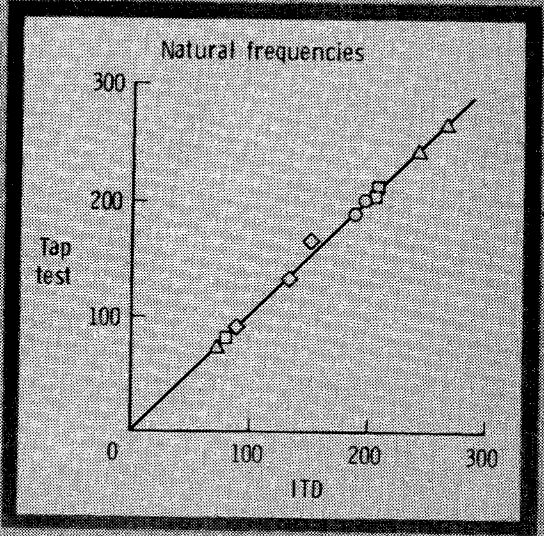

Natural frequencies

Figure 19

THERMAL ACOUSTIC FATIGUE APPARATUS AT LANGLEY RESEARCH CENTER

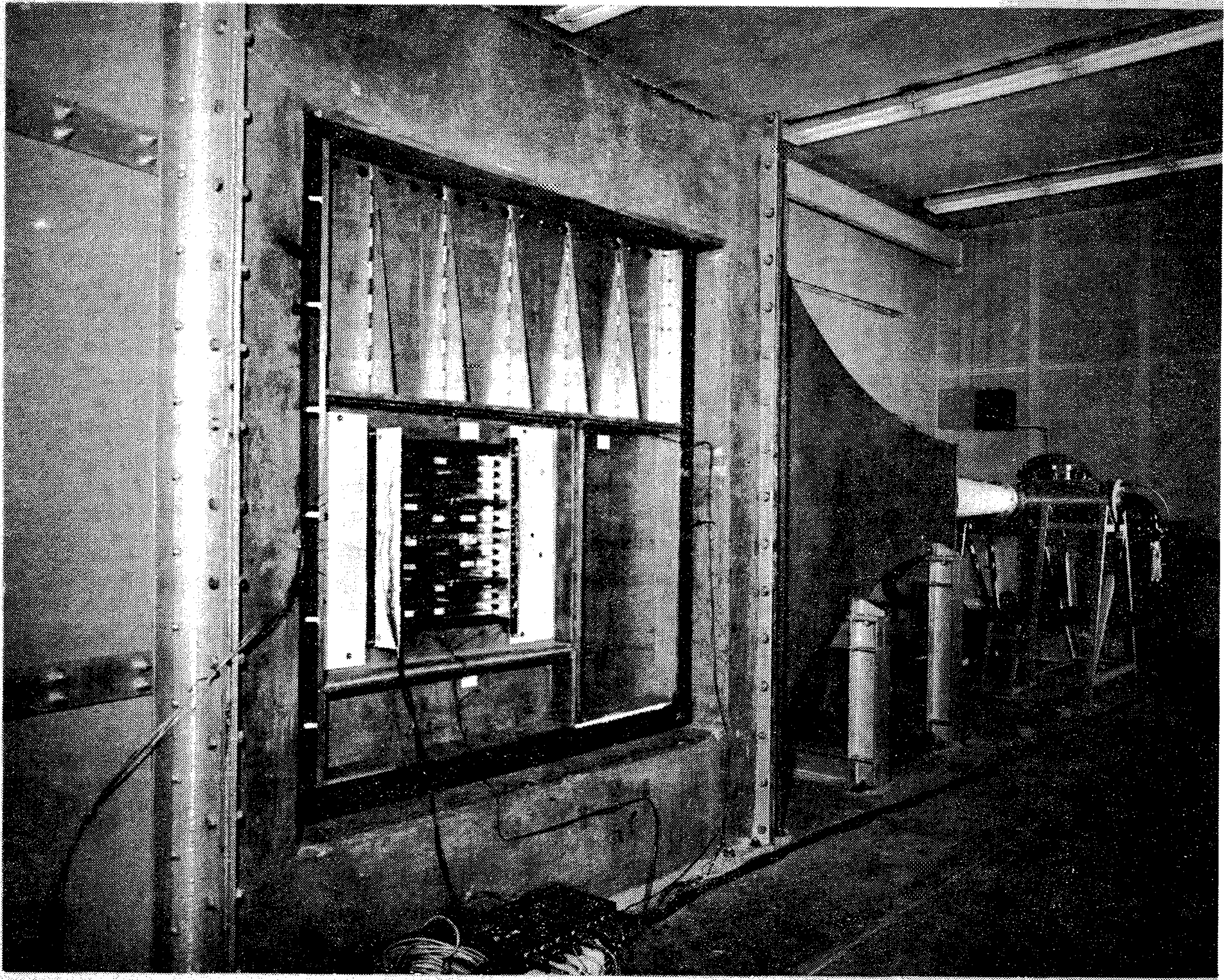


Figure 20

Standard Bibliographic Page

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15. Supplementary Notes

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16. Abstract

A number of new aircraft and spacecraft configurations are being considered for future development. These include high-speed turboprop aircraft, advanced vertical take-off and landing fighter aircraft, and aerospace planes for hypersonic intercontinental cruise or flight to orbit and return. Review of the acoustic environment expected for these vehicles indicates levels high enough that acoustic fatigue must be considered. Unfortunately, the sonic fatigue design technology used for current aircraft may not be adequate for these future vehicles. This has resulted in renewed emphasis on acoustic fatigue research at the NASA Langley Research Center. The overall objective of the Langley program is to develop new methods and information for design of aerospace vehicles that will resist acoustic fatigue without excessive weight penalties.

The program includes definition of the acoustic loads acting on structures due to exhaust jets or boundary layers, and subsequent determination of the stresses within the structure due to these acoustic loads. Material fatigue associated with the high frequency structural stress reversal patterns resulting from acoustic from acoustic loadings is considered to be an area requiring study, but no activity is currently underway.

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