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GEORGE C. MARSHALL SPACE FLIGHT CENTER

FINAL ENVIRONMENTAL STATEMENT FOR SPACE SHUTTLE MAIN ENGINE COMPONENT AND SUBSYSTEM TESTING SANTA SUSANA, CALIFORNIA

August 1973
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA

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ENVIRONMENTAL STATEMENT FOR SPACE SHUTTLE MAIN ENGINE COMPONENT AND SUBSYSTEM TESTING, SANTA SUSANA, CALIFORNIA

SUMMARY

( ) Draft (X) Final Environmental Statement

Responsible Federal Agency: National Aeronautics and Space Administration (NASA), Office of Manned Space Flight, Space Shuttle Program.

1. (X) Administrative Action ( ) Legislative Action

2. In July 1972, The National Aeronautics and Space Administration issued an Environmental Statement for the Space Shuttle Program. This subsidiary action proposes to establish for the Space Shuttle Program a Main Engine Component and Subsystem Test Site at Air Force Plant 57, Santa Susana Field Laboratory, Santa Susana, California. Existing facilities, equipment and systems provided under the Apollo Program are capable, with modifications, of supporting the testing requirements.

3. As indicated in the Environmental Statement for the Space Shuttle Program, the principal environmental concern is that the Space Shuttle Main Engine is a noise generator. Since there has been growing concern in the last few years for the environmental quality in community areas surrounding rocket engine test sites, it is NASA's objective that the environment remain within acceptable limits to the extent that the sound levels are not intrusive or annoying to the general public. The potential for adverse impact on the surrounding communities is small, in that, the predicted noise levels are well below those noted to induce community reaction. Additionally, tests will be conducted only when meteorological conditions will provide additional reductions in noise levels (5 to 10 db) in the farfield environments by refracting the acoustic energy upward from the ground plane where the energy can be dissipated.

4. We do not foresee an effect on air and water quality from the testing at Santa Susana Field Laboratory.

5. Alternatives to Santa Susana Field Laboratory as a test site are more expensive and are not environmentally superior. Advantages ascribable to testing activities at the Santa Susana site include the convenience and efficiency of all component and subsystem testing being accomplished at one location near the engineering and manufacturing staffs.

6. a. Comments were requested from: CEQ, OMB, EPA, DOD, HEW, DOC, DOD, DOT, HUD, DOI, State and local agencies.

b. Comments or acknowledgement were received from DOD, HUD, DOI, State and local agencies. All comments were given consideration in the preparation of this final statement.

7. The Draft Environmental Statement was sent to CEQ in April 1973. This Final Environmental Statement was made available to CEQ in August 1973.

Final Environmental Statement for Space Shuttle Main Engine Component and Subsystem Testing, Santa Susana, California

1. PURPOSE:

The following information is submitted to satisfy the requirements of the National Environmental Policy Act of 1969 for an Environmental Statement for Space Shuttle Main Engine Component and Subsystem Testing at Santa Susana, California.

2. SCOPE:

Sections 4 through 8 of this statement discuss the environmental factors specified by section 102(2)(c) of the National Environmental Policy Act of 1969. Specifically, the Act requires that the following factors be addressed:

a. The environmental impact of the proposed action.

b. Any adverse environmental effects which cannot be avoided should the proposed action be implemented.

c. Alternatives to the proposed action.

d. The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity.

e. Any irreversible and irretrievable commitments of natural resources which would be involved in the proposed action should it be implemented.

3. PROJECT DESCRIPTION:

The primary objective of the Space Shuttle Program is to provide reusable launch and orbiting vehicles which will significantly reduce the cost of future space transportation. The development of a reusable high-pressure throttleable liquid oxygen/liquid hydrogen rocket engine to be used on the Orbiter vehicle is required. This engine will represent a new design and will be based on newly developed technology. This project will provide modifications to existing test facilities for development and qualification testing of the engine components and for the solution of the subsystem interaction problems involved in the development of an advanced rocket propulsion system.

The existing facilities located at Santa Susana Field Laboratory, Air Force Plant 57, Santa Susana, California are proposed for this project. The Coca area at this Air Force Plant will be modified for Space Shuttle Main Engine component and subsystem integration testing. Maximum utilization will be made of existing Government and/or contractor-owned facilities and equipment at this site along with surplus equipment from other locations to reduce the modification costs. The Santa Susana Field Laboratory has been utilized for Rocket Engine and Engine Component Testing over the past decade, and the planned effort is similar to previous test activity. See Appendix A for vicinity and site maps.

This project thus necessarily provides for the design, procurement and construction modifications required to provide testing capability and to effect the increased capability required to test liquid oxygen/liquid hydrogen high pressure rocket engine components at performance levels compatible with rocket engines using chamber pressures of 3000 psi. The work includes: modifications to the run tank support structure at the test stands; installation of high pressure liquid oxygen and liquid hydrogen run tanks; installation of high pressure gaseous hydrogen and nitrogen storage batteries; modifications and additions to an existing high pressure compressor facility; procurement and installation of new high pressure distribution piping, valves, regulators and control systems; new on-stand high and low pressure fuel (liquid hydrogen), oxidizer (liquid oxygen), and gaseous nitrogen and hydrogen piping valves, regulators and control systems; special facility instrumentation; sitework, miscellaneous foundations and structures and utility connections.

Essentially the modifications will result in three test positions on the existing Coca 1 Test Stand and two test positions on the existing Coca 4 Test Stand. The testing activity by stand and position are described below:

Coca 1

Turbomachinery and Subsystem Integration Test Positions

Subsystem hot-fire testing will be conducted on three combinations of turbomachinery hardware. Low-pressure and high-pressure turbopumps will be tested together for approximately 382 and 333 tests each on the oxidizer and fuel systems, respectively; fuel turbomachinery testing will be conducted at Coca 1B and oxidizer turbomachinery testing will be accomplished at the Coca 1A test position. In addition, 102 tests are planned on the subsystem integration test position using all four turbopumps. This testing will be performed at the Coca 1C test position and the tests will have a duration of 324 seconds and a noise source (maximum on site) of 7.38×10^6 watts with an overall sound power level of 188.7 db Refer to Appendix B, Section III - Sound Source Description. Turbopump subsystem hot-fire testing will be conducted over the range of.

power levels from below Normal Power Level to Emergency Power Level. Pump head-flow characteristics and critical speeds will be verified using instrumentation including pressure transducers, accelerometers, proximity transducers and strain gauges to monitor the dynamics of the rotating assembly. Requirements and assumptions to be verified during the turbomachinery hot-fire testing include performance over the operating regime, service life, fatigue criteria, freedom from critical speeds over the entire mainstage speed range and the capability of the axial thrust control systems to perform properly. Subsystem integration testing will be used to verify low pressure turbopump requirements including duration capability, and to partially verify throttling/shutdown and service life requirements. Special task testing will be conducted with the low pressure turbopumps, including inlet pulsing, to obtain base data related to inlet impedance and transfer functions as required for possible future Space Shuttle Vehicle "POGO" studies. Overstress test methods will be used to reduce test and hardware costs. The principal period of testing is proposed from December 1974 through November 1977.

Proposed Activation Completion Dates:	Coca 1A	June 1974
	Coca 1B	August 1974
	Coca 1C	December 1974

Coca 4

Combustion Devices:

Oxidizer and fuel preburners will be hot-fire tested at Coca 4A. Approximately 235 and 341 low and high pressure tests, respectively, will be performed to verify ignition, stability, performance and durability. Ignition tests will be conducted over the required mixture ratio range to study ignition propagation and verify the absence of central hot spots. Contamination effects will be determined by purposely blocking critical elements. The adequacy of the preburner coolant will be verified by operating at limit conditions of flow and temperature, with extensive temperature instrumentation. Principal period of testing for preburners is from March 1974 through February 1976.

Thrust Chamber Assembly:

The thrust chamber assembly will be tested as part of the combustion system assembly hot-fire testing. Both flanged configuration hardware (permitting attachments to a solid wall hot gas manifold and access for inspection and modifications) and all welded hardware will be utilized. The thrust chamber assembly hot-fire test configuration will include the main combustion chamber, injector gimbal bearing, and high pressure

turbopump turbine simulators. Power level, start, mixture ratio excursion, and performance requirements will be verified by operating the thrust chamber assemblies over the entire mixture ratio and chamber pressure operating envelope. Overstress testing of the thrust chamber assembly will be accomplished during subsystem hot-fire testing by operating at low coolant flowrates.

Thrust chamber assembly stability requirements will be verified by introducing artificial combustion chamber perturbations during transition and steady state operation and measuring damptime. Test results will be correlated with stability criteria to establish stable regions of operation. Stability margins with respect to engine operating ranges of power levels, mixture ratio, and transition will be determined. Main injector baffle effectiveness will be determined; alternate baffle designs and acoustic cavities will be evaluated if required by stability test results. A total of 452 thrust chamber tests will be performed from June 1974 through February 1979.

Hot-Gas Manifold:

The hot-gas manifold, or component parts thereof, will be utilized in preburner turbomachinery, thrust chamber assembly, and subsystem integration testing resulting in data over the full range of operating conditions. These data will be utilized in support of final verification of the hot-gas manifold requirements during engine system hot-fire tests.

Ignition Systems:

High pressure oxygen and dydrogen systems will be used to conduct tests of the preburner and main chamber ignition systems. These tests will be conducted at surface pressure conditions. Limits tests will be run under all combinations of propellant pressures and fuel temperatures for both start and steady state conditions to verify functions and durability. The principal period of testing is proposed from January 1974 through February 1979.

Proposed Activation Completion Dates:		
	Coca 4A	January 1974
	Coca 4B	June 1974

Sound Pressure Levels:

It should be noted that the testing on position 1C (Subsystems Integrated Tests) will generate the maximum sound pressure levels for the longest duration. However, as will be seen later, the environmental predictions indicate there should be no adverse acoustic environmental impact on the existing communities surrounding the test site. The tests conducted on the remaining four test positions, 4A, 4B, 1A and 1B will be low noise level sources and will have no environmental impact.

Communities:

The area located within a radius of 10 miles of the test site is considered to be the zone in which the rocket noise might be discernible. This area contains 13 communities, i.e., locations with specific names, with a population of approximately 400,000.

However, most of these are not political entities. Furthermore, they are not isolated from one another and, in fact, represent a portion of the Southern California megalopolis.

It is estimated that about 500,000 to 550,000 people will inhabit this area by 1979.

4. THE ENVIRONMENTAL EFFECT OF THE SPACE SHUTTLE MAIN ENGINE COMPONENT AND SUBSYSTEM TESTING:

Air Pollution:

a. The propellant to be used consists of mixture of liquid hydrogen and oxygen whose composition is regulated by:

MSFC-SPEC-365A (April 15, 1967)
MIL-P-25508E (January 4, 1971)
MIL-P-25508E Amendment 1 (April 30, 1971)

b. The engine propellants produce only water vapor (96.5%) and free hydrogen (3.5%) from the combustion process. This combustion product does not contribute any of the five primary pollutants to air: Carbon Monoxide, Hydrocarbons, Suphur Oxides, Nitrogen Oxides and Particulates.

Water Pollution:

The Santa Susana Field Laboratory is a facility whose primary function is the research, development and testing of rocket engines. Water is used in the test firings for flame bucket coolant, Firex (system of nozzles surrounding each rocket engine test position for fire suppression fed by a high pressure water line), heat exchange equipment and washdown. Both a fresh water and reclaim water system are utilized at the facility. Fresh water is supplied from the Ventura County Water Works District No. 8 with fresh water wells No's. 6 and 12 located on the property, on standby for backup. The backup wells have been required on occasions such as interrupted service from Ventura County Water Works District No. 8, due to floods and fires. The

reclaimed water system, which was constructed for flame deflector cooling, is completely separate from the fresh water supply. There are two reclaim water reservoirs with smaller holding ponds (which are Gunite lined to prevent ground contamination) at each test position at the Santa Susana Field Laboratory. As water collects in the ponds and reservoirs it is tested for contamination, treated and then either released to the reservoir or pumped from the reservoir to storage tanks. Water is then distributed to various areas for flame deflector coolant and Firex protection from the storage tanks. Occasionally excess water must be released from the reservoirs off property down the Bell Canyon drainage channel to the Los Angeles River. The control of discharge water off property is accomplished by the State of California Regional Water Quality Control Board No. 4, Los Angeles Division and is monitored by the Los Angeles Department of Water and Power.

Acoustics

There has been growing concern in the past few years for the environmental quality in community areas surrounding noise sources such as rocket engine test sites, launch sites and large airports. In regard to aerospace related noise sources, it is the objective of the National Aeronautics and Space Administration that the total environment remain with in acceptable limits for such communities. To assess the probability and the degree of community annoyance during the Space Shuttle Main Engine Component and Subsystem Testing at the Santa Susana Field Laboratory, detailed technical studies and related surveys were conducted by elements of Marshall Space Flight Center, Huntsville, Alabama, and Rocketdyne Division of Rockwell International, Canoga Park, California and an independent firm, Wyle Laboratories, El Segundo, California. Results of these studies and surveys are included in Appendix B of this statement.

From the Marshall Center study the maximum acoustic environments for the residential boundary around the test site are indicated to range generally from 84 to 92 db (Ref. 2×10^{-5} N/m^2) or on the "A weighted" scale from 61 to 68 db (A), respectively. One small isolated residential area, three to four homes, just northwest of the test area was noted at 94 db (71 db (A)). These environments likewise apply as maximum exposure levels for automobile drivers in such areas during testing and appear to present no problem for normal driving conditions.

The farfield acoustic energy spectra contain very little of the higher frequency (100 Hz to 10 K Hz) sound, a frequency range more noticeable to the auditory system, and thus in many areas should be almost inaudible. Since most of the acoustic energy to reach the farfield is in the form of low frequency sound waves, the major portion of the energy will be infrasonic, below the frequency range of hearing. The resonant frequency of many

dwelling walls and partitions falls into this lower frequency region of the acoustic energy spectrum, however, the sound pressure levels are well below that noted to induce any significant community reaction due to building, window, or wall response, consequently no damage to buildings in the residential areas is expected to occur.

Farfield rocket noise in general is less noticeable especially to the human auditory system, even though the overall or composite sound pressure levels may be equal to or even higher than certain background noises. This is due to the fact that the lower frequency energy components of the rocket noise fall within a range where the normal hearing acuity is inherently more diminished relative to that in the higher frequency sounds. This is why airplane and traffic noise will be more annoying than rocket noise of the same composite level. Due to the spectral differences it can, however, be distinguished from the usual community background noise but the pressure amplitudes anticipated will pose no significant community impact. In general, the environments from the proposed tests should not induce any unpleasant sensations due to body organ response nor are there any anticipated problems concerning auditory response.

The environmental estimates herein were derived with consideration of no beneficial refractive effects from the atmospheric media whereas for conservatism the actual testing will be conducted only when the monitored meteorological conditions at the test site will provide environmental reductions (a minimum of 5 db as specified by the test contractor) in the farfield environments by turning or refracting the acoustic energy up where the energy can be dissipated without effect on man's environment. Thus, it is probable that the rocket induced overall sound pressure level environments in many community areas will be no greater than those resulting from everyday noise sources such as highway traffic (typically 800 feet from a 4-lane highway with heavy traffic), plane overflight (a three engine commerical jet at 10,000 feet altitude), or at 500 to 1000 feet from a passing train.

In regard to the exposure of wildlife to rocket noise in the farfield acoustic areas, no significant effects or changes in wildlife have been observed. From the major rocket test facility areas represented by: Santa Susana in the far west near Canoga Park, CA, with 27,689 tests; Mississippi Test Facility in the far south near Picayune, Miss., with almost 300 major tests; Marshall Space Flight Center in the midsouth near Huntsville, Ala., with over 700 tests; and from Kennedy Space Center in the southeast near Cape Kennedy, Fla. with the launches of all Mercury/ Redstone, Gemini, Apollo, and Skylab vehicles plus those of Air Force programs, and from the various contractor test facilities around the country, there is represented a sufficient history in approximately 31,000 rocket firings from which no significant acoustic environmental effects on wildlife have been noted.

From the history of rocket engine testing at the Santa Susana Field Laboratory, some 200 complaints were registered from 1958 to 1971 due to rocket tests in which total meteorological control was not considered. During the Saturn S-II Battleship Tests, yielding approximately the same acoustic power as the Space Shuttle Main Engine, no complaints were registered for 39 tests accounting for more than 10,000 seconds of test duration where full meteorological control was employed. From Santa Susana data, favorable meteorological conditions have been found to be prevalent 85% of the days per year for testing within a two-hour period per day. Seventy percent of the days will be suitable during a three-hour period for a favorable test condition under which 10 db reductions can be realized in actual practice from such favorable atmospheric conditions.

Additionally, at Santa Susana the community environments are further reduced by use of a considerable deflector waterflow rate effectively providing a reduction of the noise at the source. The specific exhaust deflector at Santa Susana with a water flow rate of more than a ton per second will give an effective reduction of the noise at the source by approximately 50 percent in terms of generated acoustic power, i.e., 3 db. Although it is felt that other reductions are not required, reductions could be attained by utilizing suppressors at the noise source.

Thus every precaution that is practical and necessary has been considered in controlling the farfield environment such that community awareness of these tests from the acoustic environmental aspect are minimal.

Archeology:

The Santa Susana Field Laboratory operating and test procedures set responsibilities and procedures for assuring protection of any antiquities or historic sites on or adjacent to the Santa Susana Field Laboratory as required by law.*

Specifically of concern are the Indian Caves (not on the National Register of Historic Sites) on Air Force Plant 57 which are located approximately 2500 ft. west southwest of the Coca 1 test stand. During the 39 Saturn S-II Battleship tests from 1965 thru 1968, the caves were exposed to approximately 110 db without visible adverse effect. There are no activities contemplated at Santa Susana Field Laboratory which expose the caves to higher noise levels. Coca 1 would yield about 108 db. based on extrapolation of S-II data.

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* Antiquities Act of 1906 (16 USC 431 et seq.); Historic Sites Act of 1935 (16 USC 461 et seq.) and the National Historic Preservation Act of 1966 (16 USC 470 et seq.)

Since very little energy from engine tests is transmitted through the ground, testing should cause no significant ground vibration effects. It should be noted that the caves suffered no visible damage from the large Southern California earthquake of February 1971.

5. ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED:

The testing activities at the Santa Susana Field Laboratory will have what should be termed a small and temporary adverse effect on the environment. Noise levels generated by tests will on occasion be audible to the nearest residents possibly causing sporadic complaints.

6. ALTERNATIVES TO THE PROPOSED ACTION:

In early 1970, Preliminary Engineering Reports (PERs) were prepared by Pratt and Whitney Aircraft and Rocketdyne regarding testing of the Space Shuttle Main Engine at the Mississippi Test Facility and at Haystack Butte, Edwards Air Force Base, respectively. Environmental effects on the communities surrounding these locations was considered and found to be acceptable. Subsequently an acoustic assessment has been prepared by Marshall Space Flight Center for each location under consideration - The Mississippi Test Facility, Haystack Butte and the Santa Susana Test Site. The acoustic assessment for Santa Susana is shown in Appendix B of this Environmental Statement, and included therewith in Sections XI and XII are the environmental assessments for Mississippi Test Facility and Haystack Butte, respectively. These assessments show that the acoustic environmental effects are about equal at each of the three test sites. Thus the decision to use Santa Susana could be made on the grounds of programmatic cost and schedule.

During the "fact finding" activities leading to contract negotiations, Rocketdyne was requested to prepare a cost trade study to compare the cost of testing as proposed at Santa Susana Field Laboratory versus moving some or all of the test activity to Edwards Air Force Base. Subsequently, a trade study was made by Marshall Space Flight Center to determine the feasibility of moving the Subsystem Integration Test series to Mississippi Test Facility. Both of these alternate sites were, however, rejected because of cost, schedule and programmatic considerations. (Delta costs for performing all testing at Edwards Air Force Base - $8.84 million, three months schedule slip. Delta costs for performing testing at Santa Susana and Edwards Air Force Base - $25 million with twelve month schedule slip. Delta costs for performing Subsystem Integration Testing at the Mississippi Test Facility - $7.6 million.) Advantages ascribable to testing activities at Santa Susana include the convenience and efficiency of all Component and Subsystem Integration Testing being accomplished at one location near the engineering

and manufacturing staffs and facilities. It was also considered at the time that the Santa Susana facility would support three (3) months of testing prior to availability of test facilities at Mississippi Test Facility. Location of Subsystem Integration Testing at Mississippi Test Facility would have, in effect, eliminated one of three (3) test positions and would have been detrimental to the program through deletion or slowing of necessary parallel testing in a crucial phase of the development program.

In addition to schedule delay costs, there are several other factors which make the Subsystem Integration Testing at Santa Susana Field Laboratory the most logical choice. First, additional tests would be added to the already heavily loaded engine test stands at Mississippi Test Facility, therefore, fewer tests would be accomplished in a given time; thus early flight engines would experience a loss of maturity with a resulting increase in risk of failure in engines and attendant risks to the first Space Shuttle flights. Second, flexibility in problem solving capability will be degraded by eliminating the Subsystems Integration Test position at Santa Susana Field Laboratory.

In summary, because environmental effects have been assessed as equal for all three alternatives, costs, schedules and other programmatic considerations have led to the selection of Santa Susana for Space Shuttle Main Engine Subsystem Integration Testing.

7. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE OF LONG-TERM PRODUCTIVITY

It is expected that local short-term use of the environment (1974 through 1977) in this project, being directly related to the Space Shuttle Program will contribute to the enhancement of long-term productivity. The Shuttle will provide a highly flexible payload capability to support a variety of space applications which will include man's ability to study his own planet Earth from the vantage point of space and thereby develop earth-looking systems which can test and monitor conditions in the Earth's environment thus increasing his ability to maintain and enhance the long-term productivity of his environment.

8. IRREVERSIBLE AND IRRETRIEVALBE COMMITMENTS OF NATURAL RESOURCES:

There will be no significant irreversible or irretrievable commitments of natural resources in the proposed action.

9. COMMENTS ON ENVIRONMENTAL STATEMENT FOR SPACE SHUTTLE MAIN ENGINE COMPONENT AND SUBSYSTEM TEST PROJECT:

Comments on the Draft Environmental Statement for Space Shuttle Main Engine Component and Subsystem Testing (released April 10, 1973) were requested from CEQ, OMB, EPA, DOD, HEW, DOC, DOT, HUD, DOI, State and local agencies. Responses were received from DOD, HUD, DOI, State and local agencies. All responses are included in Appendix C.

Two agencies (HUD, DOI) raised questions concerning the possible environmental effect of noise on surrounding communities. They suggested that more quantitative terminology be used to describe the effect of noise on the communities. Acoustics Subsection under Section 4 of the statement has been rewritten in a quantitative, more easily understood manner considering all questions raised, except the question concerning communities which is included under the Section entitled, Project Description.

The Department of Environmental Quality, City of Los Angeles essentially agreed with NASA's evaluation of the acoustic effect on surrounding communities.

Comments were received from DOI and the City of Los Angeles concerning the discharge of excess water from reservoirs to Simi and San Fernando Valleys. As stated in the Environmental Statement the combustion product for the engine propellants is water and therefore, there will be no contamination as a result of component and subsystem testing. However, since a large volume of water will be used for flame deflector cooling and noise reduction during testing, the probability of more frequent discharges off-site could occur. The primary sources of contamination in the reservoirs are from other test operations at the Santa Susana Field Laboratory where propellants such as nitrogen tetroxide, hydrazine or kerosene are used. Tables A and B under Section 4, Water Pollution have been removed from the Statement since they show only the maximum contaminant levels allowed by the Regional Water Quality Control Board No. 4. Actual contaminants and contaminant levels are determined by analysis by the Metropolitan Water District of Southern California upon application for discharge of water off-site to the Department of the Army, Corps of Engineers, Los Angeles District, by Rockwell International Corporation, 1700 E. Imperial Highway, El Segundo, California, 90245. Additionally, prior to any planned discharge of water from the reservoirs, Rockwell International shall obtain a National Pollutant Elimination System's permit in accordance with established procedures as requested by the Resources Agency of California.

The DOI suggested that the treatment of sanitary wastes be included in the Environmental Statement. Sanitary waste is treated in three on-site sewage treatment plants which conform to the standards of the Ventura County Health Department and the State Regional Water Quality Control Board No. 4. After chlorination, the effluent from these plants enters the same reservoirs as the water from the test operations.

Two agencies (HUD and Southern California Association of Governments (SCAG) suggested that the impact of noise on wildlife be considered in the Statement. This point has been addressed in the Acoustics Subsection under Section 4 of the statement. There has been no evidence that wildlife has been adversely affected by Rocket Engine noise at any NASA site.

SCAG suggested that the effect of testing on ground cover be considered in the statement. The testing is performed in an area resembling an inverted dome well below existing ground cover and therefore should have no effect on it.

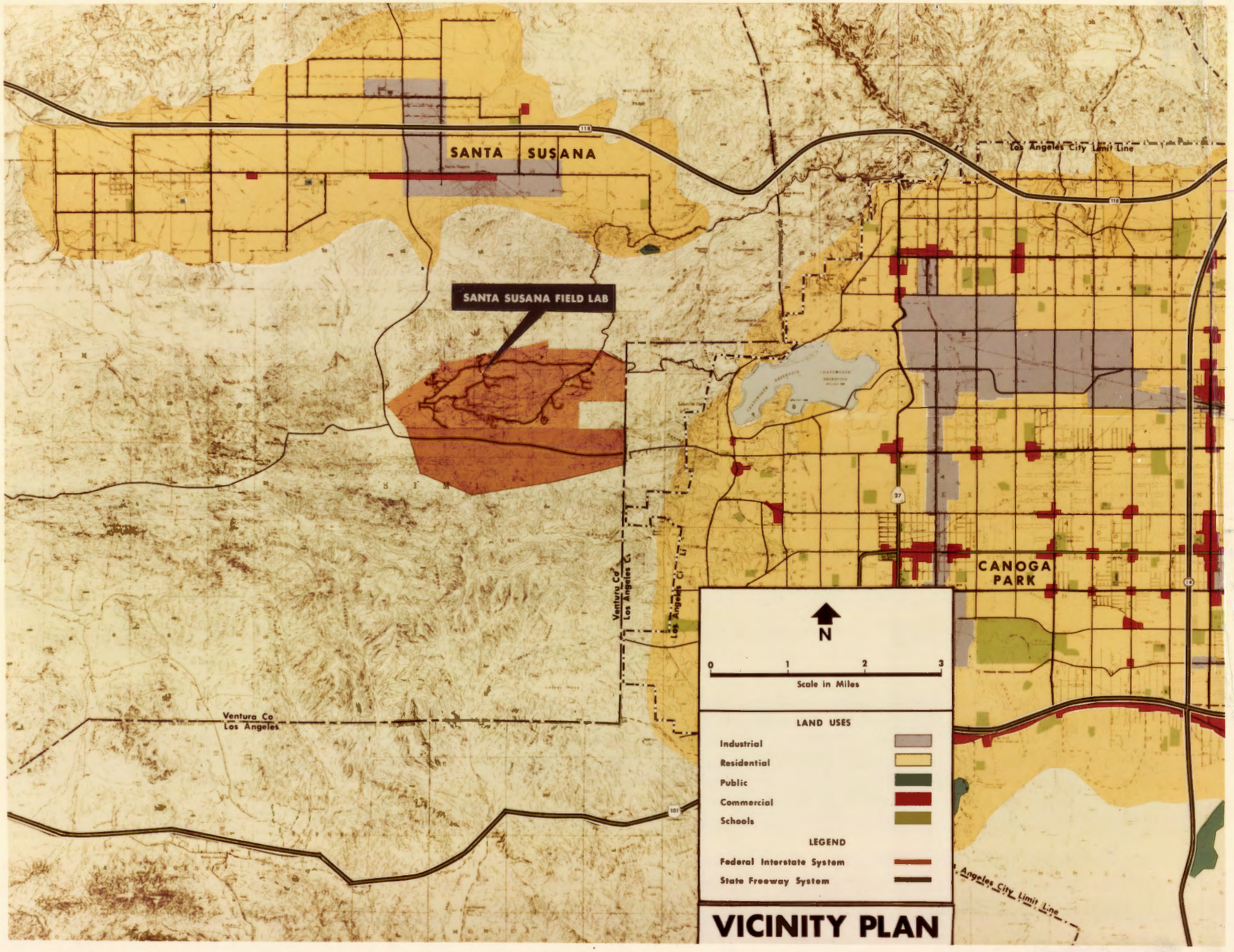
Indian Caves

The Department of Interior suggested that the services of a trained archeologist be engaged to evaluate the integrity of the Indian Caves and other cultural resources to determine the extent to which they may be subject to adverse impact from engine testing. Even though NASA maintains that the cultural resources have not and will not be harmed by engine testing, the services of a trained archeologist will be engaged by NASA to (1) assess the historical significance of the Indian Caves and other known cultural resources in close proximity to the test site, (2) to assure that their integrity have not been damaged by prior testing or, if they have, to what degree, and (3) to determine the potential impact of future SSME testing on these cultural resources, if any. It is planned for this survey to be accomplished in parallel with the construction effort and the Environmental Statement amended at a later date, if the archeological survey/study would so indicate.

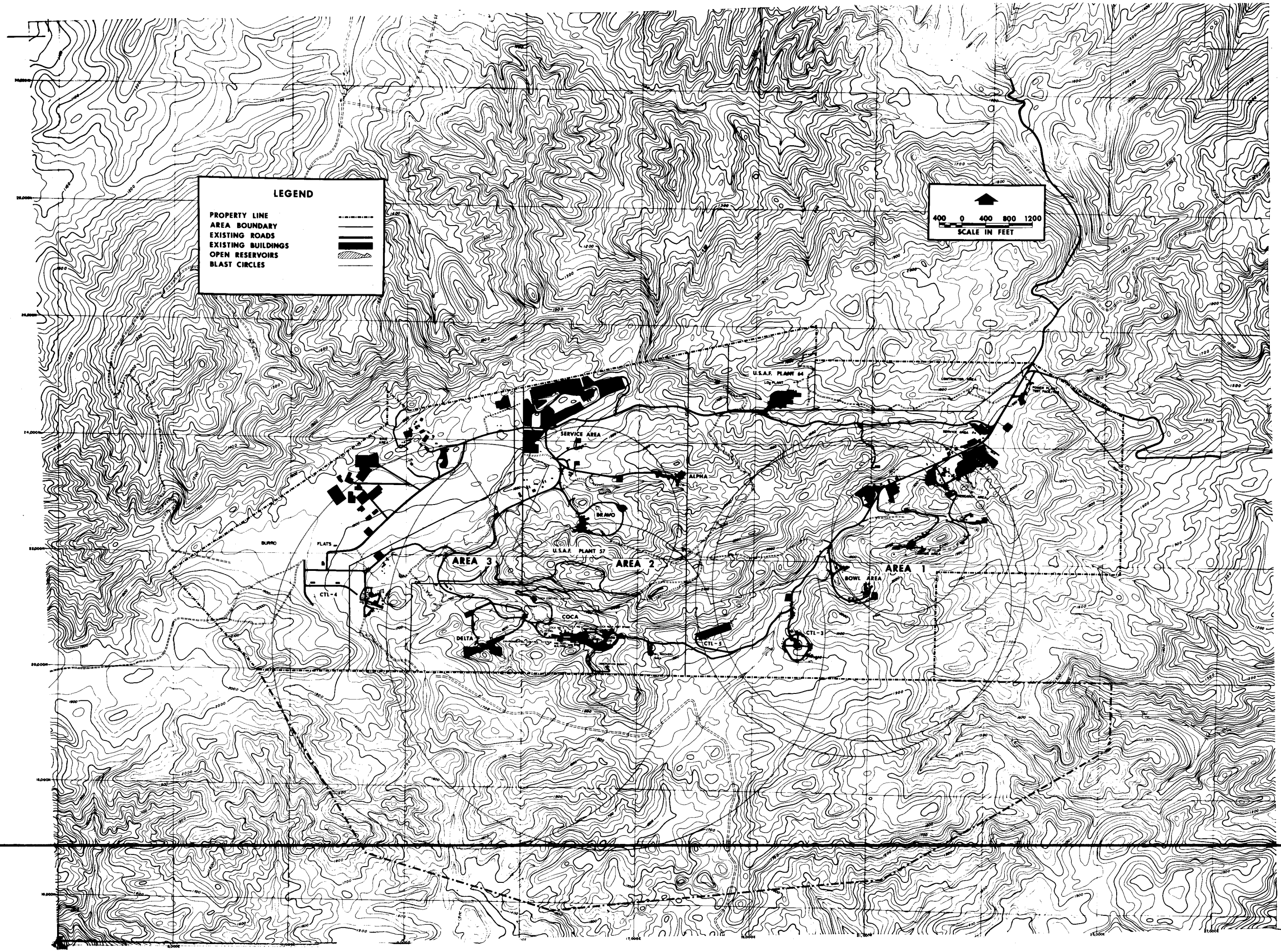
APPENDIX A

SANTA SUSANA FIELD LABORATORY VICINITY MAP

SANTA SUSANA FIELD LABORATORY SITE MAP



VICINITY PLAN


LEGEND
PROPERTY LINE
AREA BOUNDARY
EXISTING ROADS
EXISTING BUILDINGS
OPEN RESERVOIRS
BLAST CIRCLES
400 0 400 800 1200
SCALE IN FEET
U.S.A.F. PLANT 64
LOG PLANT
CONSTRUCTION AREA
POWER TEST FACILITY
SERVICE AREA
ALPHA
BRAVO
U.S.A.F. PLANT 57
BURRO
FLATS
CTL-4
AREA 3
AREA 2
AREA 1
BOWL AREA
COCA
DELTA
CTL-5
CTL-3

APPENDIX B

ACOUSTIC ANALYSIS

MARSHALL SPACE FLIGHT CENTER
AERO-ASTRODYNAMICS LABORATORY
UNSTEADY GAS DYNAMICS BRANCH
(S&E-AERO-AU)

ACOUSTIC ENVIRONMENTAL ASSESSMENT FOR SINGLE SPACE SHUTTLE MAIN ENGINE TESTS - SYSTEM INTEGRATION TEST CONFIGURATION PRIME SITE COCA I SANTA SUSANA, CALIFORNIA

I. Introduction

II. Summary

III. Sound Source Description

- A. Engine Parameters
- B. Sound Power Generation
- C. Acoustic Power Spectrum

IV. Calculation of Sound Pressure Levels in the Farfield Residential Areas

V. Sound Pressure Level Spectra for Farfield Areas

VI. Exposure Criteria

VII. "A Weighted" Sound Pressure Level Applications

VIII. Startle Reaction of Automobile Drivers

IX. Complaint History at Santa Susana

X. Conclusions

XI. Acoustic Environmental Assessment for SSME Alternate Static Test Site - Mississippi Test Facility

XII. Acoustic Environmental Assessment for SSME Alternate Static Test Site - Haystack Butte at Edwards Air Force Base, CA

XIII. References

SANTA SUSANA

ACOUSTIC ENVIRONMENTAL ASSESSMENT

I. Introduction

There has been growing concern in the last few years for the environmental quality in community areas surrounding noise sources such as rocket components or rocket engines at static test sites. It is NASA's objective that the total environment remain within acceptable limits for the various community elements such that the normal daily conditions are not aggravated or made apparent to the extent that the sound environments are intrusive or annoying to the general public. In keeping with this objective NASA has provided studies with the results, summarized to some extent, in this environmental statement to verify that the sound environments are in every way acceptable by taking every practical and necessary step to minimize these environments in all areas. In this way, the health, well being and environmental quality can be preserved for any and all such operations.

II. Summary

During the early planning portion of the engine development program many potential sites for static testing of the Shuttle main engine were studied. Many factors relating to the capabilities and assets of these sites were considered in addition to a particular site compatability with surrounding communities in regard to the acoustic environments to be produced by the exhaust flow system. From these many possibilities three sites were finally considered as being more suitable for the SSME testing. Of these three, the Santa Susana Field Laboratory (Coca #1) was considered the most advantageous test site for the early engine development program with the Mississippi Test Facility, a MSFC segment located in southern Mississippi, and Haystack Butte (Edwards Air Force Base) being the alternate sites.

In regard to the acoustic environmental conditions in the surrounding areas about the test site the prime objective is the health, safety, and well-being of the general public and the assurance that the environmental quality is not degraded to any significant extent while conducting the System Integration Tests (SIT) for the Shuttle's main engine. In providing predictions of the environments in these areas the long history of data from past static tests at various sites were utilized as a basis of prediction along with the latest data from several Hi Pc engine tests.

The environmental predictions indicate that there should be no environmental impact on the existing community areas surrounding the test site. There should be no unpleasant sensations due to body organ response and there are no anticipated problems concerning auditory response. The

farfield acoustic energy spectra contains very little of the higher frequency (100 Hz to 10 K Hz) sound that would most noticeable to the auditory system and thus in many areas should be almost inaudible. Since most of the acoustic energy to reach the farfield is in the form of low frequency waves, the major portion of the energy will be infrasonic, i.e., below the frequency range of hearing. The resonant frequency of many dwelling walls and partitions falls into this lower frequency region of the acoustic energy spectrum, however the pressure levels are well below that noted to induce community reaction due to building window or wall response.

In studying the possibility of any startle effect to drivers in the areas surrounding the test site it was found that, like in the community, the noise was not a significant factor to a driver under normal driving conditions even in the areas where the higher environments are predicted. Hence, there appears to be no significant problems either to people (as drivers) for any of the residential areas surrounding the Rocketdyne test area. This would be the anticipated result considering the atmosphere as a homogeneous medium lacking any beneficial refractive influence in the propagation of the acoustic waves.

As an additional factor for environmental control the tests will be conducted only when the meteorological conditions at the test site will provide additional reductions, 5 dB as specified by the test contractor, in the farfield environments by turning or refracting the acoustic energy upward where the energy can be dissipated without effect on mans' environment. It is probable that the rocket induced overall sound pressure level

environments in many community areas will be no greater than the overall sound pressure levels resulting from everyday sources such as traffic noise, plane over flights, trains, etc. Thus, the direct rocket noise will, in general, be less noticeable especially to the auditory system, even though the overall or composite sound pressure level may be higher than the background levels. This is because of lower frequency energy components of the rocket noise where the normal hearing acuity is inherently more diminished relative to that in the higher frequency range where airplane and traffic noise are more prevalently found. Due to the spectral differences it can, however, be distinguished from the usual community background noise but the pressure amplitudes anticipated will pose no community problems.

By selective scheduling of the tests the beneficial meteorological conditions will be a major factor in reducing farfield acoustic environments below that specified herein. In actual practice 10 dB reductions can be realized with favorable atmospheric conditions. Additionally, at Santa Susana the community environments are further reduced by use of a considerable deflector waterflow rate effectively providing a reduction of the noise at the source. The specific exhaust deflector with a water flow rate of more than a ton per second gives an effective reduction of the noise at the source by approximately 50 percent in terms of generated acoustic power. Thus every precaution that is practical and necessary is utilized in controlling the farfield environment such that community awareness of these tests from the acoustic environmental aspect are minimal.

III. Sound Source Description

A. Engine Parameters

The SSME exhaust flow is the source of the acoustic energy at the static test site. The configuration is denoted as the Subsystem Integration Test (SIT) engine with the following flow parameters:

Sea level thrust - 375,000 Lb.

Flow Rate (Total) = 1032 Lb/Sec

Effective Exhaust Velocity = 11,600 Ft/Sec

Exit Diameter = 5.0 Ft.

Expansion Ratio = 35:1

Deflector Water Flow Rate = 2860 Lb/Sec

The exhaust is deflected by a 90° open bucket type deflector. The deflector is cooled by injection of water into the bucket at a ratio of approximately 2.8 lbs. of water per lb. of fuel. Approximately 30 feet downstream from the nozzle exit plane the center of the exhaust impinges on the deflector where most of the cooling water is injected to mix with the exhaust flow products.

B. Sound Power Generation

Preceding the discussion of the acoustic power and the means of calculation are terms defining the generally accepted units.

In the field of acoustic study several specialized units of measure are found more convenient to use than others. In describing acoustic environments the use of decibel units for the pressures are more usable than the absolute pressure values themselves. This is due to the very large range of pressure valves commonly encountered, e.g. over a range of ten to a hundred million

or a factor 10^{13} or 10^{14}. Thus to facilitate expression of the acoustic pressure the sound pressure level in decibels, dB, is defined:

$$SPL = 10 \log_{10} (P/Po)^2, \text{ dB}$$

where P is the acoustic pressure and Po is the standard reference pressure for atmospheric acoustics, $20\mu N/m^2$ for the metric system of units. Examples of common sounds and their general range of valves in terms of dB's are: threshold of audibility - 0 dB, a whisper - 10 dB, an average auditorium, - 30 dB, an average conversation - 45 dB, noisy office - 75 dB, loud street noise - 100 dB, aircraft flyover noise near a large airport - 115 dB.

Just as in describing the acoustic pressure values the decibel is useful also in regard to quantifying acoustic power, a measure of the source strength. The acoustic power level is defined:

$$PWL = 10 \log_{10} (W/Wo), \text{ dB}$$

Where W is the acoustic power and Wo is the standard reference power, 10^{-12} watts for the metric system of units.

The total acoustic power developed by a hot supersonic rocket exhaust flow can be estimated from its flow parameters and from acoustic data acquired from similar rocket tests. The overall power level for deflected exhaust flows of this type are based on the total mechanical power produced by that flow and the acoustic efficiency. The acoustic efficiency is the fraction acoustic power/mechanical power, i.e., $\eta = Wa/Wm$. From the engine flow parameters the mechanical power is given by

$$Wm = .678\ T\ V_e \quad \text{watts}$$

where T = thrust lb.

Ve = effective exhaust velocity, ft/sec

Then the acoustic power condition can be expressed by:

$Wa = \eta\ (0.678)\ T\ Ve$

The overall acoustic power level is defined as OA PWL = $10 \log_{10} \left[\frac{Wa}{Wo}\right]$ dB

dB

where Wo is a standard reference power of 10^{-12} watts (used with the metric system)

or in terms of the engine flow parameters

$$OA\ PWL = 10 \log_{10} \left[\frac{\eta\ 0.678\ T\ Ve}{Wo}\right]$$

With the engine parameters listed herein the overall mechanical power in watts is 2.95×10^9 watts, using an acoustic efficiency of one-quarter of one percent ($\eta = 0.0025$), the total acoustic power is 7.38×10^6 watts, with an OA PWL = 188.7 dB, Re:Wo = 10^{-12} watts.

The acoustic efficiency used here is based on measured acoustic data acquired from Hi Pc engine tests (horizontal free flow case) and from J-2 engine tests utilizing a 90^o water cooled bucket deflector. From the free flow Hi Pc engine tests an acoustic efficiency of 0.5% was found. The J-2 engine tests (90^o bucket deflector) indicated an efficiency of 0.2%. From other tests of large rocket engines or boosters the deflector water flow rate was found to have little effect for rates less than approximately 6:1 (water to fuel). For the 2.8:1 flow rate specified by the engine test contractor a reduction in the acoustic efficiency from 0.5% to 0.25% was accepted which represents a 50% effective reduction of the sound energy at the source. Flow rates on the order of 10:1 would provide much greater reduction of the acoustic energy but would prove impractical for most rocket engines due to the quite large volume of water required.

C. Acoustic Power Spectrum

To further define the sound source characteristics the acoustic power spectrum must be provided. The acoustic power spectrum is a measure of the source strength over the frequency spectrum, i.e., the energy versus the frequency of the generated sound. The power of the source is a function of the exhaust flow characteristics; or in other terms a function of the engine operational parameters and geometrical configuration, e.g., the thrust, flow velocity, flow rate, and engine geometry.

The power spectrum, Figure 1, was scaled from test data acquired from high chamber pressure engine tests conducted with a 3000 psi Pc value (Pc = chamber pressure), and from other rocket engine data acquired from tests utilizing 90^{o} bucket deflector and similar deflector water flows. Thus the power spectrum is the best available prediction using data from all relatable sources.

The source's directional properties described in terms of directivity indices, i.e., the source's directional properties as the dB variation from a nondirectional source of equal power, were likewise obtained from high Pc engine and other high Mach number rocket engine tests making use of test data with comparable deflectors and flow conditions. The source directivity is important to the farfield environments since rocket exhaust flows have major directional energy lobes generally 40^{o} to 50^{o} relative to the flow centerline. There is 15 to 20 dB variation in the overall sound pressure level between maximum and minimum radiation lobes (See Figure 2). The ground plane environments in the maximum energy lobe areas are, of course, maximum for a given distance from the source and likewise the minimum environments are naturally produced in the minimum directivity regions relative to the exhaust flow.

IV. Calculation of Sound Pressure Levels in the Farfield Residential Areas

After the sound source is fully defined the sound pressure levels for the farfield community areas can be described by considering the losses due to the propagation of the energy to a given observation point in the farfield. The determination of the intensity at any given distance can be described in terms of the source strength (acoustic power spectrum), and all the propagational factors involved. As the pressure wave propagates away from the source the intensity is diminished. This reduction in intensity, due to a finite energy source being propagated over progressively larger and larger areas as the wave moves further from the source, is known as divergence. The sound pressure diminishes with the distance from the source. This loss alone yields 6 dB per doubling of distance from the source.

In addition there are losses due to absorption of the acoustic energy as it propagates through the atmosphere. The exact absorption rates are dependent on the atmospheric temperature and humidity and to a much lesser extent, the pressure. The major factors determining atmospheric absorption are temperature and humidity, with least losses at the higher temperatures and humidities with regard to the Santa Susana area. The minimum absorption values are for the range of normal conditions (temperature and hmidity) and are utilized herein (Figure 3) for conservatism though not extremely critical in their values over the relatively short distances being considered herein, i.e., less than 3 miles in most cases. It is seen from Figure 3, that the major effects of absorption are noticed in the higher frequency range as absorption increases

nonlinearly with frequency such that the absorption rate at 2000 Hz's is approximately 0.008 dB/M whereas at 100 Hz it's less than 0.0008 dB/M.

Also of concern in the propagation process is the absorption of sound by the ground surface. As the pressure wave propagates at grazing incidence over the ground plane, the ground surface and cover contribute to the energy absorption. The effects of heavy ground cover, i.e., deep grasses, trees, brush, are noticeable in acoustic data acquired with propagation over the various cover media. No losses of this type were considered herein because of sparce ground cover, thus yielding a slight conservatism for that aspect.

If the ground surface is not flat and smooth than additional energy losses are experienced. In the case where there are barriers, i.e., obstructions or wall-like interruptions between the source and receiver, consideration must be given in environmental prediction because of diffraction effects around the barrier. The effect of a given barrier on the diffraction of the sound energy around that barrier is function of the relative location of the barrier with respect to the source and receiver, the height and width of the barrier and the wavelength of the propagating wave, (or the frequency, since the wavelength - frequency product is equal to the wave propagation speed). The shorter the wavelength (higher frequencies) the greater the shielding effect of a given barrier. In regard to the natural barriers formed by the rather precipitous and elevated terrain features in the Santa Susana area, the effective intermediate barrier influences on the farfield have been considered for the given test site and the observation points of concern. The barrier losses can be estimated from

Figure 4. This consideration was made in terms of the natural barrier and for each frequency band of the sound pressure level spectrum.

It is known that the barrier effects depicted in Figure 4 are not totally applicable to the natural terrain barriers present in this case. However, this is a best estimate at this time for this particular case of topographical conditions since no measured data for propagation over such terrain is available. It is also suspected that ground absorption losses for this terrain are more than for the normally flatter terrain conditions. These two factors, the natural terrain producing less than the wall barrier losses, and the ground absorption being greater for the Santa Susana area than for flatter areas, may offset each other to very closely produce the composite effect that would be observed from measurement. It is thought that the complaint history resulting from testing at Santa Susana tends to substantiate this statement to some degree.

V. Sound Pressure Level Spectra for Farfield Areas

Using the acoustic power spectrum, the directional properties of the source, and the propagational losses associated with Santa Susana, the sound pressure level spectra for the farfield areas can be predicted. The meteorological conditions are of course influential to the energy received in the farfield but a non-layered homogeneous case is assumed here, e.g., no focusing or refraction of the acoustic energy either detrimentally or beneficially in regard to the induced environments.

Thus, utilizing the previously noted factors the sound pressure level spectra for specified locations and the overall sound pressure level values are provided for various positions in the nearer residential regions around the test site. Figure 5 delineates the OA SPL values for various areas of the closest residential boundary projected for the late 1970's. (Note: the dB(A) values are covered in Section VI).

The acoustic environments for the boundary of the Rocketdyne property are shown for two locations; 7800 feet and 250° where the OA SPL is denoted at 114 dB, and at 5500 ft and 20° where the OA SPL is 109 dB▽. The levels for the boundary are for non-residential zones and are to be reduced by 5 dB due to the meteorological constraints imposed to refract a portion of the sound energy upward. No problems should arise from these levels in these rather remote isolated areas.

Figure 6 depicts the spectra associated with the OA SPL's provided in Figure 5. Figure 6, curve a, presents the octave band sound pressure level spectra at the nearest residential area, i.e., at 14,000 ft. from the test site and 300° Re: North. The OA SPL is noted to be 94 dB with the peak octave band pressure at 16 Hz. (Note:▽All SPL's Re: 20 μ N/m^2).

The octave band sound pressure level spectrum at 15,000 feet and 20° is 92 dB and peaking at 30 Hz and is given in Figure 6, curve b. The spectrum for the residential area northeast of test site is shown in Figure 6, curve c, for a range of 15,000 feet and 60° from the engine exhaust flow. Just southeast of the test stand the levels at 7000 feet and 120° are still lower than the northern areas because of the directional properties of the source. The octave band spectrum provided for the northwest residential areas are shown in Figure 6, curve e, for approximately 15,000 feet and 320° to 340° from the exhaust flow engine centerline.

These environments are not considered detrimental relative to the general environmental conditions in the communities in the areas surrounding the test site.

* NOTE: Overall sound pressure level contours have not been provided for the SSTF area. To provide this would require at every change in elevation or azimuth angle a calculation of the environment with that particular source/barrier/receiver set of geometric conditions. This is due to the fact that the natural barrier's effects are dependent on both the elevation of the source and the changing elevation of an effective observatism point as would be incurred in traversing from one OA SPL contour line to another. This would be a lengthy task of considering each hill and valley for which the environments are not of concern. Contour lines for a flat terrain condition cannot be simply modified to properly show the constantly varying barrier effect as the distance from the source changes in the uneven terrain. Of course the effects of atmospheric turbulence and the other local flow effects in the uneven terrain conditions about SSFL precludes the need for exacting detail with this particular factor.

VI. Exposure Criteria

In assessing community impact the environmental conditions are usually referenced to criteria related to the description of a given reaction or response to a specified sound pressure level spectra or to specified overall sound pressure level values. There are specific criteria available for predicting or in most cases providing an assessment of the responses of personnel or structures which are exposed to various levels. These criteria range from annoyance or intrusion to physical damage, i.e., hearing loss for personnel, and material damage to structural elements of dwellings or buildings. These criteria are derived for the most part from exposure history and the observed effects. There are two general forms of criteria; those denoting potential damage and those denoting annoyance, aggravation or some measure of intrusiveness. These general criteria are specifically recognized as separate criteria basically by their differences in absolute values and their resultant effect on structures and personnel. Under damage related environments are listed various criteria (Figure 8 and Reference (2)) specifically related to:

- Hearing Loss - Permanent threshold shifts
- Temporary Threshold Shifts
- Physiological Damage - Organ or other body damage (Auditory and Non-Auditory body response)
- Structural Damage

Noise resulting from non-damaging structural panel movement, as resulting from the induced acoustic environment, and subjective reaction of humans are included in criteria related to:

- Annoyance
- Speech Interference

- Startle Effects
- Performance Degradation
- General Community Reaction
- Building Response - Panel wall or window movement, etc. (Secondary movement)

From the history of exposure and effects, most of the above types of criteria are documented or published in the open literature covering most of the commonplace noise sources or at least commonplace noise spectra and its effects on man and his environment. Hearing loss criteria and even subjective criteria for annoyance type effects received detailed attention in various publications and even laws such as the Walsh-Healy Public Contracts Act, directed toward hearing conservatism in industrial occupations, have been enacted. These particular criteria are provided in terms of level, frequency and permissable exposure duration in hours per day. In general the present standards for "whole body" personnel response are covered over most of the frequency range of interest even for rocket type sources, i.e., from infrasonic to ultrasonic. These levels are, of course, not in the range of concern to the communities surrounding the test site at Santa Susana because the environments produced in these community areas are far below or far less than the criteria denoting structural damage for building or that inducing hearing loss in humans or animals. The sound pressure level range of interest is considered to be in the subjective response region, from levels that are barely audible to the community, down to levels that may be unnoticed in comparison with everyday background noise levels.

With respect to general farfield rocket noise, the criteria available for subjective response, direct human response or structural related response inducing human reaction, i.e., dwelling wall displacement, etc., is severely lacking from the infrasonic frequency range up to 100 Hz. For example, this frequency range represents the major portion of the rocket's acoustic environment in the farfield and very little data are available concerning community response in this range other than that that has been observed in and around areas of rocket test sites and launch sites. The only known study (Ref. 3) utilizing data in the infrasonic range is one considering only rocket noise data and the resulting community response information. It is suspected however, that various communities can exhibit quite contrasting noise "sensitivities" due to the socio-economic makeup, current environmental exposure situations, current public attitudes and other intangible factors that are unpredictable in terms of a dB factor to be added to or subtracted from a sound pressure level representing the acoustic environmental condition. Thus application of criteria from a given community to another may not be valid, especially if the factors concerning socio-economic and public attitude or acceptances are drastically different.

From the study related to community noise response to rocket noise (Ref. 3) it was observed that all reactions received from the community were associated with the structural response phenomenon rather than human body or auditory response induced by the acoustic environments. Thus on this basis it is believed that the use of the dB(A) weighting scale or other related ratings designed for auditory system response simulation, is not applicable in describing the community response for rocket engine testing, since that community reaction thus far has not been related to the auditory system excitation. Some of the noise from the test is obviously heard in many instances but from static test history experience it is certainly

not felt to be the only factor in predicting public response to the acoustic environments induced in the community. (See Section VII).

Numerous rating schemes have been developed to predict intrusiveness standpoint, to a given type of noise exposure . These techniques were developed primarily to obtain a predictable measure of the reaction of a community to aircraft engine noise (ground run-up, takeoff and landing operations) at a nearby airport. A few of the more commonly used "aircraft noise" rating schemes are as follows: (1) CNR-composite noise rating, (2) NNI - noise and number index, (3) NEF - noise exposure forecast, (4) NPL - noise pollution level, and (5) CNEL - community noise equivalent level. These techniques are similar in many respects and they all attempt to measure the influence of the duration to which the community is exposed to the noise, the number of occurrences of this noise, the level of noise and the time of day to which the community was exposed. All of the rating schemes have a basic unit of measure upon which each technique was derived. In the case of the CNR, NNI and NEF, the basic unit of measure is the PNL in PN dB's. For the NPL and CNEL, the basic unit of measure is the dB(A). These basic units of measure were derived by considering the annoyance reaction from auditory stimulation in the frequency range of 100 Hz to 10K Hz. Therefore, they are based on annoyance reaction from direct auditory response and not whole body response. From these basic units for annoyance measurements evolved the more complex prediction techniques noted previously. In all cases, these more complex prediction techniques were developed from an aircraft operation standpoint, with a frequent number of exposures and moderate duration at all times of the day. Each of these rating schemes enjoy some "degree of success". This success can be attributed, however, more

to the ingenuity of the originator rather than the validity of the technique itself, i.e., the fitting of the results to rather specialized cases not specifically exemplifying the broader range of characteristics for all general sound sources of concern today.

Recent attempts have been made to apply these complex rating schemes, CNEL in particular, to predict the community reaction (annoyance or intrusiveness) to infrequent low level and low frequency acoustic rocket noise energy. The validity of applying this technique to a rocket noise environment is highly questionable. For the case of SSME rocket tests at Santa Susana, the surrounding community is exposed to acoustic energy whose spectral peak is in the infrasonic frequency range, i.e., peak frequency is in the 16 Hz octave band. The basic unit of measure for the CNEL, as indicated earlier, is the dB(A); this unit of measure was developed for auditory stimulation in the audible frequency range from 100 Hz to 10K Hz and extrapolation of the subjective reaction of communities exposed to acoustic energy, which is primarily infrasonic, is totally unjustified. This same reasoning also pertains to the other "acceptable" rating techniques. These techniques' basic unit of measure is the PN dB and the same limiting assumptions apply here also.

It is well known that the effects of low frequency noise (below 100 Hz) on humans, particularly as far as auditory response is concerned, become less and less important as the frequency is lowered. There is no acceptable technique for predicting the subjective reaction (from an annoyance standpoint) of communities exposed to infrasonic acoustic energy. Whole body response, chest cavity resonance, abdomen response, etc., become important when dealing with low frequency energy (below 100 Hz) and not the subjective auditory reactions. Damage risk criteria for whole body exposure to infra-

sonic energy is available as indicated earlier, but no specific criteria is available from an annoyance standpoint. Communities surrounding Santa Susana will be exposed to levels well below those specified by the damage criteria. Past experience with rocket engine testing (S-IC and S-II testing at MTF, F-1 and J-2 testing at Santa Susana and launches from KSC), must be relied upon for establishment of a "general acceptance" criteria. The general acceptance criteria that has been used for Space Shuttle application is that communities will only be exposed to environments which are less than 115 dB, Overall Sound Pressure Level, Re: 0.00002 N/m^2; it is further understood that the frequency content of the primary energy is approximately 50 Hz and below. The community exposure levels surrounding Santa Susana meet this general acceptance criteria, and in general appear to be as much as 20 dB's lower for most of the residential areas.

VII. "A Weighted Sound Pressure Level Applications

Figure 8 depicts farfield sound pressure level spectra at 14,000 feet from the source and at a heading of 300° from the test stand, as previously shown in Figure 6.a. The acoustic energy arriving at that point in the farfield during static test of an SSME SIT configuration is represented by the higher spectrum having an overall sound pressure level of 94 dB. The "A-weighted" spectrum representing the same acoustic energy is shown as the lower spectrum. The sum of the energy represented by this curve is known as the "A-weighted" sound level and is expressed in dB(A). This number (dB(A)) is useful only in dealing with human auditory response to a given noise from an annoyance standpoint and results obtained from otherwise use of this value may be misleading. In regard to describing the annoyance reaction of the general public to various noise sources, many schemes utilizing the "A-weighted" dB(A) scale have been devised. The noise source of concern in a great majority of these cases has been aircraft type noise or other noises having comparable spectra. In the case involving noise produced by large rocket engines, the farfield environments usually peak very near the infrasonic portion of the spectrum, i.e, generally less than 20 Hz. Application of the "A-weighting"scale to this noise spectra of Figure 8 yields quite varied results from that of aircraft type noise where the original sound pressure level peaks as much as seven octave higher. Not only are the peaks quite different but the low frequency energy content ($\approx$ 20 Hz) of the aircraft noise in general would be much, much lower than the rocket noise energy in this frequency range.

Although the purpose of the "A-weighted" scale is to aid in evaluating the annoyance to people it should be noted that from the American National Standards Institute Specification for Sound Level Meters (ANSI 51.4-1971) the "A-weighting" is presented for frequencies only down to 25 Hz. Although the auditory systems' response in the normal usage relating to hearing, is quite diminished at lower frequencies there has been noted from tests "an ear tickle" for sound below 20 Hz (reference 2). This would not be indicated by the "A-weighting" values since "tickle" is not auditory response related phenomenon. Also, response of other body organs is noted below 100 Hz where unpleasant sensations can be induced at levels below that as prescribed as damaging.

In addition to human body response the lower frequency acoustic energy is generally noted first in a house or dwelling type structure simply by observing movement of large panels, i.e., large window or wall panel vibration, producing secondary noise by vibration of dishes, etc. Since the resonance of these larger wall panels is found generally in the region from 2 to 25 Hz the problems related with such environments are not apparent from an "A-weighted" sound pressure level value where a 45 dB reduction in relative response to the auditory system is specified at 25 Hz. This could be erroneously utilized in totally assessing an environmental problem where the auditory response was not the only element of concern. In this application a 45 dB reduction implies a difference factor of more than 30,000 in energy which would certainly be misleading in evaluating anything other than true auditory response related problems from a dB(A) value.

To summarize this point, it should be emphasized that use of dB(A) for assessment of general rocket acoustic environmental problems, either from the damage or annoyance aspect, is to be avoided! Problems relating to other than the true auditory response, should not be assessed with use of the "A Weighting" scale. The application of the dB(A) values to driver startle effects would be acceptable in cases where the frequency range of interest is compatible with original annoyance or subjective response test data, i.e., 100 Hz to 10,000 Hz. (See next Section).

VIII Startle Reaction of Automobile Drivers

In the area of residential housing and commercial business zones surrounding the Santa Susana test site are the highways and streets likewise exposed to the acoustic environments as are the general public and their homes and businesses. Since drivers of vehicles on these motorways are responsible for the control of their vehicles at all times the concern for any startle effect due to the sudden onset of the rocket noise is considered. Figure 9 indicates the spread in the measured octave band sound pressure levels spectra representing internal car noise for vehicle speeds from 35 to 70 mph (Ref. 4 & 5). Comparison of the sound pressure level spectra (octave band) indicates no startle effects are to be anticipated.

The maximum rocket noise spectrum for the closest residential area, being northwest from the test site, is provided in Figure 8 with an OA SPL of 70.8 dB(A). In terms of the subjective "A Weighting" scale for simulation of the auditory response, the OA SPL in dB(A) is given for various driving speeds in the car with both windows open and closed (Figure 10). The OA SPL (A) of 70.8 dB(A) from Figure 10 is equivalent to the internal car environment at approximately 33 mph with windows open and 44 mph with windows closed. (Note: In considering the rocket noise level inside the car the transmission loss due to the car's structure is neglected as may be the case with convertible top cars). Therefore, the driver startle effect is of no concern under the normal driving conditions for the maximum environments shown.

IX. Complaint History at Santa Susana

The rocket test history at Santa Susana (Ref. 6) indicates that there have been 27,689 tests, involving rockets of T = 50,000 lb. and higher, from 1958 to 1971. From those tests there have been a total of 218 complaints from the general community. During the first two and one-half years there was no meteorological selectivity practiced, i.e., no meteorological "control" relating to the test firing time. From that first test period there were 161 complaints recorded. After that time partial test selectivity was enforced concerning meteorological conditions; during that phase 43 complaints from 9188 tests were recorded. During the test phase from 1965 to 1971, 39 S-II stage tests were conducted with total meteorological control on both day and night time firings. There were no complaints attributable to the S-II testing (Note that the S-II stage has more than twice the acoustic power output of the SSME, i.e., approximately 3 dB). From the remaining 9438 rocket tests of Atlas engines, H-1 engines, etc., some were conducted at night and some during the day. There were 14 complaints resulting specifically from daytime tests where there was no meteorological control, and again from the Atlas and H-1 engine tests conducted at night with total meteorological control, there were no complaints.

Though the number of complaints are not specifically stated for a given engine or given meteorological conditions it is observed that a definite trend is exhibited. From the data on complaint history in Reference 6, the following is noted:

Meteorological Control	Complaints Per Test
"None"	.0178
"Partial Control" (day/night tests)	.0047
Partial Control (day tests only)	.0021 *
"Total Control" (All 39 S-II tests & other night tests)	.0

*(Assumed 1/3 of tests conducted at night, i.e., after 7:00 p.m.)

From the above comments it is noted that some four to eight times the number of complaints were received from tests with no meteorological control as compared with tests conducted during the period in which partial control was exercised. Of particular interest in supporting the usefulness of meteorological control in reducing community environments and annoyances is the fact that no complaints have been attributed to the total S-II stage test program in the Coca test area, which was conducted with total meteorological selectivity.

It is known that the community reaction is a function of factors other than that induced by the meteorological effects, however, based on similar community reaction results from other rocket test areas where the atmospheric conditions have been known, it has been shown that the major factor is controlling the environment and consequently the community reaction, is the meteorological conditions. The atmosphere in certain conditions, can refract the sound energy back to the ground plane and produce higher levels or refract the energy upward and reduce the environment and the total community reaction. Specifically, data from S-IC and S-II rocket stage tests show very similar trends in that the number of

reactions were recorded along with the measured acoustic environments and detailed estimates including the propagation effects of the velocity of sound profiles existing at test time. From such a test history the number of reactions for exposure to various OA SPL values have been estimated for the Mississippi Test Facility area (Ref. 3) in southern Mississippi, but use of such criteria for other areas such as Santa Susana may not be merited due to socio-economical and population density differences which may be related to the normal background noise levels and general acceptance of such noise sources in the respective communities.

X. Conclusions

The acoustic environmental assessment for the SSME program at Santa Susana yield the following results for tests conducted with favorable meteorological conditions:

- o No structural damages to residences are anticipated.
- o No physiological damage to humans is anticipated.
- o No unpleasant sensations resulting from body response is likely.
- o There is no risk of hearing loss for those in the residential areas.
- o No startle effects to automobile drivers is likely.
- o Community reactions to the acoustic environments will be insignificant.

Additionally:

- o Rocketdyne has had previous experience in test period selectivity for optimum meteorological influence.
- o The meager test schedule will permit proper selectivity of meteorological conditions for all tests since rescheduling will be permissable if adverse conditions arise.
- o There are no foreseen community or sound source changes to alter these anticipated results, i.e., (1) community growth has been considered for the duration of the test program, (2) the number, duration and frequency of test engine firings and the acoustic source, dependent on thrust, exit velocity, geometry, etc., are not expected to deviate from current plans.

These results agree reasonably well with those reached by the engine contractors study of the environmental effects for the SIT at Santa Susana (Ref. 7).

XI. ACOUSTIC ENVIRONMENTAL ASSESSMENT FOR SSME ALTERNATE STATIC TEST SITE MISSISSIPPI TEST FACILITY

An alternate SSME test site at Mississippi Test Facility, a branch of MSFC, in southern Mississippi is herein reviewed for acoustic environmental effects in regard to the farfield community areas.

Acoustic Source Description

The engine parameters for the System Integration Test (SIT) configuration are assumed as indicated in Part III A of the main body of this document. The other test conditions and facility related factors are assumed similar to those specified for the (SIT) setup at Santa Susana. The deflector water flow rate is assumed to be approximately 2.5 to 1 , water to fuel flow by weight. An acoustic efficiency of 0.25% was utilized for this evaluation as necessitated by the engine configuration and other test conditions at the prime test site as well as for MTF.

Acoustic Power Spectrum

With the same engine as the sound source and with the same test geometry, facilities, etc., the acoustic power evaluation is idential to that presented in Santa Susana's assessment, see Figure 1.

Calculation of Sound Pressure Levels in Farfield Residential Areas

The computation of the acoustic environments for MTF was performed in the same manner as prescribed for Santa Susana. The barrier effects, of course, are not a part of the prediction scheme for MTF since the terrain features are quite smooth relative to the hilly regions around the Santa Susana test site.

The attenuation for the atmospheric portion of the absorption process and the directivity effects are the same as listed in the Santa Susana portion of the report. (Figures 2 and 3). The meteorological conditions are again assumed neutral to the propagation process, i.e., a homogeneous isentropic medium with no refraction, either away from or toward the ground plane. However, with favorable propagation conditions the farfield areas could benefit from the energy being turned upward or refracted away from the ground plane. As was stated in the section concerning the prime site, the benefits can be as much as 15 dB under the given conditions selected from within the period of the working week. However, under the controlled program at the prime site only a 5 dB additional reduction is anticipated for the test schedule currently planned and is thought to be attainable for a large percentage of the time at the prime site. Likewise tests could be conducted during favorable periods for this 5 dB benefit at MTF. A meteorological survey just prior to the test would be required to determine the atmospheric conditions at MTF or any other site to evaluate the probability of achieving a specific reduction in the sound pressure levels for given geographic positions around the test site. MTF also has a rocket sound simulation, with less power, to aid in verifying the meteoroglogical effects on the sound propagation to the community areas.

Sound Pressure Level Spectra for Farfield Areas

Utilizing the sound source characteristics previously cited for the Subsystems Integration Test configuration the acoustic environments for the MTF site have been predicted. These environments are provided mainly for application to community response related problems and are defined as the resulting environments induced under neutral meteorological conditions with respect to ground plane environments.

Figure (a) illustrates the overall sound pressure level contours resulting from static firing Space Shuttle main engine in the Subsystems Integration Test (SIT) configuration under neutral meteorological conditions, i.e., no refraction of the acoustic energy either beneficially or detrimentally for the ground plane. Under this restraining stipulation the 95 dB contour line is observed to remain within the MTF buffer zone. The community of Kiln, Mississippi, and the southern portion of Picayune would be exposed to 85 dB. Nicholson is shown to be in the 90 dB zone and Pearl River would be outside the 80 dB contour line, or below 80 dB. Interstate Highway 10 (I-10) through the southern portion of the MTF buffer zone is shown to be between the 85 and 95 dB contour lines, i.e., at approximately 90 dB.

The general acoustic spectrum for the farfield areas, i.e., beyond the MTF buffer zone, is typically peaking at less than 50 Hz, octave band center frequency. The spectrum shape is generally that shown in Figure (a-I) with the peak octave band at approximately 20 Hz generally with a decay of approximately 10 dB per decade above 20 Hz. The attenuation of the high frequency energy is obvious in the farfield and is due to the absorption effects in long range propagation. See Section IV for the Santa Susana Site.

These environments are not considered detrimental to the health, well being or safety of any persons exposed nor is it anticipated that these environments will induce any community reaction from annoyance or intrusiveness.

Exposure Criteria

The general statements concerning human exposure to the range of acoustic energy levels as specified in this study apply equally as well to the MTF test site evaluation as to the Santa Susana site. Section VI of the assessment of the main site is thus applicable to the MTF case.

In conjunction with the evaluation of the effects of the acoustic environments on the general community a detailed study was conducted with the basic effort directed toward the static testing of the Saturn V booster (S-IC stage with a 7.5×10^6 lb. thrust) and other stage tests at MTF. Reference 3 provides estimates of those acoustic environments, the measured supporting data, and the responsive information from the general community areas. Extrapolating from that data used in the S-IC test study it would appear that very few claims, less than one per 100,000 households, would be received due to exposure to 85 dB OA SPL from the SIT environments. From the same data it would be anticipated that any complaints, i.e., expressions of annoyance or intrusiveness, would only be sporadic, if any are received. The environments estimated herein assume a neutral meteorological state, i.e., no refraction. In actual practice the test scheduling is to promote further reduction in these environments for the community areas by making use of beneficial meteorological states to refract the sound energy upward or away from the ground plane. It is also stipulated at the prime test site and likewise assumed for the alternate sites, that testing would be curtailed if meteorological conditions would not benefit the farfield environments in all directions from the test site. Thus, all the environments estimated herein can be reduced by proper selection of test conditions and will be sought on each test by separate and detailed meteorological soundings.

With such meteorological selectivity as discussed here, the overall sound pressure level in many communities may be below or near the local background noise levels. Such levels are not considered detrimental to the environmental quality any more than airplane overflights even at locations far from airports and are therefore within the realm of daily noise exposure especially in larger communities or towns. From the response history in community areas around rocket static test and launch sites, e.g., Marshall Space Flight Center (Huntsville), MTF, Canoga Park Area, CA, KSC, and Edwards Air Force Base Test Area, the foregoing environmental response estimates appear well based. Under these environmental conditions, differing widely from airport noise in most cases, the exposure criteria and related limitations associated with relatively low frequency rocket noise is considered the best available guidelines for assessment of community reaction and serves to prevent encroachment of environmental quality of the public domain in such areas.

A Weighted Sound Pressure Level Applications

The general comments in the prime site text concerning the use of "A Weighted" sound pressure levels apply equally to the MTF alternate site. It is stated again that usage of the "A Weighted" scale is correct only in dealing with human auditory response to a given noise from an annoyance aspect and other forms of annoyance or intrusiveness may not be properly assessed because of primary structural response, secondary response, response to reradiate sounds, etc.

Application to evaluation of automobile drivers startle effect can make use of the dB(A) values and is discussed in Section VIII of the prime site assessment and in the next section here.

Figure (a-I) depicts a sound pressure level spectrum at a given point (15,000 feet from the test and 150° from the exhaust flow centerline) along with the corresponding "A Weighted" spectrum. As previously stated, the energy content in the farfield is shifted to the lower frequency range, from 10 to 20 Hz peak octave band, where the "A Weighted" spectral characteristics tends to diminish the concern for the energy in the low frequency range because of the rapid roll off of the "A weighting" scale depicting the ear's relative insensitivity in that frequency range. Thus, the "A Weighted" spectrum peaks much higher in frequency and the OA SPL dB(A) (generally denoted as just dB(A) alone) is almost independent of the lower frequency energy. As seen in Figure (a-I) the dB(A) value is 17 dB lower than the OA SPL in dB. Though the ear is not sensitive to the lower frequency acoustic energy, various structures and structural elements are, as are other body organs (but usually at higher sound pressure levels than are received here in the farfield).

Startle Reaction of Automobile Drivers

In the southern portion of the MTF buffer zone Interstate Highway 10 extends currently from the western edge just south of the test stand, approximately three miles away (see Figure a). The portion of I-10 to the eastern border is under construction and in the future will serve as a much used transportation link to the New Orleans area. The anticipated maximum OA SPL for I-10 is given in Figure (a-I) at $\simeq$ 90 dB with the peak octave band at $\simeq$ 20 Hz. The internal car noise, induced by the car alone, is shown in a band as acquired from references 2 and 3. The anticipated rocket noise spectrum is within the range of car noise values for normal driving speeds up to 70 mph.

Since the spectra are similar in relative spectral energy content the masking of the rocket noise will in general be considerable at the higher driving speeds. This would be more the case especially if the meteorological conditions are beneficial such that the rocket noise is further reduced by the refraction of the sound energy upward. The dB(A) value associated with this spectrum in Figure (a-I), 73 dB(A) corresponds to the same dB(A) values from Figure 10 (in the prime site assessment) at quite modest driving speeds. With car windows closed the internal level of 73 dB(A) occurs at approximately 50 mph and for open windows at approximately 40 mph. Thus, the sudden onset of the rocket noise at average driving speeds appears to be of little concern, if any, for I-10 in its maximum environment. Both dB and dB(A) values indicate compatible results.

Conclusions

The acoustic environmental assessment for the alternate test site, Mississippi Test Facility, indicates that the operation during neutral meteorological conditions yield essentially the same results as stated for the prime site:

- No structural damages are anticipated for the surrounding communities.
- No significant annoyance is expected.
- No driver startle effects are likely
- Community reaction is to be at a minimum

Additionally,

- The test schedules are rather modest compared to earlier programs and thus meteorological selectivity is achievable

- Previous test data concering community response is available providing the best possible background for environmental assessment of a community and its local sensitivity or acceptance of similar but lower level acoustic environments.

- Sophisticated prediction methods are available for pretest environmental estimates as are pretest sound propagation verifications from a horn (rocket sound source simulation) system.

XII. ACOUSTIC ENVIRONMENTAL ASSESSMENT FOR SSME ALTERNATE STATIC TEST SITE HAYSTACK BUTTE, EDWARDS AIR FORCE BASE, CA

An alternate SSME test site at Haystack Butte, test stand #156 at Edwards Air Force Base is herein reviewed for acoustic environmental effects in regard to the farfield community areas.

Acoustic Source Description

The engine parameters for the System Integration Test (SIT) configuration are assumed as indicated in Part III A of the main body of this document. The other test conditions and facility related factors are assumed similar to those specified for the SIT setup at Santa Susana. The deflector water flow rate is assumed to be approximately 2.5 to 1 water to fuel flow by weight. An acoustic efficiency of 0.25% was utilized for this evaluation as necessitated by the engine configuration and other test conditions at the prime test site as well as for MTF.

Acoustic Power Spectrum

The engine is the same as the test geometry, facilities, etc., for Santa Susana so the acoustic power evaluation is identical to that presented in Santa Susana's assessment, see Figure 1.

Calculation of Sound Pressure Levels in Farfield Residential Areas

The computation of the acoustic environments for Haystack Butte was performed in the same manner as prescribed for Santa Susana. The barrier effects, were a part of the prediction scheme since the terrain features are quite hilly for certain regions around the Haystack Butte areas as it was for the Santa Susana test site.

The attenuation for the atmospheric portion of the absorption process and the directivity effects are the same as listed in the Santa Susana portion of the report. (Figures 2 and 3). The meteorological conditions are assumed neutral to the propagation process, i.e., a homogeneous isentropic medium with no refraction, either away from or toward the ground plane. However, with favorable propagation conditions the farfield areas could benefit from the energy being turned upward or refracted away from the ground plane. As was stated in the section concerning the prime site, the benefits can be as much as 15 dB under the given conditions selected from within the period of the working week. However, under the controlled program at the prime site only a 5 dB additional reduction is anticipated for the test schedule currently planned and is thought to be attainable for a large percentage of the time at the prime site. Likewise tests could be conducted during favorable periods for this 5 dB benefit at Haystack Butte. A meteorological survey just prior to the test would be required to determine the atmospheric conditions to evaluate the probability of achieving a specific reduction in the sound pressure levels for given geographic positions around the test site.

Sound Pressure Level Spectra for Farfield Areas

Utilizing the sound source characteristics previously cited for the Subsystems Integration Test configuration the acoustic environments for the areas surrounding Haystack Butte site have been predicted. These environments are provided mainly for application to community response related problems and are defined as the resulting environments induced under neutral meteorological conditions with respect to ground plane environments.

Figure (b) illustrates the overall sound pressure level contours resulting from static firing Space Shuttle main engine in the Subsystems Integration Test (SIT) configuration under neutral meteorological conditions. The test stand orientation positions the major acoustic directivity lobes toward the northwest and east northeast. Boron, a town just north of the EAFB boundary is shown to be in the 85 dB zone. Hi Vista, just south of the boundary,would receive no audible energy due basically to the directivity, being minimum for that direction,and due to the increased distance from the test area. The area just east of the boundary receives a maximum environment for the uncontrolled area where 97 dB OA SPL (Std Re: 2×10^{-5} N/m^2) is noted.

The general acoustic spectrum for the farfield areas, i.e., beyond the EAFB boundary zone, is typically peaking at less than 50 Hz, octave band center frequency. The spectrum shape generally is that shown in Figure 3 and (a-1) with the peak octave band at approximately 20 Hz,generally with a decay of approximately 10 dB per decade above 20 Hz. The attenuation of the high frequency energy is obvious in the farfield and is due to the absorption effects in long range propagation (See Section IV for the Santa Susana Site).

These environments are not considered detrimental to the health, well being or safety of any persons exposed nor is it anticipated that these environments will induce any community reaction from annoyance or intrusiveness.

Exposure Criteria

The general statements concerning human exposure to the range of acoustic

energy levels as specified in this study apply equally as well to the Haystack Butte test site evaluation as to the Santa Susana site. The general comments in Section VI of the assessment of the main site is thus applicable to the Haystack Butte case.

From all test histories from areas where rocket tests have been conducted the results indicate that the exposure of the communities adjacent to the Haystack Butte test area to the environments induced by the SIT program would not cause any community reaction beyond that of a sporatic nature.

It is stipulated as a test requirement at the prime test site and likewise assumed for the alternate sites, that testing would be curtailed if meteorological conditions would not benefit the farfield environments in all directions from the test site. Thus, all the environments estimated herein can be reduced by proper selection of test conditions and will be sought on each test by separate and detailed meteorological soundings.

A Weighted Sound Pressure Level Applications

The general comments in the prime site text concerning the use of "A Weighted" sound pressure levels apply equally to the alternate site at Haystack Butte. It is stated again that usage of the "A Weighted" scale is correct only in dealing with human auditory response to a given noise from an annoyance aspect and other forms of annoyance or intrusiveness may not be properly assessed because of primary structural response, secondary response, response to reradiate sounds, etc.

Application to evaluation of automobile drivers startle effects can make use of the dB(A) values and is discussed in Section VIII of the prime site's assessment. (Also see Figure 8, indicating conditions at Santa Susana that would be similar to Haystack Butte's at like positions).

Startle Reaction of Automobile Drivers

The general comments concerning driver startle effects are given in Section VIII of prime site assessment and apply equally well to the Haystack Butte site. It is anticipated that for areas outside the EAFB boundary the environments and potential startle effects would be similar to that of the prime site. See Figures 9 and 10, indicating that no problems in this aspect would be anticipated.

Conclusions

The acoustic environmental assessment for the alternate test at Haystack Butte stand #156 indicates that the operation during neutral meteorological conditions yield essentially the same results as stated for the prime site:

- No structural damages are anticipated for the surrounding communities.
- No significant annoyance is expected.
- No driver startle effects are likely.
- Community reaction is to be at a minimum

Additionally,

- The test schedules are rather modest compared to earlier programs and thus meteorological selectivity is achievable.
- Previous test data concering community response is available providing the best possible background for environmental assessment of a community and its local sensitivity or acceptance of similar but lower level acoustic environments.

- Sophisticated prediction methods are available for pretest environmental estimates.

XIII. References

1. Beranek, L., Noise Reduction, McGraw-Hill Book Co., New York, N.Y., 1960.
2. Wilhold, G. A., Jones, J. H., Guest, S., et al, Chemical Rocket/Propellant Hazards Manual - Vol. I General Safety Engineering Design Criteria - Joint Army-Navy-NASA-Air Force Propulsion Committee - CPIA Publication, Chapter 7, October 4, 1971.
3. Guest, S. H., Slone, R. M., "Structural Damage Claims Resulting from Acoustic Environments Produced During Static Test Firings of Rocket Engines", NASA TMX-2570, NASA Space Shuttle Technology Conference, San Antonio, Texas, April 12, 1972.
4. Nichols, R. H., Underwood, J. and Solomon, L. P., "Interior Automobile Noise Measurements Under Various Operating Conditions", Journal of the Acoustic Society of America, Vol. 49, No. 2 (Part I), 1971.
5. Guest, S. H. and Slone, R. M., Private Data - NASA-S&E-AERO-AU, April 1972.
6. Weiss, H., "Meteorological Control of Testing (at Santa Susana)", Rocketdyne/North American Rockwell Report R-9104, October 26, 1972.
7. Sutherland, L. C., "Environmental Effects Analysis Related to Modifications at the Cocoa Test Area, Air Force Plant 57, Santa Susana, California for the Space Shuttle Subsystem Test Facilities," Wyle Lab., Report WCR 72-4(R) Revised October 27, 1972.
8. Handbook for Noise Control in Air Force Bldgs. for Air Materiel Command, WP AFB, Ohio, by Vitro Engineering Corp. Rpt. KLX 1775, Dec. 1956.
9. Noise in Hospitals - Acoustical Study of Noises Affecting the Patient - Public Health Service Publication No. 930-D-11, Dept. HEW, 1963.

MARSHALL SPACE FLIGHT CENTER

SCIENCE & ENGINEERING

PREDICTED ACOUSTIC POWER LEVEL SPECTRUM SSME STATIC TEST

LAB S&E-AERO-AU

NAME S. Guest

DATE Nov. 1, 1972

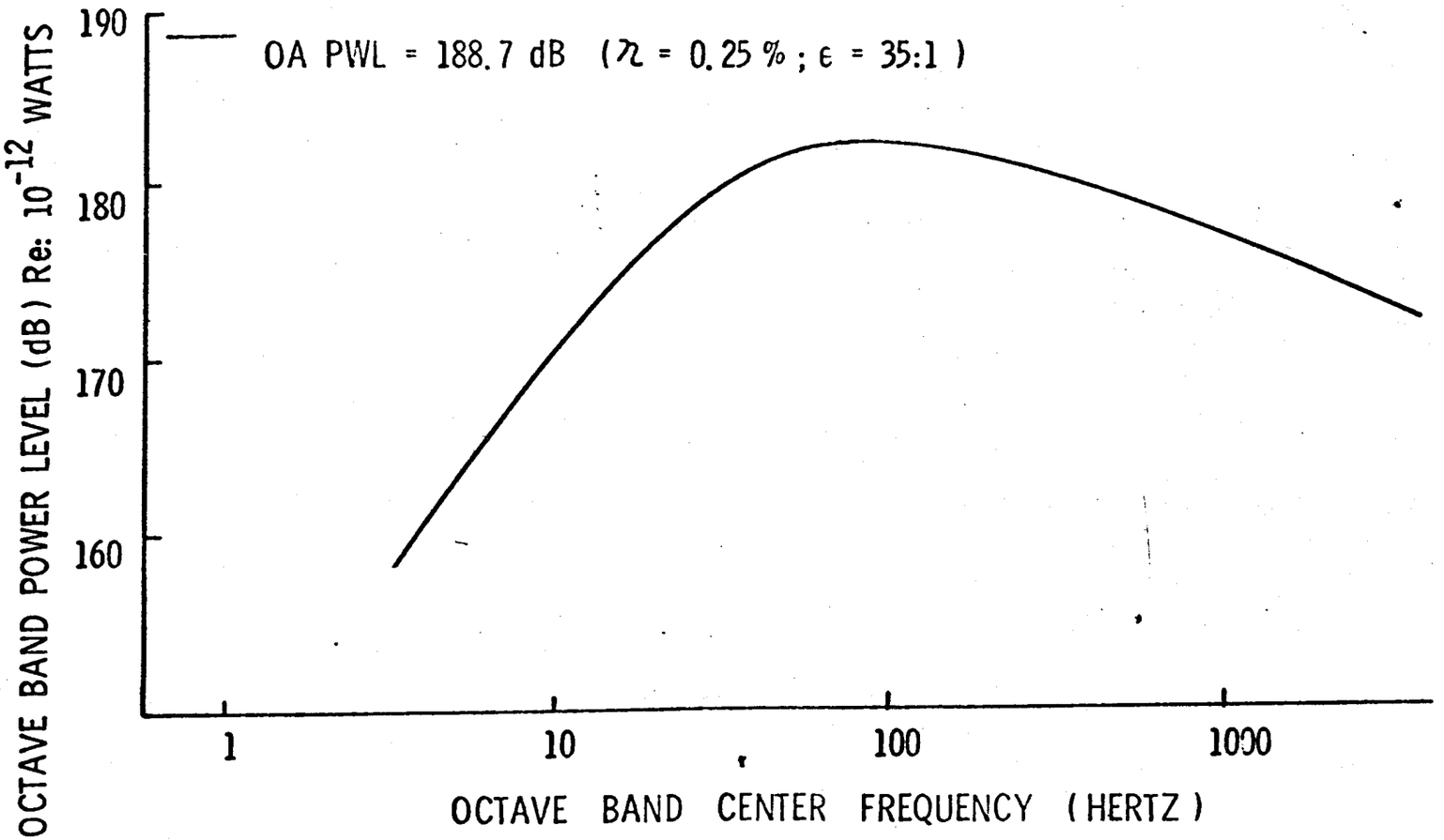
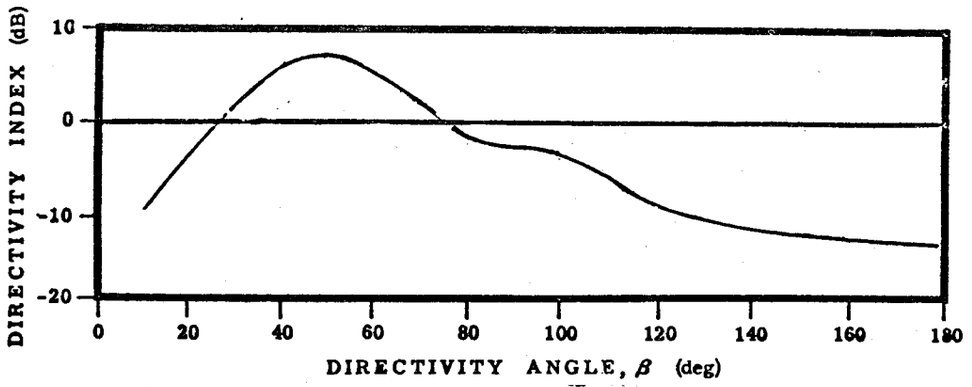


FIGURE 1

MSFC - Form 3369 (Rev June 1970)

CHART No. _____

MARSHALL SPACE FLIGHT CENTER SCIENCE & ENGINEERING	0A SPL DIRECTIVITY FOR SUBSYSTEMS INTEGRATION TESTS AT SANTA SUSANA	LAB: _____ NAME: _____ DATE: _____



Re: 0^{o} Exhaust Direction

(FOR 90^{o} OPEN BUCKET DEFLECTOR)

FIGURE 2

MARSHALL SPACE FLIGHT CENTER

SCIENCE & ENGINEERING

SOUND ABSORPTION IN AIR
(AVERAGE METEOROLOGICAL
CONDITIONS AT SANTA SUSANA)

LAB: _____

NAME: _____

DATE: _____

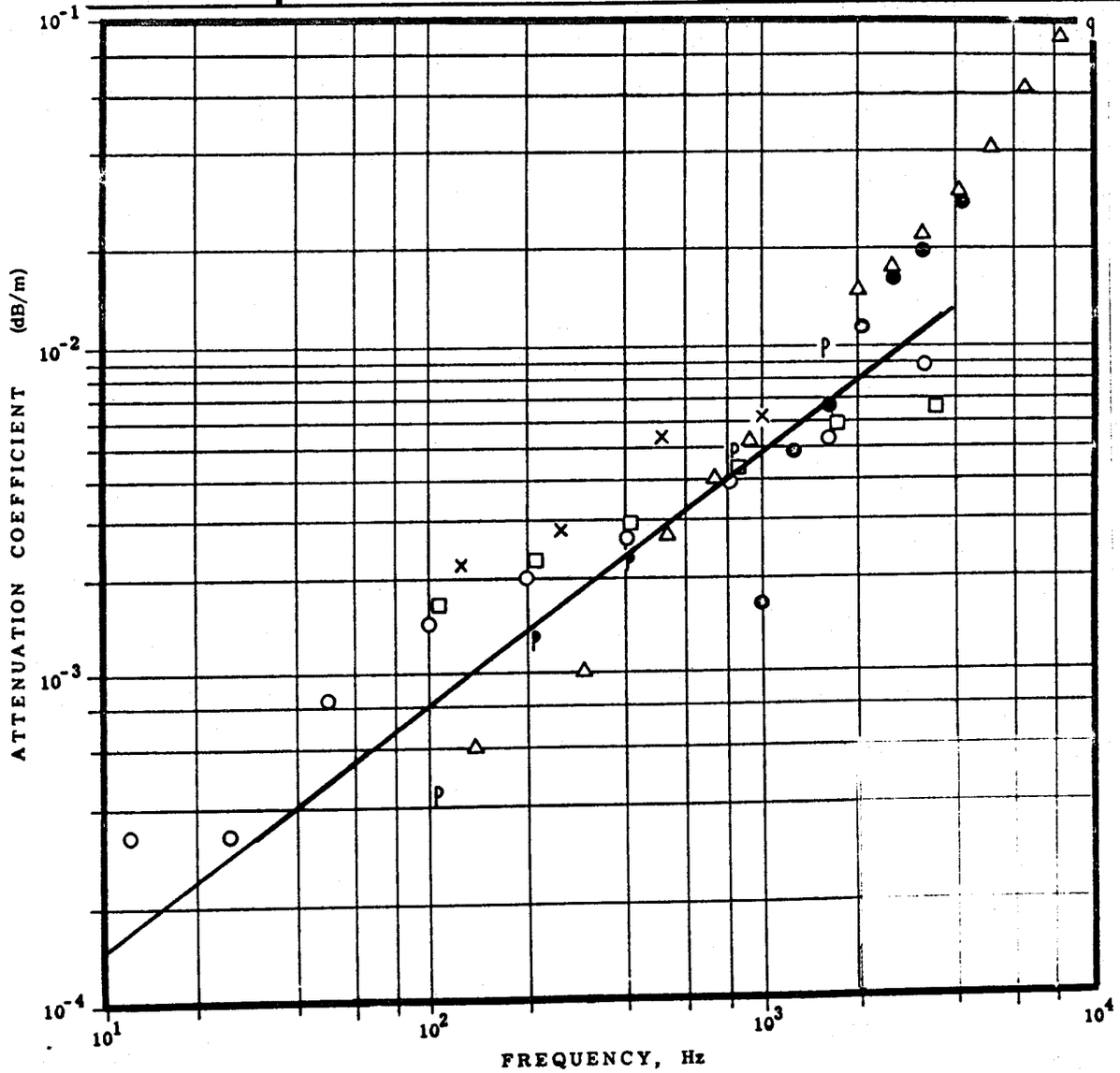


FIGURE 3

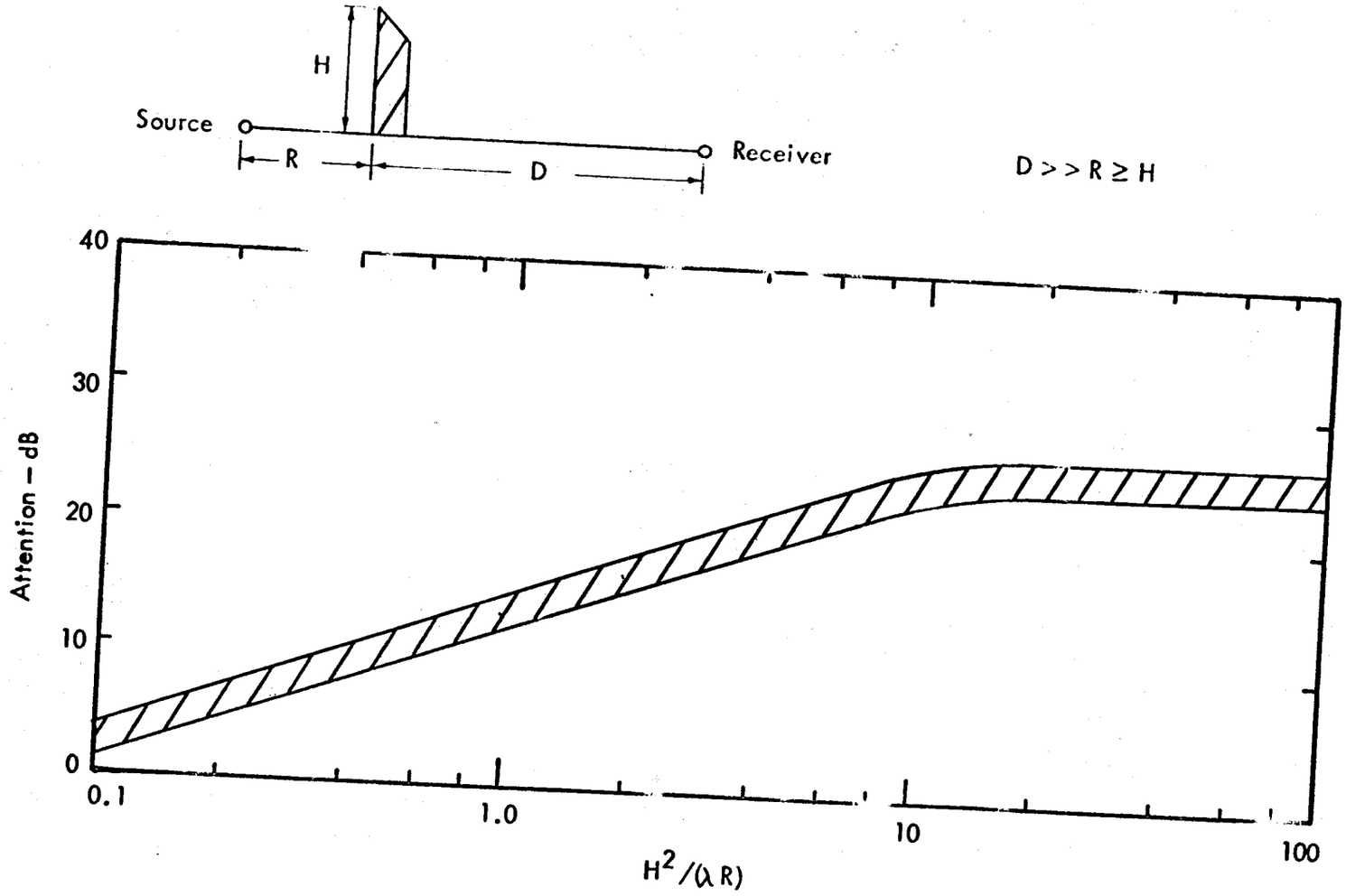


Chart for Estimating Excess Attenuation Due to Rigid Barrier
(Reference 1)

FIGURE 4

MARSHALL SPACE FLIGHT CENTER SCIENCE & ENGINEERING	OVERALL SPL's AT SSTF RESIDENTIAL BOUNDARIES - TERRAIN CONSIDERED	LAB S&E-AERO-AL NAME S. Guest DATE Nov. 1 197

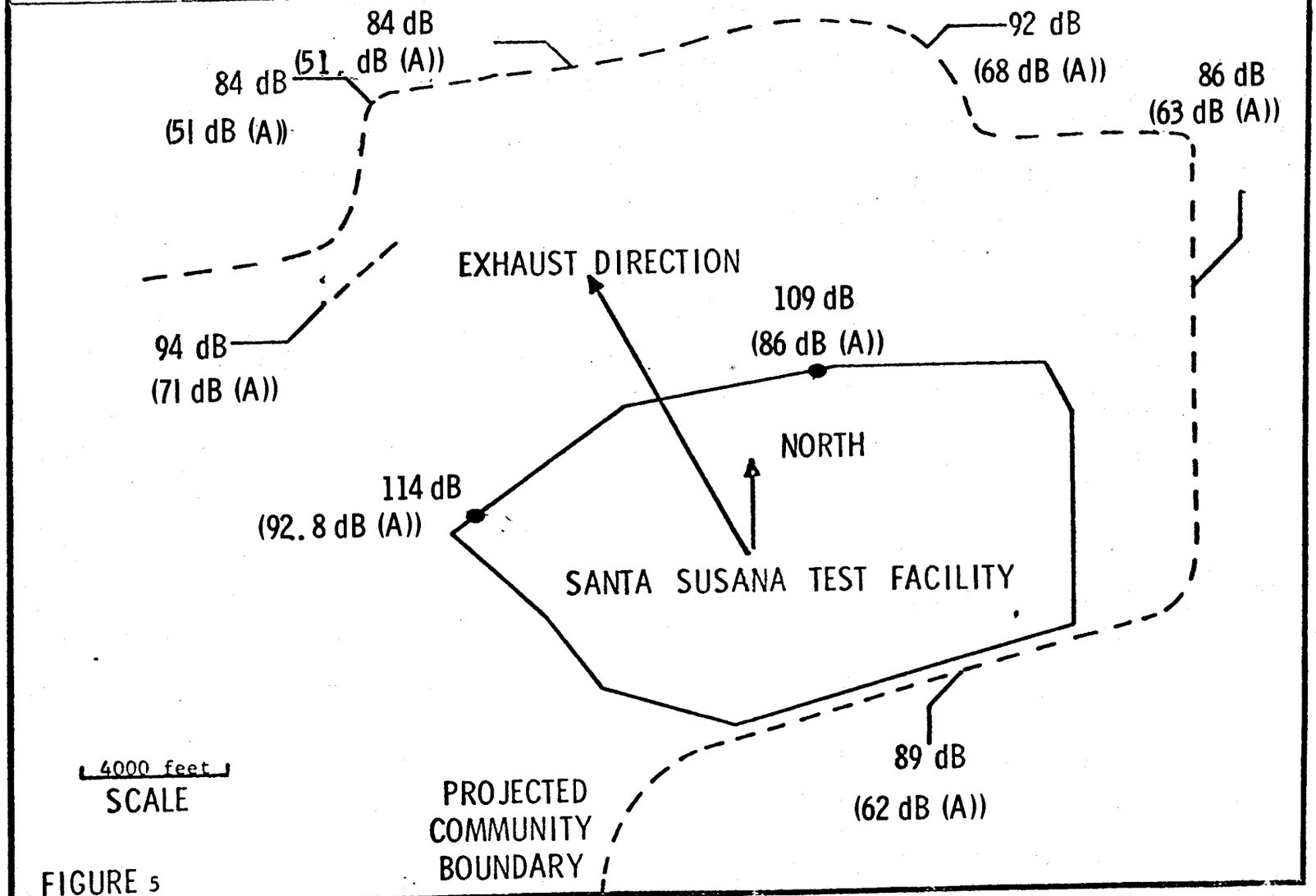


FIGURE 5

CHART No. _____

MARSHALL SPACE FLIGHT CENTER

SCIENCE & ENGINEERING

OCTAVE BAND SPECTRA FOR RESIDENTIAL AREAS AROUND SSTF

LAB: S&E-AERO-AU

NAME: S. Guest

DATE: Nov. 1, 1972

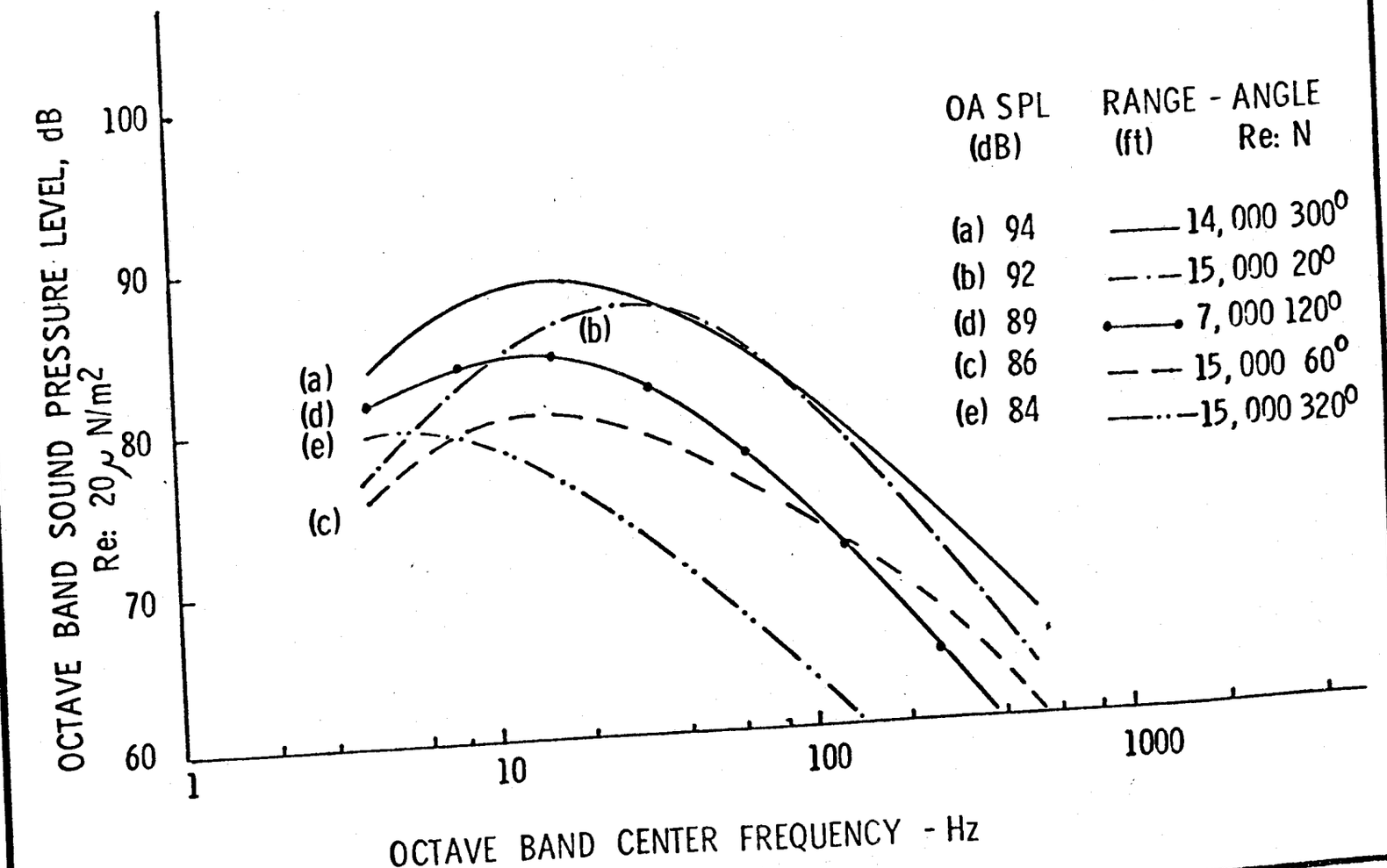


FIGURE 6

CHART No.

MSFC - Form 3359 (Rev June 1970)

ORGANIZATION:	MARSHALL SPACE FLIGHT CENTER	NAME:
S&E-AERO-AU	ESTIMATED ROCKET NOISE ENVIRONMENTS FOR HOSPITAL IN SANTA SUSANA (SIT AT COCA I)	S. Guest
		DATE: January 9, 1973

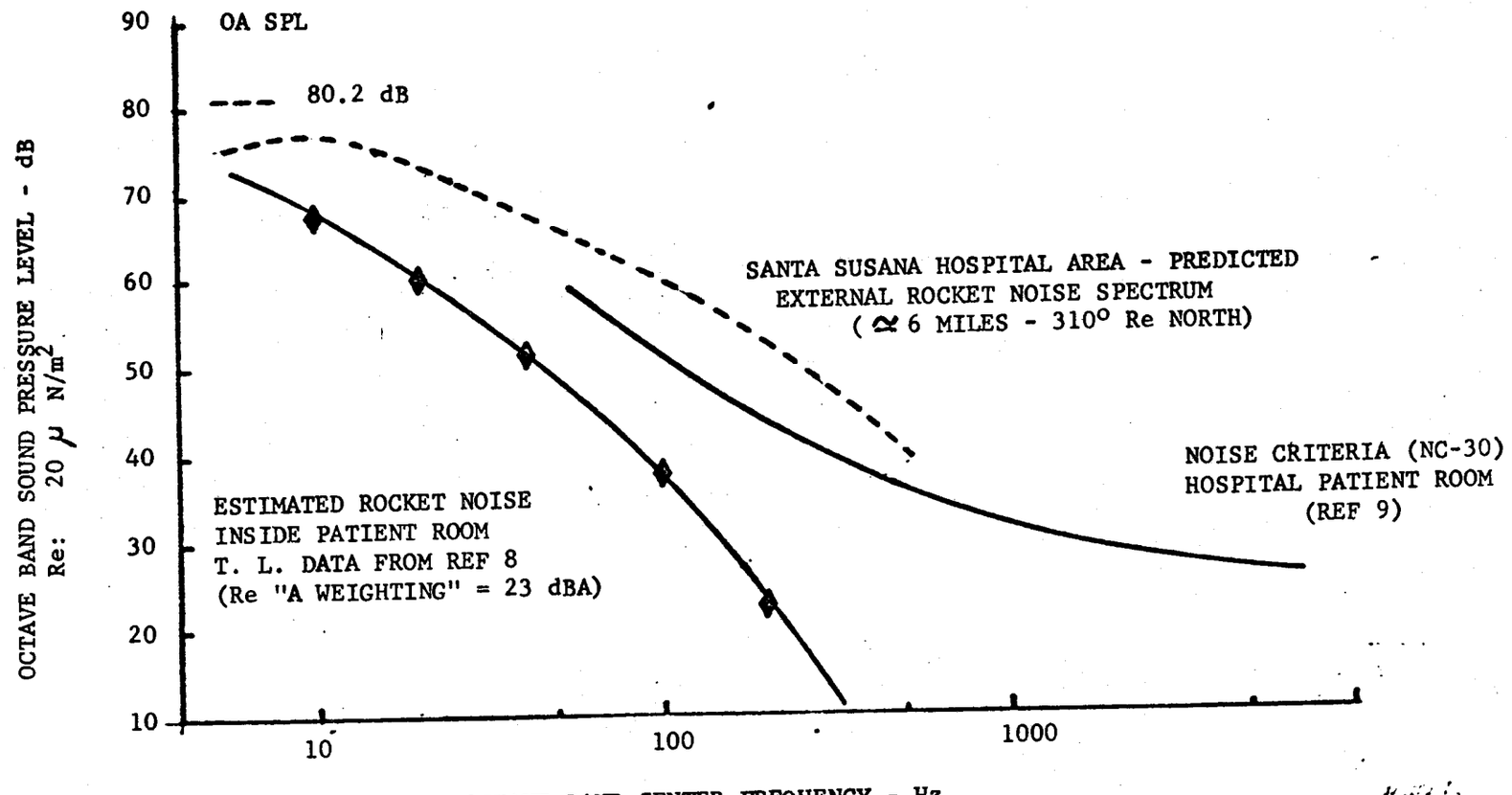


FIGURE 6 A

FILE NO.

MARSHALL SPACE FLIGHT CENTER

SCIENCE & ENGINEERING

PERSONNEL & STRUCTURAL DAMAGE CRITERIA

LAB S&E-AERO-AV

NAME S.H. GUEST

DATE 12 OCTOBER 1972

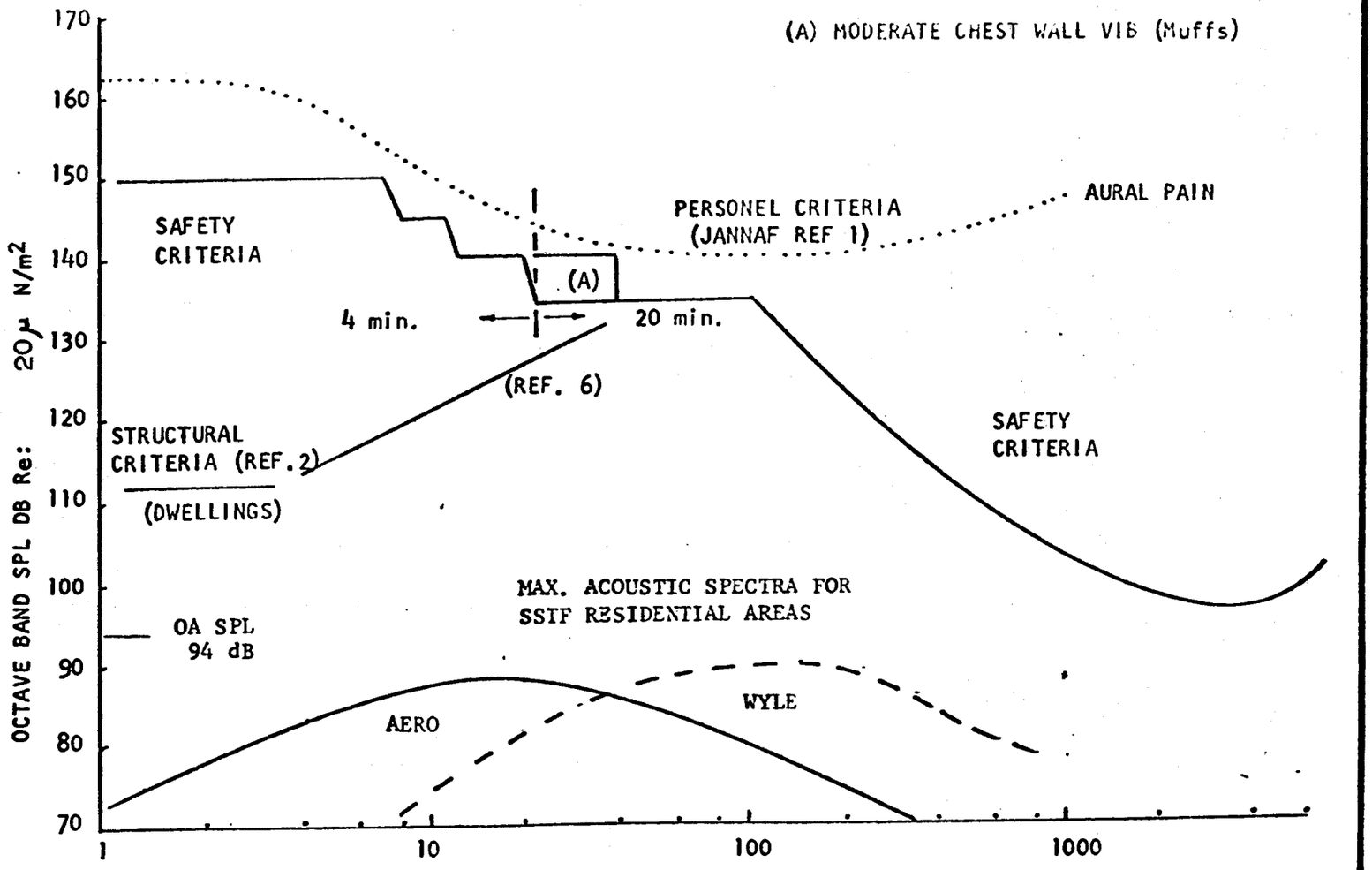


FIGURE 7

CHART No. _____

MSFC - Form 3369 (Rev June 1970)

MARSHALL SPACE FLIGHT CENTER SCIENCE & ENGINEERING	OCTAVE BAND SPL SPECTRUM WITH THE CORRESPONDING "A WEIGHTED SPECTRUM	LAB _____ NAME: _____ DATE: _____

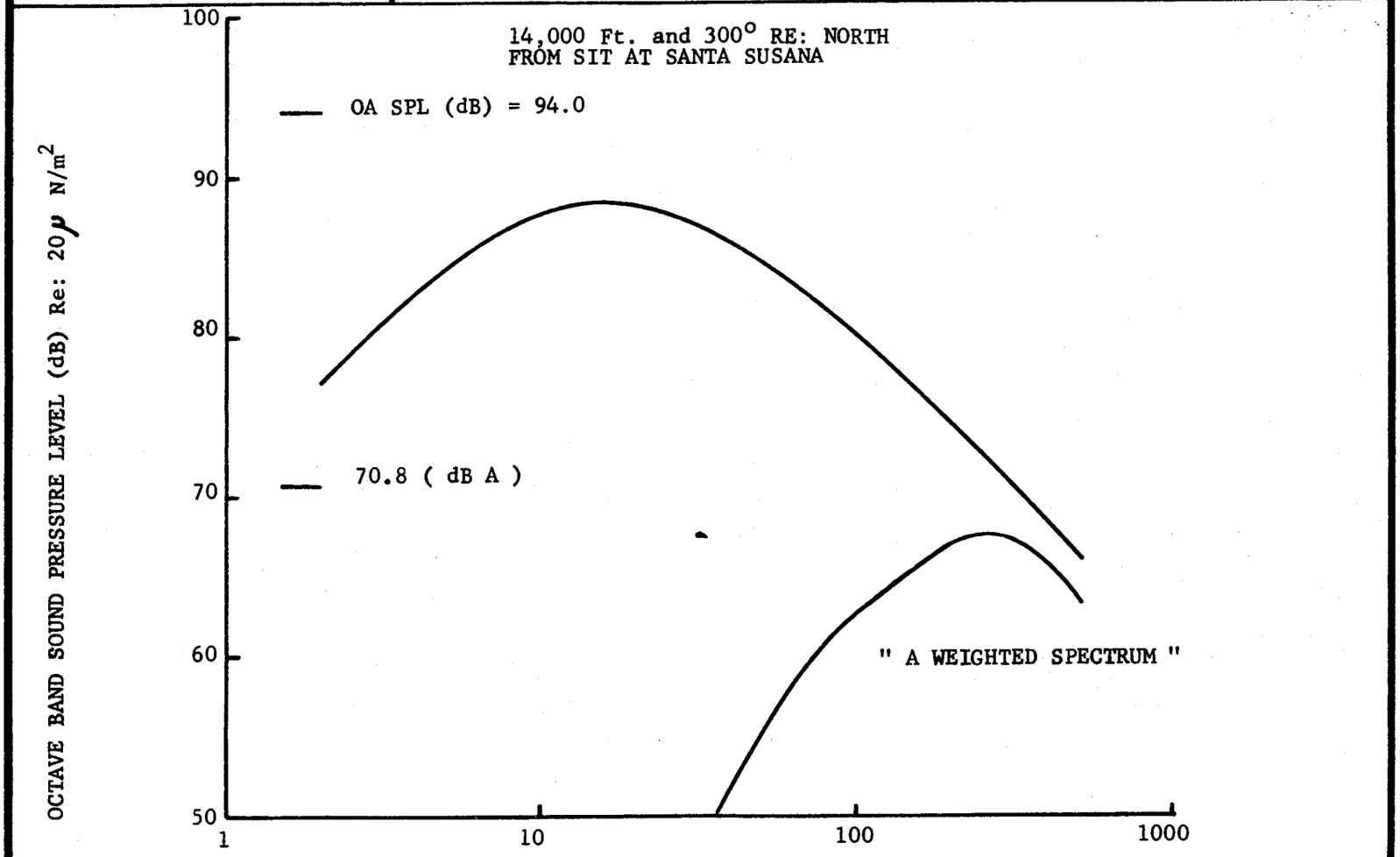


FIGURE 8

MSFC - Form 3369 (Rev June 1970)

CHART No. _____

MARSHALL SPACE FLIGHT CENTER

SCIENCE & ENGINEERING

RANGE OF INTERNAL CAR NOISE COMPARED WITH MAX. ROCKET NOISE SPECTRA

LAB S&E-AERO-AU

NAME S. Guest

DATE Nov. 1, 1972

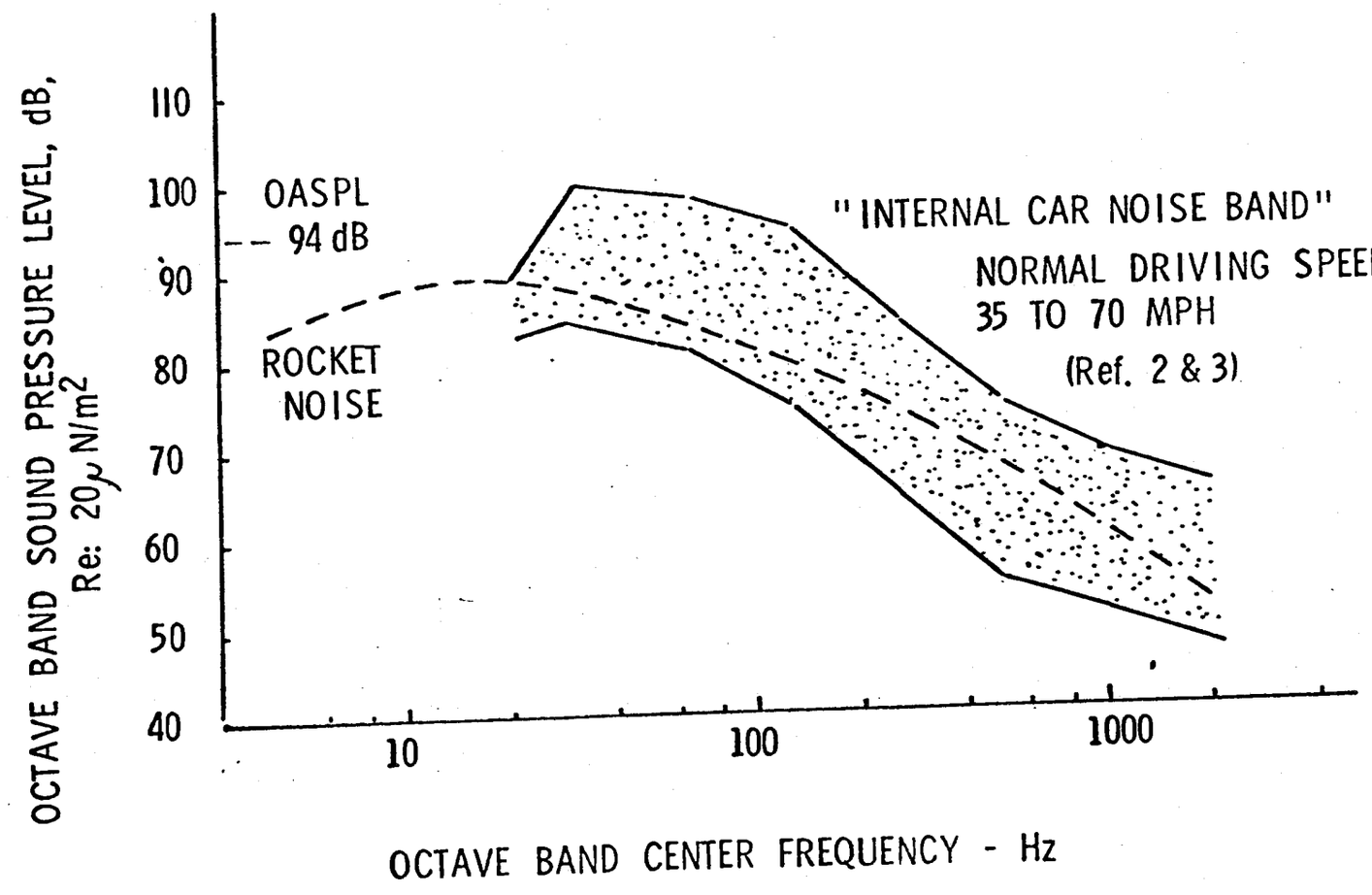


FIGURE 9

CHART No. _____

MSFC - Form 3369 (Rev June 1970)

MARSHALL SPACE FLIGHT CENTER SCIENCE & ENGINEERING	MEASURED OA SPL's (DB A) INTERNAL TO CAR FOR VARIOUS DRIVING SPEEDS	LAB AERO-AU NAME S. Guest 17 Oct. 72

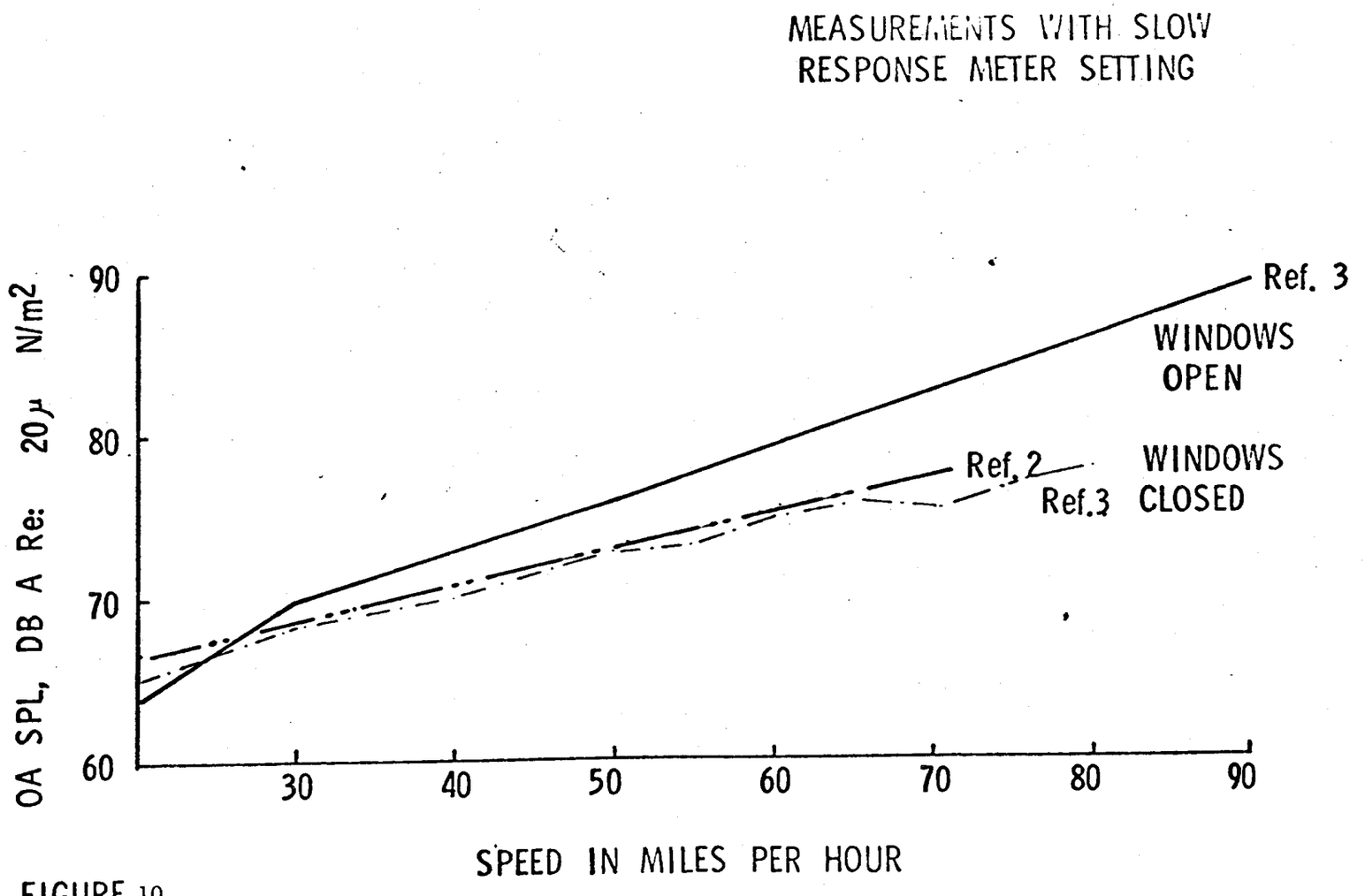


FIGURE 10

MSFC - Form 3369 (Rev June 1970)

CHART No. _____

MARSHALL SPACE FLIGHT CENTER SCIENCE & ENGINEERING	FARFIELD OA SPL CONTOURS FOR STATIC TEST OF SINGLE SSME AT MTF	LAB: S&E-AERO-AU NAME: R. M. SLONE DATE: 1 NOV, 72

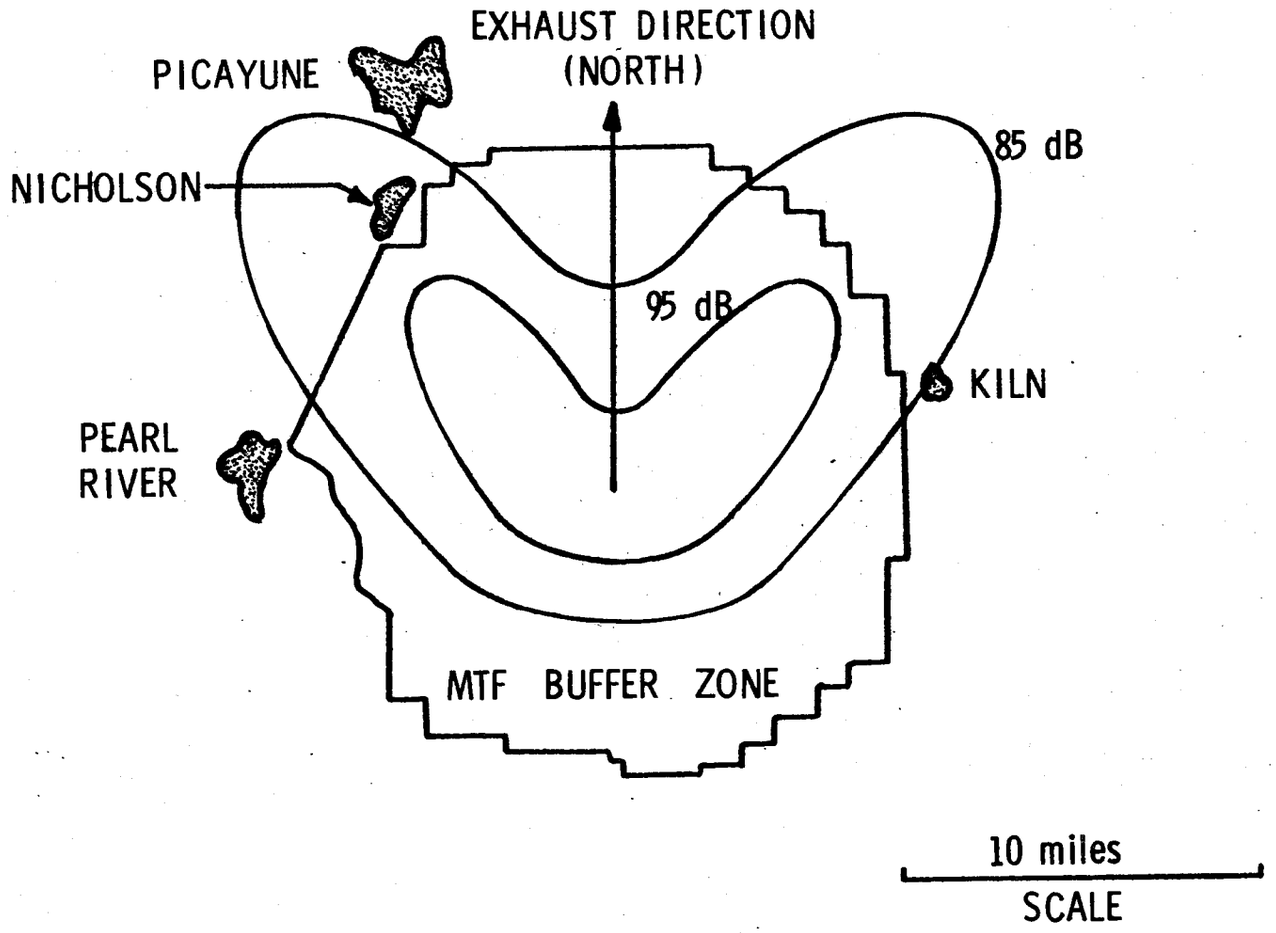


FIGURE (a)

MSFC - Form 3369 (Rev June 1970)

CHART No. _____

NASA—MSFC

MARSHALL SPACE FLIGHT CENTER SCIENCE & ENGINEERING	FARFIELD OA SPL CONTOURS FOR SSME STATIC TEST AT EAFB HAYSTACK BUTTE	LAB: S & E - AERO-AU NAME: S. GUEST DATE: 1 NOV, '72

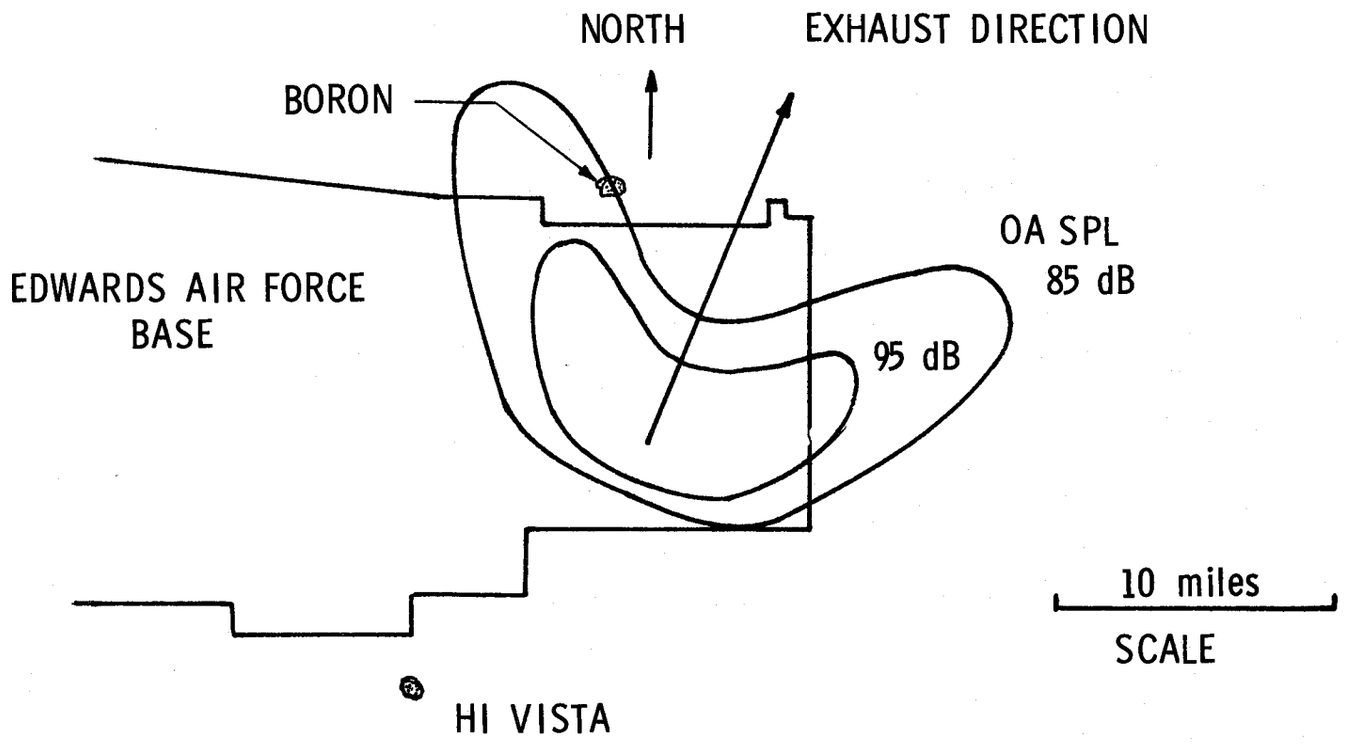


Figure (b)

MSFC - Form 3369 (Rev June 1970)

CHART No. _____

APPENDIX C

RESPONSES TO DRAFT ENVIRONMENTAL STATEMENT

FOR SPACE SHUTTLE PROGRAM

cc. Cohen

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D. C. 20301

17 MAY 1973

HEALTH AND
ENVIRONMENT

Mr. Ralph E. Cushman
Special Programs Coordinator
Office of the Comptroller
National Aeronautics and Space
Administration
Washington, D.C. 20546

Dear Mr. Cushman:

The Department of Defense has no comments on the Draft Environmental Impact Statement - Space Shuttle Main Engine Component and Subsystem Testing, Santa Susana, California.

Sincerely,

SIGNED

George W. Milias
Director for
Environmental Quality

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
AREA OFFICE
2500 WILSHIRE BOULEVARD, LOS ANGELES, CALIFORNIA 90057

AREA OFFICES:
Los Angeles, California
San Francisco, California

REGIONAL IX
REGIONAL OFFICE
SAN FRANCISCO, CALIFORNIA

JUN 1 1973

IN REPLY REFER TO:
9.2PP

Mr. Ralph E. Cushman
Special Programs Coordinator
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Mr. Cushman:

Subject: Draft EIS for the Space Shuttle Main Engine Component and Subsystem Testing: Santa Susana, California

The National Aeronautics and Space Administration (NASA) proposes to use the Santa Susana Field Laboratory as a testing facility for the main engine and subsystem components used in the Space Shuttle Program. The laboratory is located in Ventura County.

The primary environmental concern of this proposal is the potential for excessive noise exposure to residential areas and persons in autos in the surrounding area. The nearest residences to the testing facility are approximately 1-3/4 miles away in Santa Susana. The City of Los Angeles boundary line is about three miles away.

Apparently, the studies conclude that noise exposure to people in the general vicinity will not be excessive.

Upon completion of our review, we could not be certain of that conclusion. The subject environmental statement is couched in technical jargon which is difficult to understand. We feel that the Final EIS should be written in a manner which is more easily understood. The more technical presentations can be used as appendices. The Final Statement can also be improved with the addition of a better site map together with the projected noise-level contours.

One potential problem area which has not been investigated is the effect of the noise generated on wildlife in the vicinity. It is our opinion that an analysis particular to this matter should be made.

We hope our comments will be of value to you. We would appreciate receiving a copy of your Final Statement.

Sincerely,

Area Director

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER-73/530

JUN 6 1973

Dear Mr. Cushman:

Thank you for providing us with the opportunity to comment on the Draft Environmental Impact Statement for the Shuttle Main Engine Component and Subsystem Testing Facility at Santa Susana, California.

1. We agree that the noise generated by the space shuttle main engine probably represents the principal environmental concern but feel that it should not be represented as "the one concern" (paragraph 3 of Summary).

The section on acoustics covering this area relies substantially on non-quantitative terminology that makes evaluation of this environmental impact difficult. For example, the first paragraph on page 8 states that "estimated noise levels are well below those produced on other programs which were considered compatible with adjacent communities". This statement is essentially meaningless.

The last paragraph on the same page states "...there should be no environmental impact on the existing community areas surrounding the test site". There will be some if the noise is heard. The question is how much?

On page 8 (third paragraph) the statement is made that "the rocket induced overall sound pressure level environment in many community areas will be no greater than the overall sound pressure levels resulting from every day sources such as traffic noise, plane overflights, trains, etc. This statement raises a number of points that should be explained.

a. How many is "many" communities. How many people do these communities represent?

b. Is the comparison between the motor and planes and trains based on sound levels adjacent to the noise generator? What type of aircraft is the rocket engine being compared with?

c. Does the statement say that the noise of the rocket motor is equivalent to that of a jet aircraft passing overhead or a nearby passing train? If so, the duration of the noise becomes an important issue. This is not discussed.

2. The question of anticipated waste water discharges, their nature and pollution potential has not been adequately treated.

On page 5, there is reference to the testing of collected water for contamination. Since fresh water is being used, some elaboration as to the contaminant source is desirable. The tables on pages 5 and 6 are not tables of contaminants. They are water quality discharge standards. Nowhere are the actual contaminants and their respective levels shown.

The amount of excess water released from the reservoirs to the Los Angeles River and the timing of these releases should be indicated. The dilution rate at minimum river flow should also be shown.

The draft statement also describes the disposal of waste water into the San Fernando and Simi Valleys. We note that occasional releases of waste water may contain 100 ppm suspended solids at a pH between 5.5 and 11. Both of these exceed the interim effluent standards for the mining and milling industry which are 30 ppm suspended solids and pH between 6.0 and 8.5. We believe that the installation of simple water treatment facilities could bring the NASA effluent up to mining industry stardards. The statement lacks a discussion of the treatment of sanitary wastes.

Although the statement suggests that the proposed action poses a minimal threat to cultural (historic, archeological, architectural) resources, it appears that certain Federal obligations to protect such resources have been overlooked. Reference is made in the statement to one known nearby archeological site, the Indian Caves. However, correspondence from Nelson Leonard, Chief Archeologist, Archeological Survey, UCLA, indicates that there are ten additional sites within one quarter mile of the site discussed. Leonard also states that given the topography and the known site density of this particular area, numerous unrecorded archeological resources probably exist in the project area. We would point out that Section 2(a) of Executive Order 11593 directs all Federal agencies to nominate to the National Register of Historic Places all properties under their control or jurisdiction that appear to meet the criteria for registration. The Indian Caves site (and all others at the facility) should be professionally evaluated at the earliest opportunity and nominated to the National Register if they appear to meet the criteria.

The assertion that engine testing in the past has not affected the integrity of the Indian Caves site -- and that future testing will not so affect it -- is not based upon the judgments of trained archeologists. From the evidence presented, the opposite conclusion might be drawn -- that is, periodic engine testing at high noise levels may have already resulted in compaction or other disturbance that could affect the scientific potential of the Indian Caves and any other nearby cultural resources.

We suggest that the services of trained archeologists be engaged to evaluate the significance and integrity of the Indian Caves and other potentially threatened sites, and to determine the extent to which they may be subject to adverse impact from engine testing.

Sincerely yours,

Assistant Secretary of the Interior

Mr. Ralph E. Cushman
Special Programs Coordinator
Office of the Comptroller
National Aeronautics and Space Administration
Washington, D.C. 20546

NORMAN B. LIVERMORE, JR.
SECRETARY

RONALD REAGAN
GOVERNOR OF
CALIFORNIA

OFFICE OF THE SECRETARY
RESOURCES BUILDING
1416 NINTH STREET
95814

Department of Conservation
Department of Fish and Game
Department of Navigation and
Ocean Development
Department of Parks and Recreation
Department of Water Resources

Air Resources Board
Colorado River Board
San Francisco Bay Conservation and
Development Commission
State Lands Commission
State Reclamation Board
State Water Resources Control Board
Regional Water Quality Control Boards

THE RESOURCES AGENCY OF CALIFORNIA
SACRAMENTO, CALIFORNIA

JUN 15 1973

National Aeronautics and
Space Administration
6633 Canoga Avenue
Canoga Park, CA 91304

Attention: Mr. Mike J. Vukovich

Gentlemen:

The State of California has reviewed the "Draft Environmental Statement for Space Shuttle Main Engine Component and Subsystem Testing, Santa Susana, California", dated January 2, 1973, A & PS-SF-W, which was submitted to the Office of Intergovernmental Management (State Clearinghouse) within the Governor's Office. The review accomplished by the State fulfills the requirements under Part II of the U. S. Office of Management and Budget, Circular A-95, and the National Environmental Policy Act of 1969.

The Statement was reviewed by the State Departments of Justice, Commerce, Food and Agriculture, Public Works (Division of Highways), Public Health, Conservation, Fish and Game, Navigation and Ocean Development, Housing and Community Development, Parks and Recreation, Water Resources; the Public Utilities Commission; the State Lands Division of the State Lands Commission; the State Water Resources Control Board and the Air Resources Board.

The State's comment is as follows:

Since reclaimed waste water from onsite storage reservoirs is occasionally discharged to Bell Creek, a tributary to Los Angeles River in San Fernando

Valley, Los Angeles County, this surface discharge will require a National Pollutant Discharge Elimination System's permit in accordance with established procedures.

Thank you for the opportunity to review and comment on this Statement.

Sincerely yours,

N. B. LIVERMORE, JR.
Secretary for Resources

By Paul L. Clifton

DEP-M Action A+PS-SF / COL WESSELS ✓
Info ~~Mr. Cook~~, MR. NEWBY, Mr. Foster A+PS, A+PS-FAC
AD-M ACTION LOG JUNE

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS
REGIONAL COOPERATION FOR REGIONAL PROBLEMS
1111 WEST SIXTH STREET • SUITE 400 • LOS ANGELES • CALIFORNIA • 90017 • 213/481-0095

May 29, 1973

Mr. R. W. Cook
National Aeronautics and
Space Administration
Marshall Space Flight Center
Alabama 35812

Direct Federal Development
Environmental Impact Report
Space Shuttle Main Engine
Testing at Santa Susana, Ca.
SCAG File Number: 3455-DF-73

Dear Mr. Cook:

In accordance with OMB Circular A-95 and the National Environmental Policy Act, the above referenced draft report was submitted to SCAG for review. Notification of the proposed project was distributed to all cities, counties and environmental control agencies in the region. We received the attached comments from the City of Los Angeles in response to this general circulation.

The project was also submitted to a staff review team which found that:

1. The draft EIR does not address the potential adverse effect on flora and fauna. This should be considered in the final Environmental Impact Report.

2. All stages of project development should be closely coordinated with the City of Los Angeles Department of Environmental Quality.

We hope these comments are useful and we would appreciate receiving two copies of the final Environmental Impact Report.

Sincerely,

Ray Remy
Executive Director

RR:KH:bl

ACTION COPY _____ DATE _____
INFO Copy(ies) to Rochester, Mr. Lehman
cc: Mr Godfrey
cc Col Wessels SP-5F

CITY OF LOS ANGELES
CALIFORNIA

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DEPARTMENT OF
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ROOM 550, CITY HALL EAST
LOS ANGELES, CALIF. 90012
485-4242

JACK GREEN
GENERAL MANAGER

PLEASE REFER TO
FILE NO.

May 16, 1973

MAY 17 1973

SOUTHERN CALIFORNIA ASS'N.
OF GOVERNMENTS

Mr. Victor Magistrale
City Planner
Southern California Association of Governments
1111 West Sixth Street
Suite 400
Los Angeles, California 90017

Dear Mr. Magistrale:

SUBJECT: DRAFT EIR FOR SPACE SHUTTLE MAIN ENGINE TESTING AT SANTA SUSANA, CALIFORNIA

At your request, Mr. Optican has reviewed the subject NASA EIR (as related to noise) and has made the following comments:

The subject EIR is the only EIR (related to noise) we have seen to date that presents adequate quantitative predictions of the magnitude of noise to be expected as a result of the project. The analysis gives a predicted value of an overall sound pressure level of 70.8 dBA for the closest residential area. This A-weighted value was calculated for a predicted 94 dB spectrum peaking at 16 Hz. An overall sound pressure level of 70.8 dBA is roughly equivalent to the noise made by a vacumn cleaner at 10 feet, a freight train at 100 feet, or freeway traffic at 50 feet. Since the duration of this noise level will be experienced by persons in the nearest residential area for periods of about 5½ minutes per period (for a total number of 414 periods spread out over a 3 year test schedule) it would appear that there will be some citizen complaints for both day and night tests unless "total control" is practiced, i.e., mateorological control and reduction of power watt levels with high ratio (water to fuel) deflector water flow rates. There seems to be a conflict in the analysis about these water flow rates. One sentence states the flow rate specified by the engine test contractor for a 50% reduction (in power watts) is 2.8:1 while another sentence states that for large rocket engines the deflector water flow rate was found to have little effect for rates less than 6:1.

A 50% reduction in sound power energy is equal to a 3 dBA reduction in sound pressure level. If you add to this a 5 dBA SPL reduction under favorable meteorological conditions you can expect the 70.8 dBA in the nearest residential area to be reduced to about 63 dBA. The presumed ambient noise level (minimum or threshold ambient noise level) for purposes of enforcing the Los Angeles City Noise Regulation Ordinance at the boundary of residential zones is 55 dBA daytime and 45 dBA night time. These minimum ambients may be legally exceeded by 5 dBA. On the basis of this analysis, the test firings could be in violation both day and night. However, if the actual residential ambient is higher than the minimum (presumed) threshold and/or meteorological conditions are such that more than 5 dBA reduction from this factor is obtainable, the noise impact on the residential zones may fall within the limit of the ordinance at least during day time firings. Of course, the NASA analysis was conservative in that it ignored barrier effects that might result from the topography surrounding the Santa Susana firing area. The topography might produce some SPL reduction. On the other hand, reflections due to topography plus possible downward diffraction caused by atmospheric layers could make the situation worse. My opinion is that we have a borderline case ordinance-wise but balanced by an excellent complaint history at Santa Susana when "total control" has been applied to other engine test firings.

We would appreciate being allowed to retain the copy of NASA's study for our files.

Sincerely,

Jack Green

JACK GREEN
General Manager

JG:AWO:jcc