MEMORANDUM

(NASA-TM-X-72777) NEAR NOISE FIELD
CHARACTERISTICS OF NIKE ROCKET MOTORS FOR
APPLICATION TO SPACE VEHICLE PAYLOAD
ACOUSTIC QUALIFICATION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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NEAR NOISE FIELD CHARACTERISTICS OF NIKE ROCKET MOTORS FOR APPLICATION TO SPACE VEHICLE PAYLOAD ACOUSTIC QUALIFICATION

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INTRODUCTION

The Space Shuttle launch vehicle/shuttle orbiter combination has been designed to provide low cost transportation to and from earth's orbit. During the launch and ascent flight phases, the vehicle and the payload it carries can be subjected to high level acoustic energy produced by the first stage rocket motors. Concern has been expressed as to the effects of this noise on the payloads being carried in the Orbiter cargo bay. Estimates have been made of the internal acoustic environment of the cargo bay which indicate relatively high levels during lift-off (ref. 1), thus, it may be desirable that certain vehicle and payload components be environmentally qualified utilizing a noise source which would produce a sound field with characteristics similar to the noise environment that had been estimated for the cargo bay.

In the past, several types of sources have been utilized for high level acoustic testing, the exhaust of jet engines, the exhaust of blow down wind tunnels, and others (refs. 2-7). The Nike solid propellant rocket motor
was suggested as a source whose noise field may be suitable to reproduce the interior noise environment that had been predicted for the Shuttle Orbiter cargo bay during lift-off. The Nike motor, developed in the 1950's as the booster stage for an antiaircraft missile, is still readily available in reasonable quantity. These motors are easy to handle, are relatively low in cost, and seem to offer the possibility of an acceptable noise source for the proof testing of Shuttle payloads.

The purpose of this paper is to present the results of a series of noise measurements that were made under controlled conditions during the static firing of two Nike solid propellant rocket motors. The objective of the measurements was to assess the usefulness of these motors as sources for general spacecraft noise testing, but in particular to reproduce the noise expected in the cargo bay of the Orbiter.

Presented in the paper are brief descriptions of the Nike motor, the general procedures utilized for the noise tests, and representative noise data including overall sound pressure levels, one-third octave band spectra, and octave band spectra. Data are presented on two motors of different ages in order to show the similarity between noise measurements made on motors having different loading dates. The measured noise from these tests is then compared to that estimated for the Space Shuttle Orbiter cargo bay.

SPACE SHUTTLE VEHICLE

The Space Shuttle flight system is composed of the Orbiter, an external tank (ET) that contains the ascent propellant to be used by the Orbiter main
engines, and two solid rocket boosters (SRB's). The Orbiter and SRB's are reusable; the external tank is expended on each launch. A sketch of the complete vehicle is shown in figure 1.

The Orbiter spacecraft contains the crew and payload for the Space Shuttle system. The Orbiter can deliver to orbit payloads of 29,500 kilograms (65,000 pounds) with lengths to 18 meters (60 ft.) and diameters of 5 meters (15 ft.). The Orbiter is comparable in size and weight to modern transport aircraft; it has a dry weight of approximately 68,000 kilograms (150,000 lbs.), a length of 37 meters (122 ft.), and a wingspan of 24 meters (78 ft.). During the launch, the three Orbiter main propulsion engines are used along with the two solid rocket boosters, producing a total thrust at lift-off of approximately $30 \times 10^6$ newtons ($6.7 \times 10^6$ pounds).

A number of estimates have been made of the Orbiter cargo bay noise environment during lift-off; the crosshatched area of figure 2 encompasses the limits of all of these estimates (ref. 1). The predicted octave band levels vary somewhat due to the use of different assumptions (concerning the characteristics of the acoustic field within the cargo bay) and a band encompassing all the estimates is shown in the figure. The generalized spectra tend to reach maximum levels in excess of 145 dB in the frequency range of 100-300 Hz. The objective of the tests as described in the document was to determine if the noise field generated during the static firing of a Nike solid rocket motor was representative of the estimated internal noise environment for the Space Shuttle Orbiter cargo bay.
Apparatus and Methods

**Nike Rocket Motor.** - The Nike rocket motor was developed in the early 1950's as a first stage for several types of antiaircraft missile systems. One of these, the Nike-Ajax, is shown in the left hand photograph of figure 3. The Nike solid fueled motor was found to be very stable, easy to handle, and highly reliable. These characteristics allowed for its wide use as a booster for scientific payloads in addition to the military mission. One example of this, a Nike-Iraquouis, is shown in the right hand photograph of figure 3.

The Nike M-88 (NASA M5-E1 Booster) is a solid propellant rocket motor. The casing weighs approximately 208 kilograms (460 pounds), and the propellant grain weighs approximately 342 kilograms (755 pounds) for a total Nike motor loaded weight of 550 kilograms (1,215 pounds). The motor is approximately 3.6 meters (12 feet) in length and has a maximum outside case diameter of approximately 42 centimeters (16-1/2 inches). The maximum thrust developed by the Nike motor is approximately 204,608 newtons (46,000 pounds), and the burn time is on the order of 3 seconds.

**Test Area.** - Wallops Flight Center, on the Eastern Shore of Virginia, is approximately 145 km (90 miles) north of the Langley Research Center. The administrative offices, technical service support shops, etc., are located at the Main Base on the mainland. Wallops Island, off the coast of Virginia, is approximately 11 km (7 miles) southeast of the Main Base separated from the mainland by a causeway and bridge. The island is approximately 10 km (6 miles) long and about 0.8 km (1/2 mile) in width at its widest point. Launch sites were established on Wallops Island in 1945 by the Langley Research Center.
Shown in the photograph of figure 4 is an aerial view of Wallops Island looking north. The general area of the pad and blockhouse area chosen for the static firing of the Nike motors for the subject tests is indicated by the arrow. A more detailed pictorial of the blockhouse and pad arrangement is shown in figure 5.

Test Arrangement.- The test motors were mounted on the pad vertically with the exhaust nozzle up as shown in the photograph of figure 6. The thrust was transmitted to the concrete pad through a spider-ring assembly, and three guy wire assemblies were utilized to stabilize the motor.

Acoustic Measurements.- In order to determine the characteristics of the near acoustic field of the Nike motors, a microphone array was deployed as indicated in figure 7. As shown in the figure, a total of 16 measurement locations were utilized; 2 microphones were placed in the horizontal plane of the exit nozzle and the other 14 microphones were placed on 1.2 meter stands at distances as indicated. The total acoustic measurement and recording system used for the Nike tests are the standard systems utilized by the Langley Research Center for aircraft noise flyover measurements. This system has a usable frequency range of from approximately 6 Hz to 20 kHz and a maximum acoustic level capability of approximately 160 dB and has been utilized in aircraft certification type testing (ref. 8). A general instrumentation block diagram for the measurement and recording system is shown in figure 8. All signal conditioning, recording, and playback equipment was located in blockhouse number 3 during the tests (see fig. 5).
During the firings "quick look" data analysis was provided for by the use of a narrow band analyzer equipped with a CRT display and hard copier. The "after test" analysis was performed by utilizing a standard General Radio type one-third octave band analyzer with the general specifications as shown required by reference 9.

The firings were made on 2 consecutive days. For Nike 1 the ambient temperature was 1.1°C (93°F), the relative humidity was 83 percent, and the winds were calm. For Nike 2, the ambient temperature was 2.8°C (98°F), the relative humidity was 79 percent, and the winds were 7-8 knots from the south.

RESULTS AND DISCUSSION

Measured Noise Data.- Time histories of the rms value of the overall sound pressure level as measured at microphone 1 for the firing of Nike 1 and Nike 2 are shown in figure 9. One can observe the buildup and decay of the overall noise level over the burn time of the motor and can observe the variations in overall sound pressure level as a function of time. These variations in level were apparent to observers standing outside of the blockhouse during the firing and were described as having a crackling, tearing, characteristic. It can be seen, however, that the overall noise levels for both motors measured at microphone position 1 are approximately the same magnitude, and the burning time of both motors was approximately the same.

In order to determine if there were any distinct tones in the noise spectrum of the two motors, narrow band analyses techniques were utilized.
An example of this type of analysis is shown in figure 10. Represented on the figure is the narrow band (10 Hz bandwidth) spectral characteristics of the noise as measured at microphone 1 for the firing of Nike 1. It can be seen that the only distinct peak occurs at approximately 100 Hz and is thought to be associated with a cavity resonance of the motor. Above that frequency, the noise seems to be somewhat broadband in nature and decreases in level with an increase in frequency.

In order to compare the noise data from the rocket motor firing with the estimates for the Shuttle cargo bay compartment, a one-third octave band analysis was performed on the data from each microphone position for each firing. A complete listing of these data are contained in Table I. Plotted in figure 11 for comparison are the one-third octave data from microphone 1 for both firings. The spectra peak generally in the 160 Hz frequency range and are very similar in shape for the two firings. Inspection of the third octave band listings as shown in Table I indicate that the noise data taken at the same microphone position for both rocket motors are generally comparable even though one motor was loaded in 1955 and the second loaded in the early 1970's. This is some indication of the stability of the particular propellant grain utilized for the Nike motor. Due to the short burn time of the Nike motor some care must be exercised when interpreting the one-third octave band data below 125 Hz. The total burning time on the Nike motor is on the order of 2-1/2 to 3 seconds; at the lower frequencies, the analysis
sample time is too short to give results having reasonable confidence limits. At such frequencies, the levels as indicated in the tables could vary ± several dB. In interpreting the data of Table II, it should also be noted that all acoustic measurements were taken either in or below the plane of the exhaust nozzle. Higher noise levels would be obtained by making measurements along a line approximately 45° to centerline of the exhaust nozzle.

Comparison of Measured With Predicted Levels

In order to determine if the noise field of the Nike rocket motor is suitable for Space Shuttle payload qualification testing, a comparison was made between the measured Nike noise levels and the estimates of reference 1 for the Shuttle Orbiter cargo bay. As the data of reference 1 are shown in octave form, the one-third octave band data for the Nike firings as listed in Table I were corrected to octave band data and the results are listed in Table II.

The boundary lines encompassing the range of estimated noise levels for the Shuttle cargo bay area (from fig. 2) are shown for comparative purposes in figure 12. The range of octave band levels as measured at microphone positions 1, 2, 3, and 5 for the firing of the two Nike motors is indicated by the crosshatched area. These particular measured data are shown as they seem to offer the best "fit" when compared to the range of estimated levels. The levels are in good agreement for the octave bands having center frequencies from 31.5 to 500 Hz. Depending on which estimation technique is used for comparison, the measured levels at frequencies below 125 Hz may be
somewhat low, and the measured levels above 1000 Hz frequency tend to be higher than those estimated. However, the data of this figure indicates that the Nike rocket motor may be an acceptable noise source for some qualification testing of Shuttle payloads and perhaps other types of general noise testing. The data of Tables I and II indicate that the spectral shape and level of the noise is fairly constant over the distances for which measurements were made. This would lead one to conclude that a relatively uniform sound field exists for the testing of large objects.

CONCLUDING REMARKS

Noise measurements under controlled conditions have been accomplished during the firing of two Nike rocket motors. These measurements indicate that the Nike rocket motor could be a suitable noise source for the qualification testing of Space Shuttle or other payloads and structures. In addition, the measurements indicate that Nike rocket motors loaded at different times exhibit very similar acoustic characteristics. The level and spectral content of the noise field of these motors may also make them applicable to other acoustic proof testing purposes and the uniformity of the sound field out to distances of approximately 41 meters (135 feet) would allow the noise testing of relatively large objects.
REFERENCES


| NIKE | Mic | OA | 6  | 8  | 10 | 12 | 16 | 20 | 25 | 32 | 40 | 50 | 63 | 80 | 100 | 125 | 160 | 200 | 250 | 320 | 400 | 500 | 630 | 800 | 1K | 1.25K | 1.6K | 2K | 2.5K | 3K | 4K |
|------|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1    | 1   | 150| 120| 118| 117| 122| 125| 123| 121| 126| 126| 127| 129| 129| 124| 133| 141| 143| 140| 186| 160| 136| 135| 135| 134| 133| 133| 132|
| 2    | 1   | 150| 114| 114| 118| 121| 125| 126| 130| 130| 130| 130| 130| 130| 128| 134| 141| 143| 139| 137| 139| 137| 136| 136| 136| 135| 134| 133|
| 3    | 1   | 149| 118| 115| 116| 119| 122| 121| 121| 125| 126| 127| 129| 128| 125| 132| 140| 143| 138| 136| 140| 137| 137| 134| 135| 134| 133| 132|
| 4    | 1   | 150| 122| 120| 122| 125| 127| 125| 126| 130| 129| 129| 127| 125| 135| 140| 144| 141| 136| 143| 136| 136| 136| 136| 136| 136| 136| 135| 133|
| 5    | 1   | 149| 113| 112| 117| 122| 123| 122| 121| 122| 126| 126| 128| 129| 129| 125| 131| 142| 138| 136| 139| 137| 137| 134| 135| 134| 133| 132|
| 6    | 1   | 148| 115| 113| 114| 119| 122| 121| 121| 125| 126| 127| 129| 131| 129| 124| 133| 136| 139| 139| 139| 139| 139| 139| 139| 139| 139| 138| 137|
| 8    | 1   | 145| 113| 113| 114| 119| 120| 120| 120| 124| 124| 126| 129| 131| 129| 127| 132| 137| 137| 137| 137| 137| 137| 137| 137| 137| 137| 137| 137|
| 9    | 1   | 143| 111| 112| 114| 115| 118| 119| 118| 123| 122| 124| 129| 130| 130| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129|
| 10   | 1   | 143| 110| 110| 112| 116| 120| 119| 119| 123| 122| 124| 129| 130| 130| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129| 129|
| 12   | 1   | 141| 109| 113| 111| 114| 118| 116| 116| 120| 121| 124| 124| 124| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121| 121|
| 13   | 1   | 142| 115| 116| 115| 119| 119| 118| 120| 122| 123| 125| 126| 127| 127| 131| 127| 127| 127| 127| 127| 127| 127| 127| 127| 127| 127| 127| 127| 127|
| 14   | 1   | 140| 108| 109| 110| 112| 117| 117| 115| 121| 121| 121| 123| 126| 127| 128| 127| 126| 126| 126| 126| 126| 126| 126| 126| 126| 126| 126| 126| 126|
| 15   | 1   | 151| 122| 120| 120| 123| 124| 127| 129| 130| 129| 128| 128| 128| 127| 128| 128| 128| 128| 128| 128| 128| 128| 128| 128| 128| 128| 128| 128| 128|
| 16   | 1   | 147| 116| 114| 112| 118| 120| 119| 119| 123| 122| 123| 128| 133| 135| 135| 133| 134| 134| 134| 134| 134| 134| 134| 134| 134| 134| 134| 134| 134|

**TABLE I.- ONE-THIRD OCTAVE BAND SOUND PRESSURE LEVELS IN dBA RE 0.0002 DYNES/cm²**
FOR THE STATIC FIRING OF NIKE 1 AND NIKE 2

Third-Octave Band Sound Pressure Level, dBA

Note: Data due to microphone failure is not shown.

- OA: Octave Band
- 6, 8, 10, 12, 16, 20, 25, 32, 40, 50, 63, 80, 100, 125, 160, 200, 250, 320, 400, 500, 630, 800, 1K, 1.25K, 1.6K, 2K, 2.5K, 3K, 4K: Frequency Bands in Hertz

Data validity: All data within this table are considered valid.
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No data due to microphone failure
Figure 1.- Space Shuttle vehicle.
Figure 2. Estimated noise levels in the orbiter cargo bay during lift-off.
NIKE-AJAX (DEFENSE)

NIKE-IROQUOIS (RESEARCH)

Figure 3.- Typical launch vehicles utilizing a Nike booster.
Figure 5.- Nike static firing site - launch pad 3B.
Figure 7. Microphone array as utilized for the Nike static firing noise measurements.

NOTE: MICROPHONES LOCATED AT 3.6 meter INTERVALS ALONG THE MICROPHONE LINE.
Figure 8.- Instrumentation block diagram - Hike static noise measurements.
Figure 9 - Overall noise time histories as measured at microphone position 1 during the static firing of Nike 1 and Nike 2.
Figure 10.- Narrow band analysis (10 Hz bandwidth) of the noise as measured at microphone position 1 during the static firing of Nike 1 and Nike 2.
Figure 11.- One-third octave band analysis of the noise as measured at microphone position 1 during the static firing of Nike 1 and Nike 2.
Figure 12.- Comparison of the estimated noise levels in the orbiter cargo bay with the range of noise levels measured at microphone positions 1, 2, 3, and 5 during the static firing of Nike 1 and Nike 2.
Near Noise Field Characteristics of Nike Rocket Motors for Application to Space Vehicle Payload Acoustic Qualification

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16. Abstract
During the launch and ascent flight phases of large space vehicles such as the Space Shuttle, the vehicle itself and the payload it carries can be subjected to high level acoustic energy produced by the first stage rocket motors. It is highly desirable that certain vehicle and payload components be environmentally qualified before flight and considerable effort has been expended in the search for suitable noise sources that could be used conveniently for the proof testing of space vehicle structures and payloads. It had been suggested that the exhaust noise of a Nike solid propellant rocket motor might be suitable to reproduce the interior noise environment that had been predicted for the Shuttle Orbiter cargo bay during lift-off. The Nike motor is easy to handle, readily available in reasonable quantity, and relatively low in cost. In order to document the noise field of a typical Nike motor during static firing, noise measurements were recently accomplished at the NASA Wallops Flight Center during the firing of two Nike boosters. The boosters were mounted vertically with the exhaust nozzle up and an array of 16 microphones was located around the test stand. Two boosters of different ages were fired in order to determine the degree of correlation between noise measurements made on motors having different loading dates. This paper presents the results of these measurements in octave and 1/3 octave form along with corresponding overall noise level listings. There was very good agreement between the data as measured for the two Nike motors tested although the first motor was loaded in 1955, and the second motor was loaded in the early 1970's. As applied to the specific case of the Space Shuttle; the noise field of the Nike motor provided a reasonable reproduction of the estimated interior noise levels.
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Rocket Noise
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