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# EVALUATION OF SPACE TRANSPORTATION SYSTEM (STS) OV-102 ORBITER PAYLOAD BAY ACOUSTIC ENVIRONMENT

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DECEMBER 1982



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## PREFACE

This report presents the results of an evaluation performed by the Mechanical Engineering Branch (Code 731) on the payload bay internal acoustic data measured on the STS-1 through STS-4 flights. The results are used as a basis for developing the required baseline acoustic environment specification to be used in establishing design and test criteria for STS payloads and are documented as part of the NASA Dynamics Acoustic Thermal Environments (DATE) program activity.

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## 1.0 INTRODUCTION

During the first four launches (STS-1 through STS-4) of the Space Shuttle (OV-102 vehicle), sound pressure levels were measured at various locations inside the payload bay. This report summarizes the analysis and evaluations of the data from these four Shuttle flights for the purpose of developing a baseline acoustic environment criteria for Shuttle payloads.

The data used for the analysis and evaluation presented herein were provided by the NASA "30 Day Reports" (references (a) - (c)) and by additional data reduction performed by NASA/Goddard Space Flight Center (GSFC) on measurements from the STS-4 flight (reference (d)). The general procedure followed in the analysis of these data is as summarized under Sections 4 and 5 of this report.

In addition, the results of the acoustic data analysis and evaluation correspond to a launch vehicle configuration and conditions defined as the following:

- OV-102 vehicle
- Launch from the Kennedy Space Center (KSC)
- No thrust augmentation
- Full complement of thermal radiator panels
- Payload bay vents fully opened at all times
- Payload bay with small payload ($\leq$ 9 feet in diameter)

## 2.0 INSTRUMENATION

### 2.1 Measurement Locations

During the four launches of the Shuttle Orbiter OV-102, sound pressure levels were measured inside the payload bay of the orbiter using various number of microphones. Microphones were mounted on the orbiter structure, on the Development Flight Instrumentation (DFI) package and on the pallet payload (STS-2, 3, and 4). In all launches, the microphones designated V08Y9405A and V08Y9403A were located as close to the orbiter center line as structure permited, at the forward bulkhead and on the aft bulkhead, respectively. One microphone, V08Y9219A, was located on the port fuselage sidewall. Specific information on microphone locations, measurement parameters and data output for each launch are summarized in Appendix A.

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## 2.2 Data Output

In general, data from the microphones were scanned via oscilloscope and oscillograms for overall quality and event identification. The output data were grouped and presented in terms of overall and one-third octave band level time histories, instantaneous level time histories, and one-third octave band spectral plots of specific events of interest. The overall level and one-third octave band level time histories of figures A.1 and A.2, respectively, which correspond to the internal location at the port fuselage sidewall (microphone V08Y9219A) display patterns common to all the microphone data on all the flights. The patterns are characterized by peaks which are associated with the following events:

- o Space Shuttle Main Engine (SSME) rough burn at 20 percent thrust
- o Solid Rocket Booster (SRB) ignition
- o Maximum exhaust deflection effects at lift-off
- o Transonic noise
- o Maximum dynamic pressure

The upper and lower plots of figure A.1 are typical of overall levels representing the bands of 12.5 to 10 KHz for analysis averaging times of 0.1 and 0.5 seconds, respectively. As expected, the averaging time differences affect transient acoustic levels and not the sustained acoustic levels. The plots shown in figure A.2 represent typical one-third octave band level time histories using an averaging time of 0.5 second which was considered optimal for all one-third octave band analysis. For the significant event times of the flight profile defined in table A.1, the maximum one-third octave band levels are summarized in references (a) through (d) for STS-1 through STS-4 respectively.

The Appendix A of this report summarizes only the data used in the evaluation study reported herein. The data corresponds to the lift-off and transonic flight events which represented the two worst-case events on all flights. Note that for transonic flight, the data are tabulated only for the one-third octave bands of 250, 315 and 400 Hz to assess the effect of payload bay venting. The levels in all other frequency bands were less than the lift-off levels.

# 3.0 DATA ASSESSMENT

The acoustic data presented in the "30 day reports" (references (a) through (d)) were generally of acceptable quality in the frequency range of 25 Hz to 1000 Hz. Beyond this, some of the data displayed a poor signal-to-noise (S/N) ratio. It was observed that the S/N ratio is smaller for microphones with an upper frequency limit of 2000 Hz than for microphones with an 8000 Hz upper limit. Consequently, it is believed that the poor S/N ratio at high frequencies is attributed to instrumentation effects. To enhance the quality of the data prior to statistical computations, correction procedures contained in Appendix B and Appendix C were applied to the data when appropriate.

## 4.0 STATISTICAL EVALUATION OF DATA

The development of an acoustic criteria for the payload bay requires a statistical analysis of the flight data. This analysis involves certain numerical manipulations where statistical techniques are involved. As has been in the past, the flight data acquisition configuration from a statistical evaluation point of view is far from being ideal. Statistical treatment of the truly nonstationary acoustic flight data assumes the data to be a piecewise stationary random process. By invoking this assumption over the various time events (e.g., lift-off, transonic, etc.), numerical manipulations of the statistical analysis is simplified while still yielding sufficiently valid results. In addition, the varied concentration of measurement locations in certain regions of the payload bay during each flight presents a spatial biasing problem. To minimize these problems, the following procedure was adopted to develop the payload bay acoustic environment criteria for the OV-102 vehicle:

a. Divide the payload bay longitudinally into four zones of equal length.

b. Compute the pressure energy-average and variance of the sound pressure levels measured in each zone.

c. Estimate the space average and variance for the entire payload bay from the pressure energy-average computed in the four zones.

d. Conduct steps a. through c. for each of the flights.

e. Estimate the mean and variance of the space average over the four flights from the energy-average of the space average levels computed for each flight.

f. Compute the K% probability levels for the flight space average based on a Student "t" distribution.

### 4.1 Zone Definition

The division of the payload bay longitudinally into four zones of equal lengths is shown in figure 1. Table 1 summarizes the microphone locations in the various zones of the payload bay for STS-1 through STS-4 flights.

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### 4.2 Zone Average and Variance of Average

For each STS flight, the mean pressure energy[1] value in the ith zone (i = 1 (Zone A), 2 (Zone B), 3 (Zone C), 4 (Zone D)) is computed by,

$$\overline{P}_i = (1/N_i) \cdot \sum_{j=1}^{N_i} P_{ij} \qquad (1)$$

and the variance[2] of the sampling distribution on the sample mean in each zone is computed by,

$$\sigma_{\overline{i}}^2 = (1/N_i) \cdot \sigma_i^2 \qquad (2)$$

where:

$\sigma_i^2$ = variance of pressure energy values in zone $= (1/(N_i - 1)) \cdot \sum_{j=1}^{N_i} (P_{ij} - \overline{P}_i)^2$

$P_{ij}$ = pressure energy values in zone "i" ($j = 1, 2, \ldots N_i$)

$P$ = $10^{L/10}$

$L$ = SPL in dB

$N_i$ = number of pressure measurements in zone "i"

The problem of calculating $\sigma_i^2$ when only one sample value exists in a zone is treated by applying the following procedure:

a. The average variance of the other zones is used to estimate the variance.

b. When this is not possible, the average variance of the other flights for that zone is used to estimate the variance after at least two zonal variances have been obtained.

### 4.3 Payload Bay Space Average and Variance of Sample Space Average

Based on the pressure energy-average computed in the four zones, the space pressure energy-average for the entire payload bay for any one flight is computed by:

$$\overline{Y}_{STS} = (1/N_z) \cdot \sum_{i=1}^{N_z} \overline{P}_i \qquad (4)$$

---

[1]Pressure energies are normalized to $P_{ref}^2$ where $P_{ref} = 20\ \mu\ N/m^2$.

[2]Variances of mean square pressure ratio ($psi^2/P_{ref}^2$).

The variance of the sampling distribution on the sample space presssure energy-average is:

$$\sigma^2_{\bar{Y}_{STS}} = (1/N_z)\cdot\left(\sigma^2_z + \sum_{i=1}^{N_z} \sigma^2_i\right) \tag{5}$$

where,

$\sigma_z{}^2$ = variance of the zone averages

$$= (1/(N_z-1))\cdot\sum_{i=1}^{N_z} (\bar{P}_i - \bar{Y}_{STS})^2 \tag{6}$$

$N_z$ = total number of zones (4)

The calculation of space average variance using equation (5) presumes that the variances of the sampling distribution of zone averages are statistically independent of the variances of the energy values within the zone. Equation (5) hence, yields a conservative estimate for the space average variance.

## 4.4 Flight Space Average and Total Variance of Average

Based on the payload bay space average for each STS flight, the mean space energy-average over the four flights is computed by:

$$\bar{f}_F = (1/N_F)\cdot\sum_{k=1}^{N_F} \bar{Y}_{STS_k} \tag{7}$$

where $N_F$ = total number of flights (4).

The flight to flight variability is computed by:

$$\sigma^2_{Flt.} = (1/(N_F-1))\cdot\sum_{k=1}^{N_F} (\bar{Y}_{STS_k} - \bar{f}_F)^2 \tag{8}$$

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The total variance (flight to flight plus space average) is therefore given by:

$$\sigma^2_{F/SA} = (1/N_F) \cdot \sum_{k=1}^{N_F} \sigma^2_{\bar{Y}_{STSk}} + \sigma^2_{Flt} \qquad (9)$$

where,

$\sigma^2_{\bar{Y}_{STS}}$ for each flight "k" is given by equation (5) and $\sigma^2_{Flt}$ by equation (8).

4.5 Probability Levels for Flight Space Average

Consider the mean value of $N_F$ number of flights from the payload bay space average energy $\bar{Y}_{STS}$, as given by equation (7). If $\bar{Y}_{STS}$ is normally distributed with a mean value $\mu_{\bar{f}}$ and an unknown variance $S^2_F$ it follows that a probability statement concerning future values of the mean $\bar{f}_F$ may be made as follows:

$$\text{Prob} \left[ \bar{f}_F > ( \sigma_{F/SA} \; t_{n;\alpha} + \mu_{\bar{f}} ) \right] = \alpha \qquad (10)$$

or

$$\text{Prob} \left[ \bar{f}_F \leq ( \sigma_{F/SA} \; t_{n;\alpha} + \mu_{\bar{f}} ) \right] = ( 1 - \alpha ) \qquad (11)$$

where $t_{n;\alpha}$ is the $\alpha$ percentage point of the Student "t" variable with $n = N_F - 1$ degrees of freedom (DOF). A $(1-\alpha)$ confidence interval for the variance $S^2_F$ based upon the sample variance $\sigma^2_{F/SA}$ from a sample of size $N_F$ is:

$$\left[ ( n/\psi^2_{n;\alpha/2} ) \, \sigma^2_{F/SA} \leq S^2_F < ( n/\psi^2_{n;1-\alpha/2} ) \, \sigma^2_{F/SA} \right] \qquad (12)$$

where $n = N_F - 1$

$\psi^2_{n;\alpha/2} = \alpha/2$ percentage of chi-square variable with $n = N_F-1$ degrees of freedom

For an assumed 50 percent confidence level,

$$S^2_F = \sigma^2_{F/SA}$$

It follows that the "K" percent probability level (at the 50 percent confidence level) for the flight-space average acoustic level is:

$$\text{K\% Prob. Level (dB)} = 10 \log \left[ \bar{f}_F + k\, \sigma_{F/SA} \right] \quad (13)$$

where,

$$K = (1-\alpha) \quad (14)$$
$$k = t_{n;\alpha}$$

For $N_F = 4$, n = 3 DOF; examples of parameter pairs "K" and "k" of interest are:

| K | k |
|---|---|
| 84.13 | 1.2 |
| 97.73 | 3.4 |
| 99.87 | 10.0 |

## 5.0 ACOUSTIC CRITERIA DEVELOPMENT

In the development of a baseline payload bay acoustic environment criteria for the OV-102 vehicle, only the worst-case flight events need to be considered. The worst-case flight events based on the "30 day reports" of references (a) through (c) are the lift-off and the transonic flight events. In fact, acoustic levels at lift-off exceeded the levels at transonic flight in all frequency bands except at bands between approximately 250 to 400 Hz. In Appendix A, lift-off flight measurements and limited transonic flight measurements at the 250, 315 and 400 Hz bands are presented.

The statistical analysis procedure described in Section 4 was applied to the lift-off and transonic flight data with the results presented in tables 2 through 7 for the lift-off event and tables 8 through 17 for the transonic flight event. Of particular significance are the percent probability levels of table 7 and figure 2 for lift-off and table 17 for transonic flight.

A comparative evaluation of the variance analysis results indicates that the variance of the transonic flight acoustics at the critical band of 315 Hz is approximately 30 times greater than the largest variance observed at lift-off. This variance is attributed to the large dispersion in acoustic levels from region to region and from flight to flight due to payload bay venting. For this reason, the results of table 17 for transonic flight should not be used in establishing a baseline acoustic criteria for the payload bay.

### 5.1 Alternate Procedure for Transonic Flight Data Analysis

An alternate procedure consists of determining the worst-case zone average levels measured during the transonic flight event of each STS flight. At each one-third octave band center frequency of 250, 315 and 400 Hz the average of the worst-case zone levels during the four flights is then used in the development of the baseline acoustic criteria. The results obtained with this procedure are shown in table 18.

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## 5.2 Recommended Acoustic Criteria

The NASA Goddard Space Flight Center philosophy in establishing acoustic environment design and test criteria for payloads is to define the environment at the 97.73 percent probability level. The acoustic criteria recommended herein is therefore consistent with this philosophy and is subject to the launch vehicle configuration and conditions defined under Section 1.0.

Figure 3 is a plot of the computed 97.73 percent flight space average levels for the lift-off event and the worst-case zone average levels for STS-1, 2, 3 and 4 transonic flight event at 250, 315 and 400 Hz. Smoothing is exercised in order to provide a spectrum that is reasonably independent of band to band variability since the variability will be highly sensitive to physical details of the payload complement within the payload bay. In figure 4, the smoothed curve in the low frequency region (25 Hz $\leq$ f $\leq$ 125 Hz) is constrained to pass through statistically derived data points at 50, 63 and 125 Hz and the average of data points at 25 and 31.5 Hz. In the high frequency range, the curve is smoothed through 115 dB at 2000 Hz.

In order to cover the acoustic environment during transonic flight, the curve is also constrained to pass through the mean of the worst-case zone average levels observed at the 315 Hz band. This mean level is selected to minimize overconservatism in the predicted effects of payload bay venting. Since the 315 Hz transonic level has been identified with fully opened condition of the vents, it should be recognized that modified venting may result in deviation from these levels. At the present time, the NASA has no plans to provide any modification to the vents to alleviate its effect on the acoustic environment. Based on the smoothed envelope of the 97.73 percent probability level occurrence of the maximum levels during lift-off and the mean of the worst-case zone average levels during transonic flight, the recommended space averaged payload bay acoustic criteria applicable for small payloads (i.e., $\leq$ 9 feet in diameter) is as shown in figure 5 and in column 3 of table 19 in terms of the one-third octave band levels. For comparison, the smoothed envelope without the transonic level is shown in column 2.

The duration of the lift-off acoustic environment will not exceed 15 seconds. Duration is defined as the total time over which acoustic levels are within 10 dB of the maximum. The duration of the transonic flight acoustic environment will not exceed 30 seconds. In order to insure that payloads are designed and tested to cover the acoustic environment during transonic flight, the recommended duration for the composite acoustic environment criteria of figure 5 and table 19 is 30 seconds.

In figure 6, the GSFC levels are compared with the current proposed revision to the JSC-ICD levels (reference (e)), the "old" JSC-ICD levels (reference (f)), the current Aerospace Corporation levels for Department of Defense (DOD) payloads (reference (h)), and the GSFC criteria of October 1980 (reference (i)).

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### 5.3 Payload Effects

The effect of payloads remains a complex issue and highly configuration dependent. Although payload effects should be evaluated on a case-by-case basis via the application of the Payload Acoustic Environment for Shuttle (PACES) program reference (g), the following generalizations can be applied. Payloads that are less than 9 feet in diameter generally show insignificant changes from empty payload bay levels. Payloads of size greater than 9 feet in diameter can have the effect of increasing the levels by 2 to 4 dB over the entire frequency band. In order to establish payload unique criteria, the following payload information will be required:

a. Overall dimensions and geometry.

b. Planned location in the cargo bay.

c. Payload surface materials.

## 6.0 CONCLUSIONS

The payload bay acoustic measurements from the STS-1 through STS-4 flights of the OV-102 orbiter vehicle have been evaluated for the primary purpose of developing a baseline acoustic environment criteria for STS payloads.

The evaluation was performed based on data from the two worst-case flight events (i.e., lift-off and transonic flight) using acceptable statistical methods concurred with by others (Bolt Beranek and Newman (BBN), Aerospace, and Rockwell International (RI)). The results of the statistical analysis has provided the required basis for producing baseline payload bay acoustic levels to be used for establishing STS payload design and test criteria consistent with the NASA/GSFC philosophy of a 97.73 percent probability level of occurrence.

As the STS flights carried only payload volumes of less than 10 percent of the total payload bay volume, the payload bay was essentially representative of an empty bay condition, or a bay with a small payload. Hence, the levels provided herein represent the current best prediction of the maximum expected acoustic levels in the payload bay with a small payload ($\leq$ 9 feet in diameter). The effect of larger payloads remains a complex issue and highly configuration dependent. The unique criteria for such payloads should continue to be evaluated on an individual basis via the PACES program.

Based on the results of this study, the following recommendations are made:

a. The smoothed envelope acoustic spectrum with transonic noise shown in figure 4 and table 19 is recommended to be used as the general acoustic environment for flight acceptance of small STS payloads (less than 9 feet in diameter).

b. Adjustment of the empty payload bay acoustic environment to account for effects of large payloads (greater than 9 feet in diameter) should continue to be treated on an individual basis.

c. For design qualification and certification of payloads, 3 dB is to be added to the flight acceptance levels.

d. The herein proposed flight acceptance and qualification levels can be applied to STS payloads which will be launched at the KSC Test Range.

e. If later data results in a change to the acoustic environment, due to either changes in launch vehicle configuration or conditions, the payload bay acoustic environmental levels should be updated accordingly.

f. The current STS flight assignment working manifest indicates a new orbiter vehicle (OV-099) to be flown starting with STS-6 through STS-10. The impact on the payload bay acoustic environment due to structural changes in the OV-099 vehicle mid-fuselage should be evaluated.

REFERENCES


a. W.B. Keegan, et. al., "Payload Bay Acoustic and Vibration Data From STS-1 Flight", DATE Report 002, NASA, June 1981

b. A.F. White, J.A. Garba, et. al., "Payload Bay Acoustic and Vibration Data From STS-2 Flight", DATE Report 003, NASA, January 1982

c. A.F. White, J.A. Garba, et. al., "Payload Bay Acoustic and Vibration Data From STS-3 Flight", DATE Report 004, NASA, June 1982

d. A.F. White, et. al., "Payload Bay Acoustic and Vibration Data From STS-4 Flight", DATE Report 005, NASA, (to be published)

e. JSC-ICD 2-19001, Interface Revision Notice (IRN) JSC-045, subject: Shuttle Orbiter/Carge Standard Interface, Date May 3, 1982

f. JSC 07700 Volumn XIV of September 22, 1978, Attachment 1 (ICD 2-19001) Shuttle Orbiter/Cargo Standard Interfaces, Revision F

g. A.G. Piersol, et. al., "Space Shuttle Payload Acoustics Prediction Study", NASA CR-159956 (5 volumes), NASA Goddard Space Flight Center, Greenbelt, MD, March 1980

h. Aerospace Corporation Document No. SD-YV-0093, "Acoustic Requirements for DOD Shuttle Payloads Launched from KSC", June 9, 1982

i. Memorandum for the Record of October 9, 1980, Mr. On to Code 731 Branch Files, subject: Update to Acoustic Environments for STS Payloads.

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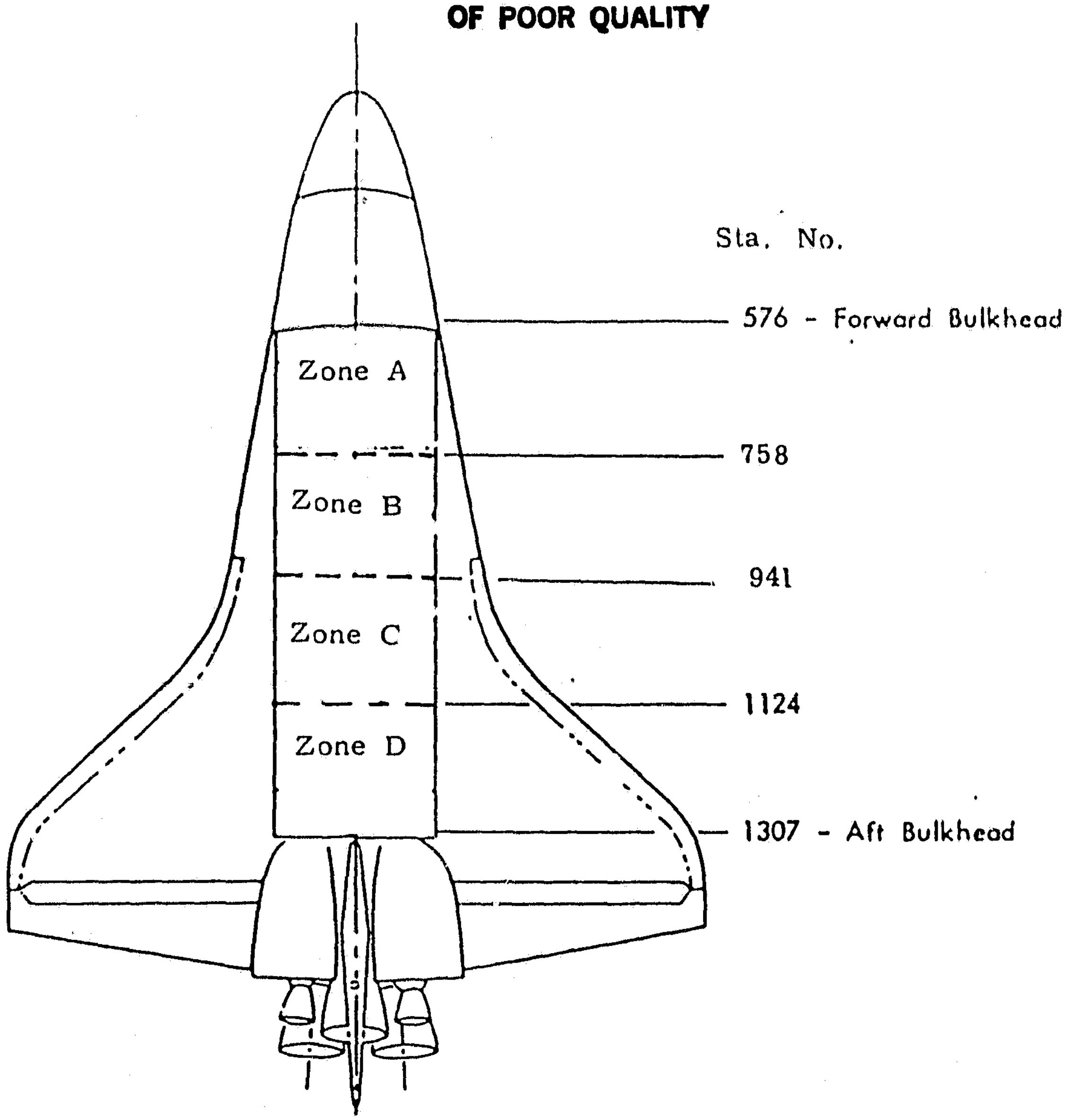


Figure 1 - Subdivision of Payload Bay

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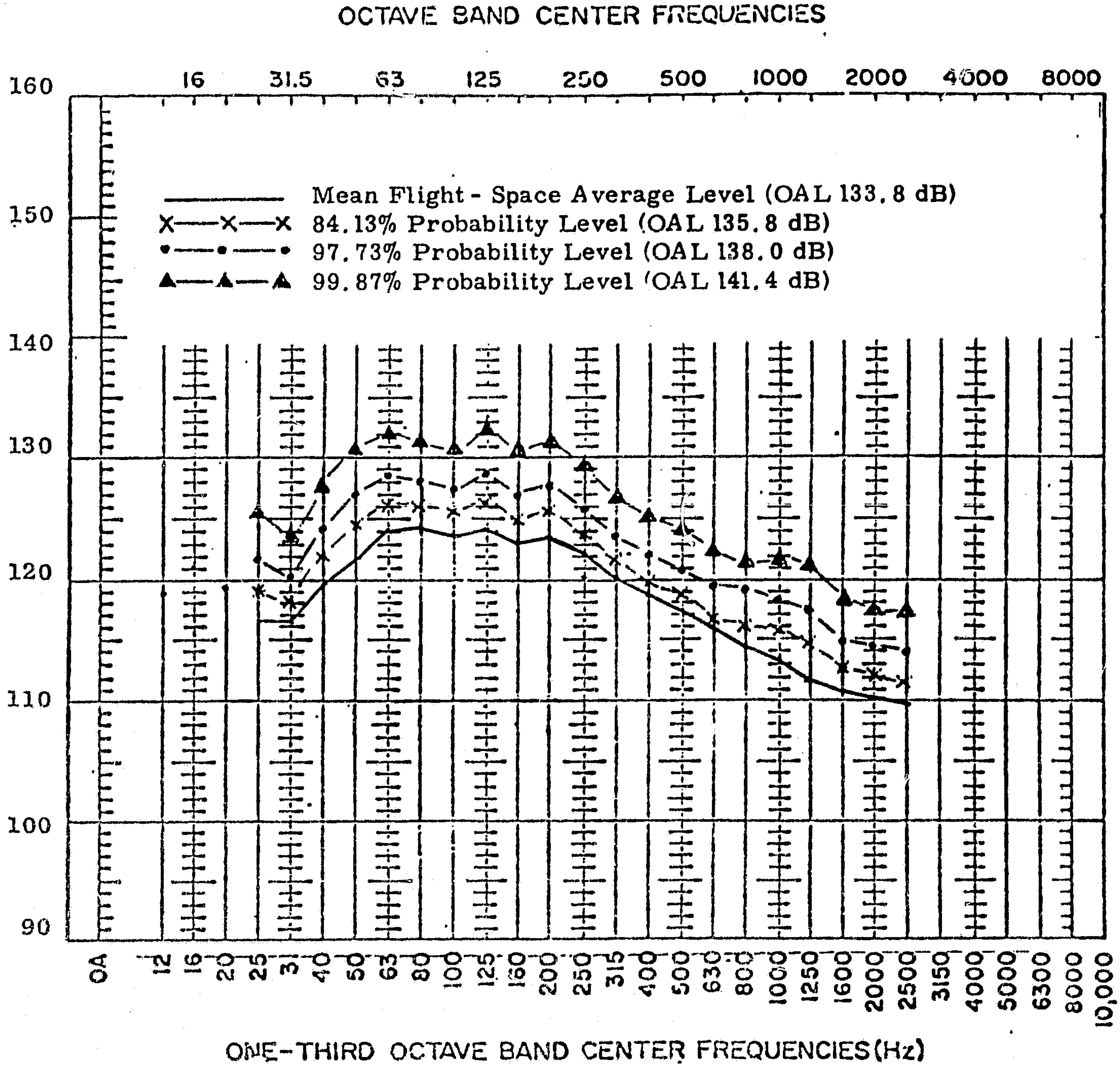


Figure 2 - Percent Probability Flight-Space Average Sound Pressure Levels in Payload Bay Based on STS-1 Through STS-4 Data Lift-Off: T-6 sec to T+12 sec

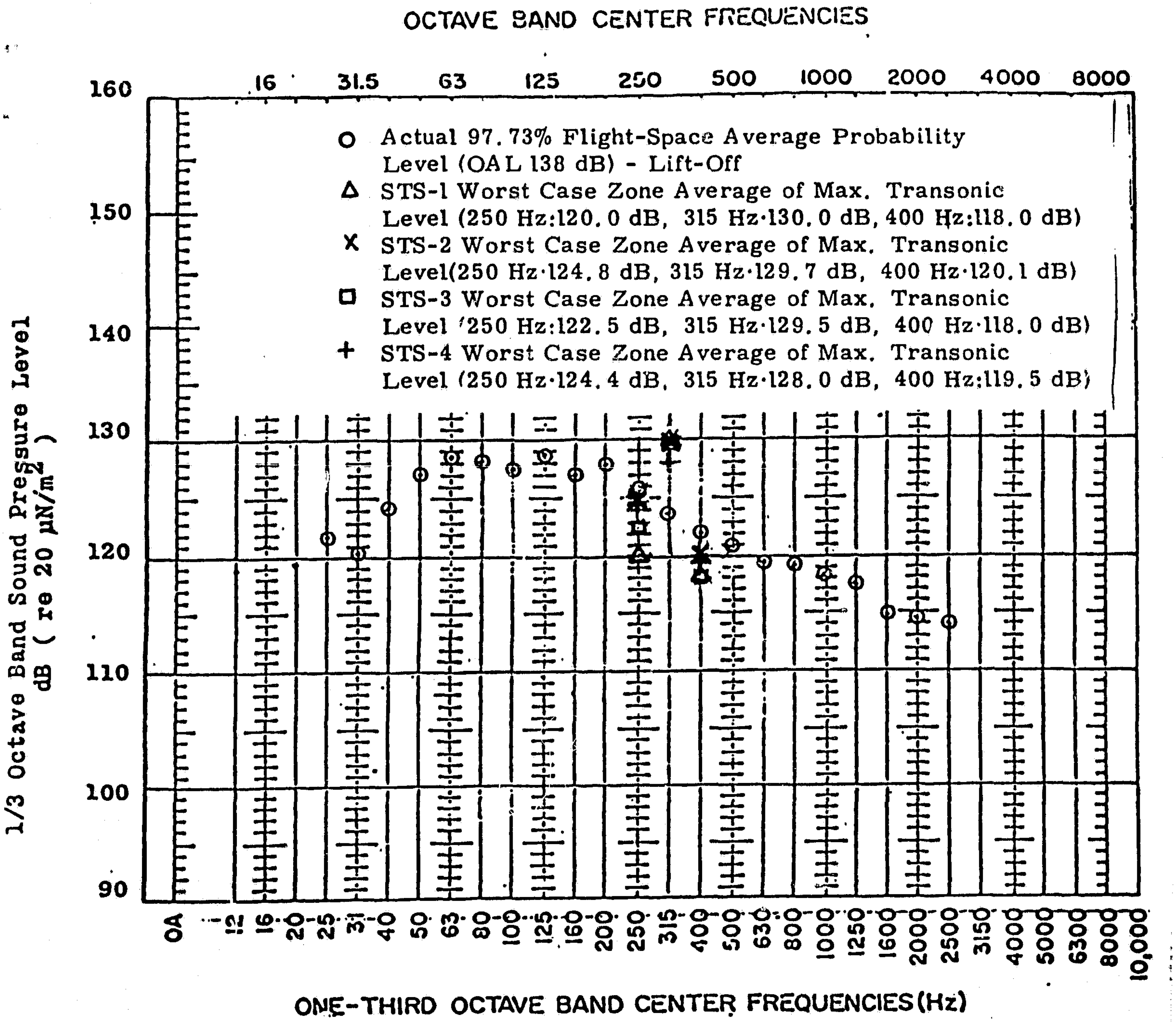


Figure 3- Actual 97.73% Flight-Space Average Levels for Lift-Off and Worst Case Zone Average Levels for STS-1, 2, 3 & 4 Transonic at 250, 315. & 400 Hz.

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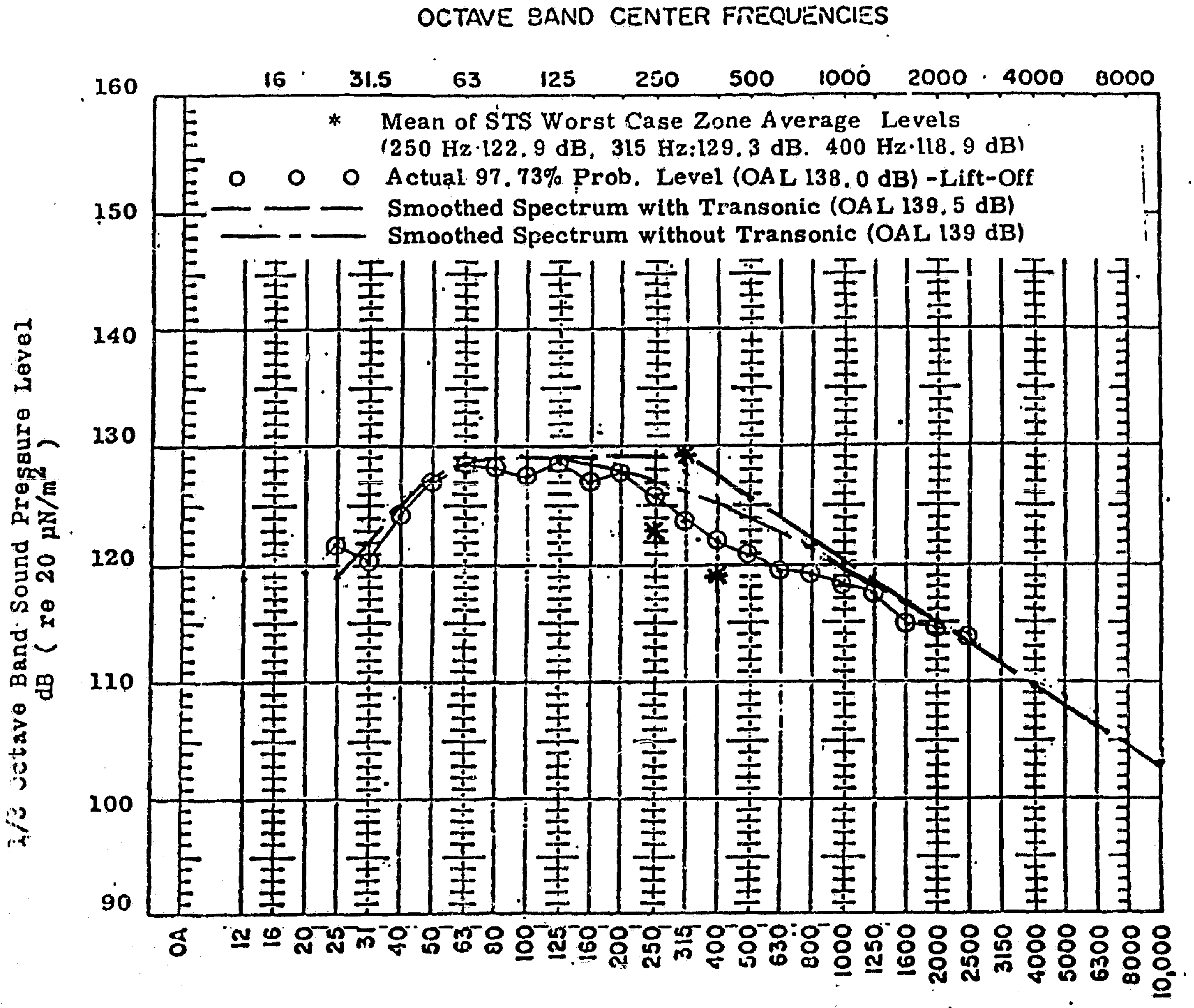


Figure 4 - Smoothed 97.73% Probability With and Without Transonic Noise

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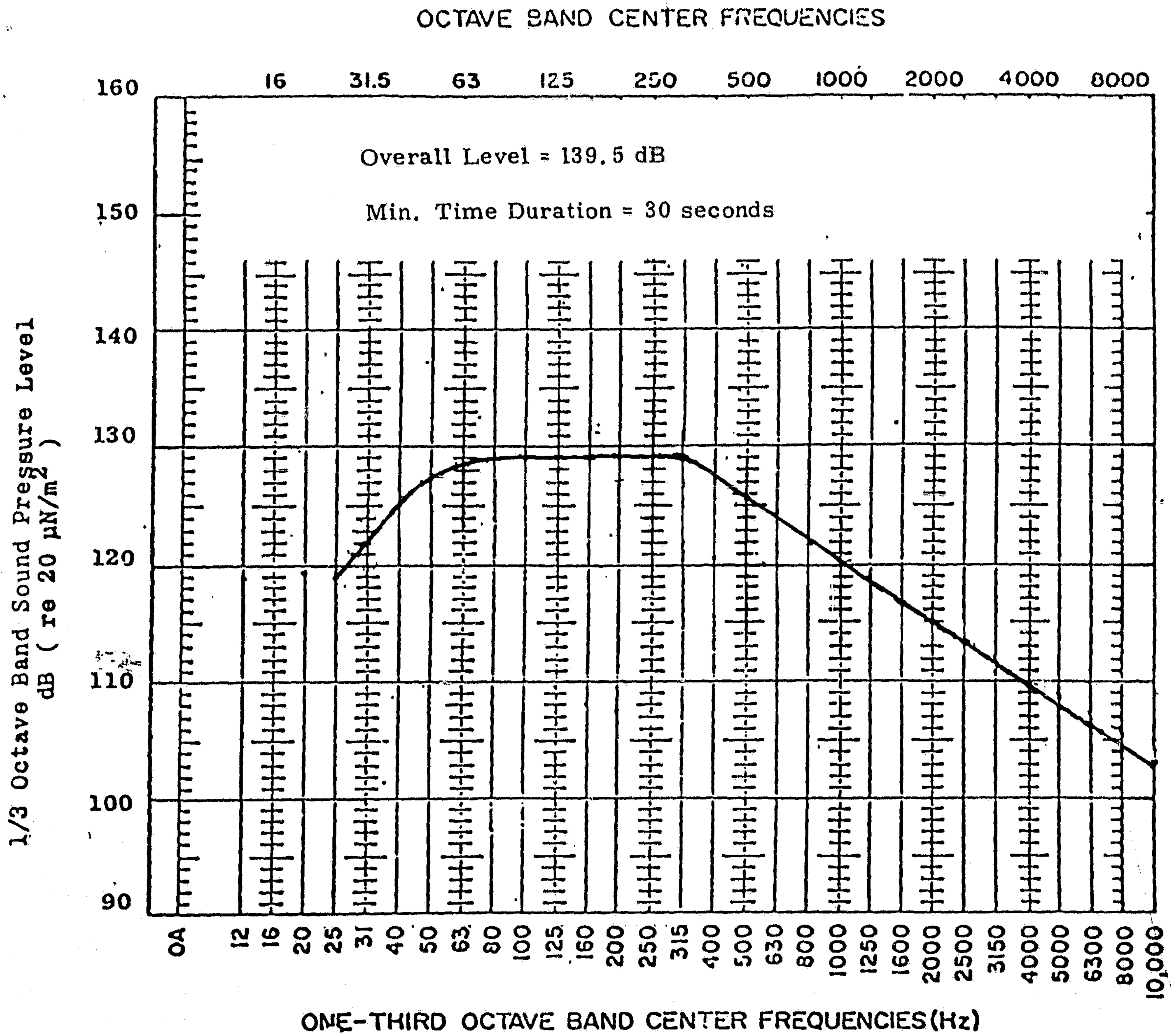


Figure 5 - Recommended Baseline Acoustic Criteria for Small Payloads
( STS Payloads Less Than 9.0 Feet Diameter )

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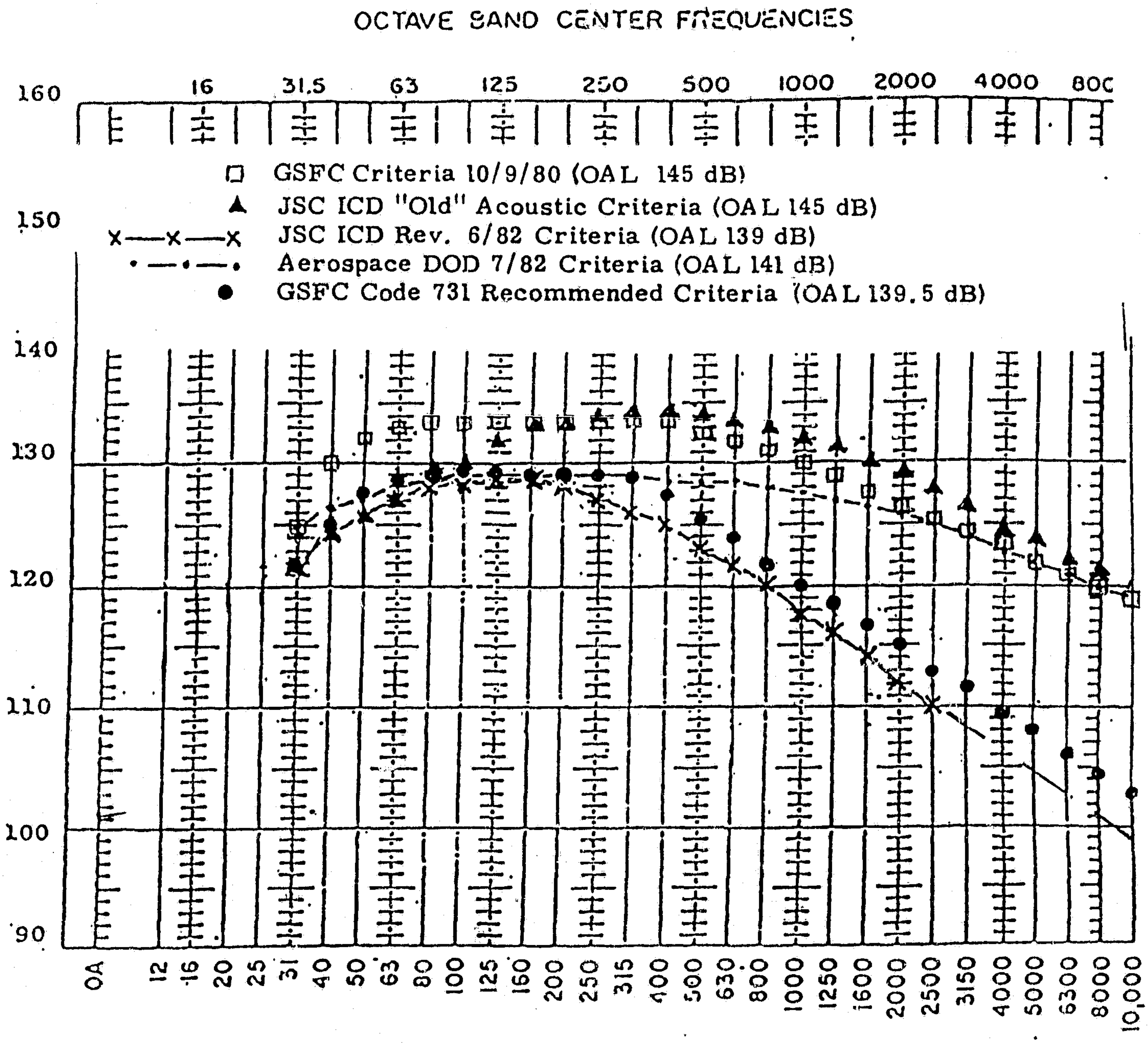


Figure 6 - Comparison of Payload Bay Acoustic Criteria

Table 1 - Microphone Locations in Zones of the Payload Bay

| Zone Identification | Zone Bounds (Sta. Nos.) | Measurement Locations in Zone STS - 1 | STS - 2 | STS - 3 | STS - 4 |
|---|---|---|---|---|---|
| A | 576 - 758 | I1 | I1 | I1 | I1 |
| B | 759 - 941 | I2 | I2, I13, I15 | I2 | I2 |
| C | 942 - 1124 | I4 | I12, I14, I16-I18 | I19, I20, I22 | I23 |
| D | 1125 - 1307 | I3 | I3 - I11 | I3, I4, I5, I7 | I3, I4, I5, I6, I7, I8, I9, I11 |



* I1 - I3 installed at same location on all four flights

I4 installed at same location on STS-2, 3 and 4 but at different location on STS-1.

I5 installed at same location on STS-2 and 4, at different location on STS-3 and not present on STS-1.

I7 installed at same location on STS-2, 3 and 4, but not present on STS-1.

I23 installed on DOD classified payload.

I6, I8-I9, I11 installed at same location on STS-2 and 4 but not present on STS-1 and STS-3.

I10 installed only on STS-2

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Table 2 - STS-1 Flight Data Analysis
Zonal Average Statistics - Lift-Off

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | 117.1 | 0.32 | 109.1 | 0.32 | 111.0 | 0.12 | 116.1 | 0.52 |
| 16 | 120.1 | 0.24 | 116.1 | 0.24 | 120.0 | 0.29 | 114.1 | 0.19 |
| 20 | 117.1 | 0.30 | 114.1 | 0.29 | 114.0 | 0.57 | 112.1 | 0.03 |
| 25 | 116.1 | 4.58 | 114.1 | 4.58 | 115.0 | 8.39 | 111.1 | 0.77 |
| 31.5 | 116.1 | 0.90 | 116.2 | 0.90 | 113.0 | 1.26 | 109.1 | 0.55 |
| 40 | 122.1 | 2.76 | 117.2 | 2.76 | 115.0 | 4.26 | 109.1 | 1.25 |
| 50 | 123.1 | 44.40 | 118.3 | 44.40 | 118.0 | 87.[illegible] | 111.1 | 1.41 |
| 63 | 127.1 | 43.00 | 120.4 | 43.00 | 119.0 | 78.00 | 112.1 | 8.90 |
| 80 | 124.2 | 34.00 | 124.6 | 34.00 | 121.0 | 63.60 | 119.2 | 4.50 |
| 100 | 123.2 | 30.20 | 123.8 | 30.20 | 122.0 | 46.80 | 121.2 | 13.70 |
| 125 | 123.2 | 145.00 | 126.2 | 145.00 | 121.0 | 286.00 | 121.2 | 4.21 |
| 160 | 122.3 | 71.00 | 123.7 | 71.00 | 121.0 | 136.00 | 122.3 | 6.60 |
| 200 | 122.3 | 102.00 | 121.0 | 102.00 | 123.0 | 198.00 | 121.3 | 5.40 |
| 250 | 120.4 | 36.70 | 122.0 | 36.70 | 122.0 | 70.00 | 122.3 | 3.40 |
| 315 | 118.7 | 12.50 | 120.0 | 12.50 | 120.0 | 22.30 | 120.6 | 2.66 |
| 400 | 117.1 | 4.68 | 119.0 | 4.68 | 116.0 | 8.70 | 117.9 | 0.66 |
| 500 | 115.6 | 2.00 | 118.0 | 2.00 | 114.0 | 3.58 | 115.3 | 0.41 |
| 630 | 112.9 | 0.66 | 117.0 | 0.66 | 111.7 | 0.98 | 116.4 | 0.34 |
| 800 | 114.0 | 0.72 | 115.0 | 0.72 | 109.4 | 1.26 | 111.7 | 0.18 |
| 1000 | 112.0 | 1.20 | 115.0 | 1.20 | 108.0 | 2.12 | 108.7 | 0.29 |
| 1250 | 111.0 | 1.12 | 115.0 | 1.12 | 109.3 | 1.96 | 106.8 | 0.28 |
| 1600 | 111.7 | 0.02 | 113.0 | 0.02 | 110.3 | 0.03 | 107.8 | 0.01 |
| 2000 | 111.6 | 0.02 | 111.4 | 0.02 | 109.0 | 0.05 | 108.8 | 0.003 |
| 2500 | 110.0 | 0.03 | 111.3 | 0.03 | 108.4 | 0.05 | 109.4 | 0.004 |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

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Table 3 - STS-2 Flight Data Analysis
Zonal Average Statistics - Lift-Off

| 1/3 OB Cent. Freq. Hz | Zone A | | Zone B | | Zone C | | Zone D | |
|---|---|---|---|---|---|---|---|---|
| | 1/3 OBSPL dB | Variance $10^{22}$ | 1/3 OBSPL dB | Variance $10^{22}$ | 1/3 OBSPL dB | Variance $10^{22}$ | 1/3 OBSPL dB | Variance $10^{22}$ |
| 12.5 | 116.1 | 0.13 | 108.3 | 0.01 | 111.8 | 0.05 | 114.1 | 0.33 |
| 16 | 120.1 | 0.13 | 113.1 | 0.06 | 117.8 | 0.06 | 112.6 | 0.27 |
| 20 | 116.6 | 0.35 | 112.9 | 0.04 | 116.4 | 1.00 | 110.0 | 0.02 |
| 25 | 117.6 | 0.41 | 116.9 | 0.37 | 115.6 | 0.78 | 112.9 | 0.07 |
| 31.5 | 118.6 | 1.02 | 115.4 | 0.43 | 117.6 | 2.40 | 114.0 | 0.22 |
| 40 | 123.1 | 4.40 | 118.6 | 4.70 | 119.3 | 7.80 | 116.6 | 0.73 |
| 50 | 124.6 | 56.40 | 120.9 | 0.04 | 124.0 | 168.00 | 117.6 | 1.30 |
| 63 | 126.6 | 41.80 | 123.3 | 28.30 | 123.8 | 96.00 | 118.3 | 1.20 |
| 80 | 126.7 | 48.90 | 123.3 | 30.30 | 124.9 | 114.00 | 120.7 | 2.30 |
| 100 | 125.2 | 11.40 | 123.3 | 19.30 | 124.2 | 10.60 | 122.2 | 4.30 |
| 125 | 123.7 | 105.50 | 124.1 | 13.30 | 126.3 | 300.00 | 122.1 | 3.20 |
| 160 | 122.3 | 41.50 | 123.7 | 6.00 | 124.5 | 116.00 | 121.6 | 2.40 |
| 200 | 125.3 | 81.10 | 122.7 | 1.27 | 125.9 | 240.00 | 122.4 | 3.30 |
| 250 | 121.4 | 26.90 | 122.8 | 10.30 | 123.6 | 68.00 | 121.9 | 2.30 |
| 315 | 119.7 | 7.50 | 120.4 | 0.73 | 121.9 | 28.00 | 120.5 | 1.40 |
| 400 | 117.1 | 4.00 | 117.9 | 0.01 | 120.2 | 10.40 | 118.3 | 0.50 |
| 500 | 116.6 | 2.00 | 117.1 | 0.47 | 118.9 | 5.00 | 116.7 | 0.44 |
| 630 | 112.9 | 0.49 | 115.3 | 0.09 | 116.6 | 1.08 | 116.1 | 0.31 |
| 800 | 113.0 | 0.50 | 112.9 | 0.20 | 115.6 | 1.08 | 114.0 | 0.39 |
| 1000 | 112.0 | 1.39 | 111.9 | 0.25 | 116.6 | 3.40 | 113.7 | 0.74 |
| 1250 | 111.0 | 1.39 | 110.1 | 0.02 | 111.0 | 3.40 | 108.3 | 0.74 |
| 1600 | 109.0 | 0.05 | 109.9 | 0.08 | 109.5 | 0.05 | 107.1 | 0.02 |
| 2000 | 109.0 | 0.09 | 109.3 | 0.18 | 108.7 | 0.09 | 106.7 | 0.01 |
| 2500 | 108.0 | 0.10 | 109.2 | 0.18 | 108.0 | 0.10 | 106.5 | 0.01 |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

Table 4 - STS-3 Flight Data Analysis
Zonal Average Statistics - Lift-Off

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | 119.1 | 0.49 | 110.6 | 0.49 | 112.3 | 0.19 | 116.3 | 0.78 |
| 16 | 119.1 | 0.32 | 111.6 | 0.32 | 115.8 | 0.53 | 111.6 | 0.11 |
| 20 | 120.6 | 0.08 | 111.6 | 0.08 | 112.8 | 0.13 | 110.2 | 0.02 |
| 25 | 119.1 | 9.08 | 116.6 | 9.08 | 120.1 | 16.00 | 118.8 | 2.15 |
| 31.5 | 119.0 | 0.72 | 115.7 | 0.72 | 114.1 | 0.11 | 114.9 | 1.32 |
| 40 | 124.1 | 1.60 | 119.7 | 1.60 | 118.1 | 0.73 | 116.5 | 2.48 |
| 50 | 127.1 | 4.40 | 120.3 | 4.40 | 121.2 | 7.00 | 117.5 | 1.88 |
| 63 | 127.1 | 40.50 | 125.9 | 40.50 | 123.9 | 60.00 | 120.6 | 21.00 |
| 80 | 127.2 | 10.20 | 126.6 | 10.20 | 123.3 | 13.00 | 120.8 | 7.00 |
| 100 | 126.2 | 59.00 | 125.8 | 59.00 | 123.9 | 83.00 | 123.7 | 35.00 |
| 125 | 122.2 | 141.00 | 128.2 | 141.00 | 124.9 | 273.00 | 121.8 | 8.20 |
| 160 | 124.3 | 86.20 | 124.2 | 86.20 | 124.0 | 157.00 | 122.7 | 15.50 |
| 200 | 124.3 | 83.00 | 123.5 | 83.00 | 124.0 | 157.00 | 122.8 | 9.00 |
| 250 | 121.4 | 39.50 | 122.5 | 39.50 | 123.6 | 73.00 | 122.0 | 6.00 |
| 315 | 119.7 | 11.10 | 121.0 | 11.10 | 120.8 | 16.70 | 121.3 | 5.50 |
| 400 | 117.1 | 4.09 | 120.0 | 4.09 | 118.7 | 7.00 | 118.4 | 1.18 |
| 500 | 115.6 | 1.44 | 119.0 | 1.44 | 117.0 | 2.17 | 115.8 | 0.70 |
| 630 | 113.9 | 0.72 | 119.0 | 0.72 | 115.0 | 0.87 | 115.0 | 0.58 |
| 800 | 114.0 | 0.78 | 116.5 | 0.78 | 114.2 | 1.43 | 112.2 | 0.12 |
| 1000 | 113.0 | 0.47 | 115.0 | 0.47 | 113.4 | 0.83 | 110.3 | 0.10 |
| 1250 | 112.0 | 0.30 | 115.0 | 0.30 | 110.0 | 0.53 | 107.7 | 0.06 |
| 1600 | 110.0 | 0.00 | 113.5 | 0.00 | 108.0 | 0.00 | 107.0 | 0.00 |
| 2000 | 109.0 | 0.001 | 113.0 | 0.001 | 107.0 | 0.001 | 106.4 | 0.001 |
| 2500 | 110.0 | 0.001 | 113.0 | 0.001 | 107.0 | 0.001 | 105.4 | 0.001 |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

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Table 5 - STS-4 Flight Data Analysis
Zonal Average Statistics - Lift-Off

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | 116.9 | 0.28 | 108.5 | 0.28 | 111.3 | 0.12 | 116.1 | 0.44 |
| 16 | 120.1 | 0.24 | 116.1 | 0.24 | 117.6 | 0.29 | 112.5 | 0.18 |
| 20 | 115.9 | 0.30 | 112.1 | 0.30 | 116.1 | 0.57 | 102.6 | 0.04 |
| 25 | 115.9 | 4.24 | 115.5 | 4.24 | 113.2 | 8.39 | 111.9 | 0.10 |
| 31.5 | 118.7 | 0.68 | 116.6 | 0.68 | 118.4 | 1.26 | 112.0 | 0.11 |
| 40 | 123.6 | 2.40 | 119.2 | 2.40 | 118.7 | 4.26 | 114.7 | 0.55 |
| 50 | 124.0 | 44.30 | 121.5 | 44.30 | 120.7 | 87.50 | 116.3 | 1.04 |
| 63 | 127.7 | 41.00 | 123.5 | 41.00 | 122.5 | 78.00 | 119.9 | 4.40 |
| 80 | 126.9 | 33.80 | 124.2 | 33.80 | 123.0 | 63.60 | 120.4 | 4.10 |
| 100 | 123.8 | 24.40 | 122.2 | 24.40 | 121.2 | 46.80 | 121.7 | 1.90 |
| 125 | 124.2 | 144.00 | 123.6 | 144.00 | 123.6 | 286.00 | 121.2 | 1.22 |
| 160 | 123.0 | 69.00 | 123.2 | 69.00 | 123.8 | 136.00 | 121.3 | 1.80 |
| 200 | 124.0 | 101.00 | 124.4 | 101.00 | 124.2 | 198.00 | 122.1 | 4.00 |
| 250 | 120.6 | 36.00 | 124.2 | 36.00 | 120.7 | 70.00 | 121.4 | 1.80 |
| 315 | 118.3 | 11.70 | 121.2 | 11.70 | 119.9 | 22.30 | 119.6 | 1.09 |
| 400 | 115.3 | 4.50 | 120.6 | 4.50 | 119.3 | 8.70 | 117.2 | 0.30 |
| 500 | 115.3 | 1.84 | 120.9 | 1.84 | 117.7 | 3.58 | 115.2 | 0.10 |
| 630 | 113.1 | 0.55 | 119.3 | 0.55 | 117.6 | 0.98 | 114.8 | 0.12 |
| 800 | 113.3 | 0.64 | 116.9 | 0.64 | 115.5 | 1.26 | 111.0 | 0.03 |
| 1000 | 112.8 | 1.07 | 115.6 | 1.07 | 115.5 | 2.12 | 109.6 | 0.02 |
| 1250 | 112.1 | 1.00 | 115.5 | 1.00 | 114.0 | 1.96 | 107.1 | 0.03 |
| 1600 | 110.8 | 0.01 | 114.5 | 0.01 | 113.0 | 0.03 | 106.5 | 0.001 |
| 2000 | 110.3 | 0.02 | 114.1 | 0.02 | 112.0 | 0.05 | 106.6 | 0.002 |
| 2500 | 110.0 | 0.03 | 114.2 | 0.03 | 111.0 | 0.05 | 106.7 | 0.004 |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

Table 6 - STS Flight Data Analysis
Payload Bay Spatial Average Statistics - Lift-Off

| 1/3 OB Cent. Freq. Hz | STS-1 1/3 OBSPL dB | STS-1 Variance $10^{22}$ | STS-2 1/3 OBSPL dB | STS-2 Variance $10^{22}$ | STS-3 1/3 OBSPL dB | STS-3 Variance $10^{22}$ | STS-4 1/3 OBSPL dB | STS-4 Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | 114.5 | 1.42 | 113.4 | 0.67 | 115.8 | 2.99 | 114.4 | 1.28 |
| 16 | 118.3 | 4.14 | 117.0 | 4.03 | 115.7 | 2.82 | 117.4 | 3.44 |
| 20 | 114.7 | 0.87 | 114.7 | 1.15 | 116.0 | 6.38 | 114.2 | 0.94 |
| 25 | 114.4 | 4.92 | 116.1 | 1.08 | 118.8 | 10.48 | 114.4 | 4.56 |
| 31.5 | 114.4 | 1.57 | 116.8 | 2.22 | 116.4 | 2.22 | 117.1 | 2.48 |
| 40 | 118.0 | 14.80 | 120.1 | 16.40 | 120.6 | 24.60 | 120.2 | 21.40 |
| 50 | 119.4 | 61.40 | 122.6 | 85.40 | 123.1 | 114.00 | 121.4 | 63.30 |
| 63 | 122.5 | 173.00 | 123.9 | 106.80 | 125.0 | 115.50 | 124.3 | 161.00 |
| 80 | 122.8 | 59.00 | 124.4 | 104.90 | 125.2 | 103.20 | 124.2 | 99.80 |
| 100 | 122.7 | 36.10 | 123.9 | 23.40 | 125.0 | 81.00 | 122.3 | 30.10 |
| 125 | 123.4 | 191.00 | 124.3 | 136.50 | 125.1 | 281.00 | 123.3 | 152.00 |
| 160 | 122.4 | 76.00 | 123.2 | 42.50 | 123.8 | 89.80 | 122.9 | 74.00 |
| 200 | 122.0 | 105.00 | 124.3 | 110.10 | 123.7 | 85.90 | 123.8 | 108.00 |
| 250 | 121.7 | 38.50 | 122.5 | 27.30 | 122.5 | 43.30 | 122.0 | 48.00 |
| 315 | 119.9 | 13.20 | 120.7 | 11.10 | 120.7 | 11.90 | 119.9 | 13.50 |
| 400 | 117.6 | 5.39 | 118.5 | 5.40 | 118.7 | 5.09 | 118.5 | 7.70 |
| 500 | 116.0 | 2.67 | 117.4 | 2.06 | 117.1 | 2.43 | 117.9 | 6.34 |
| 630 | 115.1 | 1.42 | 115.4 | 0.82 | 116.2 | 2.32 | 116.8 | 2.65 |
| 800 | 113.0 | 0.98 | 114.0 | 0.65 | 114.5 | 1.13 | 114.7 | 1.28 |
| 1000 | 111.8 | 1.54 | 114.0 | 1.89 | 113.2 | 0.65 | 114.0 | 1.51 |
| 1250 | 111.6 | 1.48 | 110.2 | 1.41 | 112.0 | 0.62 | 113.1 | 1.42 |
| 1600 | 111.1 | 0.10 | 109.0 | 0.06 | 110.4 | 0.16 | 112.1 | 0.27 |
| 2000 | 110.4 | 0.06 | 108.5 | 0.10 | 109.7 | 0.13 | 111.5 | 0.22 |
| 2500 | 109.9 | 0.05 | 108.0 | 0.10 | 109.8 | 0.14 | 111.3 | 0.24 |
| OAL | 132.8 | | 134.0 | | 134.6 | | 133.7 | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/P_{ref}^2$)

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Table 7 - OV-102 Flight Data Analysis
Flight-Spatial Average Statistics - Lift-Off

| 1/3 OB Cent. Freq. Hz | Mean - Flight Spatial Average 1/3 OBSPL dB | Mean - Flight Spatial Average Variance $10^{22}$ | 84.13% Prob. Level 1/3 OBSPL dB | 97.73% Prob. Level 1/3 OBSPL dB | 99.87% Prob. Level 1/3 OBSPL dB |
|---|---|---|---|---|---|
| 12.5 | 114.6 | 2.00 | 116.6 | 118.9 | 122.4 |
| 16 | 117.2 | 5.20 | 119.0 | 121.1 | 124.5 |
| 20 | 115.0 | 2.70 | 117.1 | 119.4 | 122.9 |
| 25 | 116.3 | 10.00 | 119.1 | 121.8 | 125.6 |
| 31.5 | 116.3 | 3.20 | 118.1 | 120.2 | 123.5 |
| 40 | 119.8 | 24.00 | 121.9 | 124.2 | 127.7 |
| 50 | 121.8 | 110.00 | 124.4 | 127.0 | 130.7 |
| 63 | 124.0 | 170.00 | 126.1 | 128.4 | 132.0 |
| 80 | 124.2 | 130.00 | 126.0 | 128.1 | 131.4 |
| 100 | 123.6 | 87.00 | 125.3 | 127.4 | 130.6 |
| 125 | 124.1 | 220.00 | 126.4 | 128.8 | 132.4 |
| 160 | 123.1 | 78.00 | 124.9 | 127.0 | 130.4 |
| 200 | 123.5 | 120.00 | 125.6 | 127.8 | 131.3 |
| 250 | 122.2 | 41.00 | 123.8 | 125.8 | 129.1 |
| 315 | 120.3 | 14.00 | 121.8 | 123.7 | 126.8 |
| 400 | 118.3 | 6.40 | 119.9 | 121.9 | 125.1 |
| 500 | 117.2 | 4.20 | 118.8 | 120.9 | 124.1 |
| 630 | 115.9 | 2.30 | 117.6 | 119.6 | 122.8 |
| 800 | 114.1 | 1.20 | 115.9 | 119.0 | 121.3 |
| 1000 | 113.3 | 1.60 | 115.7 | 118.1 | 121.7 |
| 1250 | 111.8 | 1.40 | 114.7 | 117.4 | 121.3 |
| 1600 | 110.8 | 0.27 | 112.6 | 114.7 | 118.1 |
| 2000 | 110.2 | 0.21 | 112.0 | 114.2 | 117.5 |
| 2500 | 109.9 | 0.22 | 111.9 | 114.1 | 117.5 |
| OAL | 133.8 | | 135.8 | 138.0 | 141.4 |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($p_{sl}^2/p_{ref}^2$)

Table 8 - STS-1 Flight Data Analysis
Zonal Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | | | | | | | | |
| 16 | | | | | | | | |
| 20 | | | | | | | | |
| 25 | | | | | | | | |
| 31.5 | | | | | | | | |
| 40 | * | | | | | | | |
| 50 | | | | | | | | |
| 63 | | | | | | | | |
| 80 | | | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 160 | | | | | | | | |
| 200 | 118.4 | 410.00 | 120.0 | 410.00 | 117.6 | 800.00 | 133.3 | 20.10 |
| 250 | 124.2 | 7300.00 | 130.0 | 7300.00 | 120.0 | 14500.00 | 133.6 | 31.80 |
| 315 | 114.1 | 39.00 | 118.0 | 39.00 | 112.0 | 76.00 | 130.9 | 2.03 |
| 400 | | | | | | | | |
| 500 | | | | | | | | |
| 630 | | | | | | | | |
| 800 | | | | | | | | |
| 1000 | | | | | | | | |
| 1250 | | | | | | | | |
| 1600 | * | | * | | | | | |
| 2000 | | | | | | | | |
| 2500 | | | | | | | | |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio $(psi^2/Pref^2)$

Levels in these freq. bands < lift-off levels.

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Table 9 - STS-2 Flight Data Analysis
Zonal Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | | | | | | | | |
| 16 | | | | | | | | |
| 20 | | | | | | | | |
| 25 | | | | | | | | |
| 31.5 | | | | | | | | |
| 40 | * | | * | | * | | * | |
| 50 | | | | | | | | |
| 63 | | | | | | | | |
| 80 | | | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 160 | | | | | | | | |
| 200 | | | | | | | | |
| 250 | 118.4 | 590,00 | 121,3 | 110.00 | 124.8 | 1600.00 | 117.9 | 57.00 |
| 315 | 124.2 | 10500.00 | 126.4 | 2400.00 | 129.7 | 29000.00 | 119.6 | 89.00 |
| 400 | 113.1 | 54.00 | 117.6 | 6.50 | 120.1 | 150.00 | 115.1 | 5.20 |
| 500 | | | | | | | | |
| 630 | | | | | | | | |
| 800 | | | | | | | | |
| 1000 | | | | | | | | |
| 1250 | | | | | | | | |
| 1600 | * | | * | | * | | * | |
| 2000 | | | | | | | | |
| 2500 | | | | | | | | |
| OAL | | | | | | | | |

* dB re. 20 μN/$m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

Levels in these freq. bands < lift-off levels.

Table 10 - STS-3 Flight Data Analysis
Zonal Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | | | | | | | | |
| 16 | | | | | | | | |
| 20 | | | | | | | | |
| 25 | | | | | | | | |
| 31.5 | | | | | | | | |
| 40 | * | | * | | * | | * | |
| 50 | | | | | | | | |
| 63 | | | | | | | | |
| 80 | | | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 160 | | | | | | | | |
| 200 | | | | | | | | |
| 250 | 118.9 | 1.08 | 122.5 | 1.08 | 114.2 | 0.36 | 113.3 | 1.80 |
| 315 | 125.2 | 12.60 | 129.5 | 12.60 | 118.6 | 22.00 | 113.9 | 3.10 |
| 400 | 113.6 | 1.82 | 118.0 | 1.82 | 115.6 | 2.9 | 112.8 | 0.74 |
| 500 | | | | | | | | |
| 630 | | | | | | | | |
| 800 | | | | | | | | |
| 1000 | | | | | | | | |
| 1250 | | | | | | | | |
| 1600 | * | | * | | * | | * | |
| 2000 | | | | | | | | |
| 2500 | | | | | | | | |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

Levels in these freq. bands < lift-off levels

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Table 11 - STS-4 Flight Data Analysis
Zonal Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Zone A 1/3 OBSPL dB | Zone A Variance $10^{22}$ | Zone B 1/3 OBSPL dB | Zone B Variance $10^{22}$ | Zone C 1/3 OBSPL dB | Zone C Variance $10^{22}$ | Zone D 1/3 OBSPL dB | Zone D Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | | | | | | | | |
| 16 | | | | | | | | |
| 20 | | | | | | | | |
| 25 | | | | | | | | |
| 31.5 | | | | | | | | |
| 40 | * | | * | | * | | * | |
| 50 | | | | | | | | |
| 63 | | | | | | | | |
| 80 | | | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 160 | | | | | | | | |
| 200 | | | | | | | | |
| 250 | 118.7 | 400.00 | 121.8 | 400.00 | 124.4 | 800.00 | 113.1 | 1.60 |
| 315 | 121.0 | 7200.00 | 128.0 | 7200.00 | 123.0 | 14500.00 | 113.9 | 3.40 |
| 400 | 111.6 | 38.00 | 118.8 | 38.00 | 119.5 | 76.00 | 110.4 | 0.16 |
| 500 | | | | | | | | |
| 630 | | | | | | | | |
| 800 | | | | | | | | |
| 1000 | | | | | | | | |
| 1250 | | | | | | | | |
| 1600 | * | | * | | * | | * | |
| 2000 | | | | | | | | |
| 2500 | | | | | | | | |
| OAL | | | | | | | | |



* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}{}^2$)

Levels in these freq. bands < lift-off levels

Table 12 - STS-1 Flight Data Analysis
Payload Bay Spatial Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Spatial Average 1/3 OBSPL dB | Spatial Average Variance $10^{22}$ | 84.13% Prob. Level 1/3 OBSPL dB | 97.73% Prob. Level 1/3 OBSPL dB | 99.87% Prob. Level 1/3 OBSPL dB |
|---|---|---|---|---|---|
| 12.5 | | | | | |
| 16 | | | | | |
| 20 | | | | | |
| 25 | | | | | |
| 31.5 | | | | | |
| 40 | | | | | |
| 50 | | | | | |
| 63 | | | | | |
| 80 | | | | | |
| 100 | | | | | |
| 125 | | | | | |
| 160 | | | | | |
| 200 | | | | | |
| 250 | 117.9 | 410.00 | 124.8 | 128.8 | 133.2 |
| 315 | 125.4 | 7700.00 | 131.5 | 135.2 | 139.6 |
| 400 | 114.8 | 40.00 | 120.3 | 123.9 | 128.2 |
| 500 | | | | | |
| 630 | | | | | |
| 800 | | | | | |
| 1000 | | | | | |
| 1250 | | | | | |
| 1600 | | | | | |
| 2000 | | | | | |
| 2500 | | | | | |
| OAL | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

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Table 13 - STS-2 Flight Data Analysis
Payload Bay Spatial Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Spatial Average 1/3 OBSPL dB | Variance $10^{22}$ | 84.13% Prob. Level 1/3 OBSPL dB | 97.73% Prob. Level 1/3 OBSPL dB | 99.87% Prob. Level 1/3 OBSPL dB |
|---|---|---|---|---|---|
| 12.5 | | | | | |
| 16 | | | | | |
| 20 | | | | | |
| 25 | | | | | |
| 31.5 | | | | | |
| 40 | | | | | |
| 50 | | | | | |
| 63 | | | | | |
| 80 | | | | | |
| 100 | | | | | |
| 125 | | | | | |
| 160 | | | | | |
| 200 | | | | | |
| 250 | 121.5 | 620.00 | 126.4 | 130.0 | 134.2 |
| 315 | 126.3 | 11000.00 | 132.2 | 136.0 | 140.3 |
| 400 | 117.3 | 57.00 | 121.6 | 124.9 | 129.1 |
| 500 | | | | | |
| 630 | | | | | |
| 800 | | | | | |
| 1000 | | | | | |
| 1250 | | | | | |
| 1600 | | | | | |
| 2000 | | | | | |
| 2500 | | | | | |
| OAL | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

Table 14 - STS-3 Flight Data Analysis
Payload Bay Spatial Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Spatial Average 1/3 OBSPL dB | Spatial Average Variance $10^{22}$ | 84.13% Prob. Level 1/3 OBSPL dB | 97.73% Prob. Level 1/3 OBSPL dB | 99.87% Prob. Level 1/3 OBSPL dB |
|---|---|---|---|---|---|
| 12.5 | | | | | |
| 16 | | | | | |
| 20 | | | | | |
| 25 | | | | | |
| 31.5 | | | | | |
| 40 | | | | | |
| 50 | | | | | |
| 63 | | | | | |
| 80 | | | | | |
| 100 | | | | | |
| 125 | | | | | |
| 160 | | | | | |
| 200 | | | | | |
| 250 | 118.8 | 14.00 | 120.8 | 123.1 | 126.6 |
| 315 | 125.2 | 410.00 | 127.6 | 130.1 | 133.7 |
| 400 | 115.5 | 2.80 | 117.4 | 119.5 | 123.1 |
| 500 | | | | | |
| 630 | | | | | |
| 800 | | | | | |
| 1000 | | | | | |
| 1250 | | | | | |
| 1600 | | | | | |
| 2000 | | | | | |
| 2500 | | | | | |
| OAL | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio $(psi^2/P_{ref}^2)$

Table 15 - STS-4 Flight Data Analysis
Payload Bay Spatial Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Spatial Average 1/3 OBSPL dB | Spatial Average Variance $10^{22}$ | 84.13% Prob. Level 1/3 OBSPL dB | 97.73% Prob. Level 1/3 OBSPL dB | 99.87% Prob. Level 1/3 OBSPL dB |
|---|---|---|---|---|---|
| 12.5 | | | | | |
| 16 | | | | | |
| 20 | | | | | |
| 25 | | | | | |
| 31.5 | | | | | |
| 40 | | | | | |
| 50 | | | | | |
| 63 | | | | | |
| 80 | | | | | |
| 100 | | | | | |
| 125 | | | | | |
| 160 | | | | | |
| 200 | | | | | |
| 250 | 121.2 | 430.00 | 125.8 | 129.2 | 133.4 |
| 315 | 123.9 | 7300.00 | 131.0 | 135.0 | 139.4 |
| 400 | 116.8 | 42.00 | 121.0 | 124.3 | 128.4 |
| 500 | | | | | |
| 630 | | | | | |
| 800 | | | | | |
| 1000 | | | | | |
| 1250 | | | | | |
| 1600 | | | | | |
| 2000 | | | | | |
| 2500 | | | | | |
| OAL | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

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Table 16 - STS Flight Data Analysis
Payload Bay Spatial Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | STS-1 1/3 OBSPL dB | STS-1 Variance $10^{22}$ | STS-2 1/3 OBSPL dB | STS-2 Variance $10^{22}$ | STS-3 1/3 OBSPL dB | STS-3 Variance $10^{22}$ | STS-4 1/3 OBSPL dB | STS-4 Variance $10^{22}$ |
|---|---|---|---|---|---|---|---|---|
| 12.5 | | | | | | | | |
| 16 | | | | | | | | |
| 20 | | | | | | | | |
| 25 | | | | | | | | |
| 31.5 | * | | * | | * | | * | |
| 40 | | | | | | | | |
| 50 | | | | | | | | |
| 63 | | | | | | | | |
| 80 | | | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 160 | | | | | | | | |
| 200 | | | | | | | | |
| 250 | 117.9 | 410.0 | 121.5 | 620.0 | 118.8 | 14.0 | 121.2 | 430.0 |
| 315 | 125.4 | 7700.0 | 126.3 | 11000.0 | 125.2 | 410.0 | 123.9 | 7300.0 |
| 400 | 114.8 | 40.0 | 117.3 | 57.0 | 115.5 | 2.8 | 116.8 | 42.0 |
| 500 | | | | | | | | |
| 630 | | | | | | | | |
| 800 | | | | | | | | |
| 1000 | | | | | | | | |
| 1250 | * | | * | | * | | * | |
| 1600 | | | | | | | | |
| 2000 | | | | | | | | |
| 2500 | | | | | | | | |
| OAL | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio ($psi^2/p_{ref}^2$)

Levels in these freq. bands < lift-off levels

Table 17 - OV-102 Flight Data Analysis
Flight-Spatial Average Statistics - Transonic

| 1/3 OB Cent. Freq. Hz | Mean - Flight Spatial Average 1/3 OBSPL dB | Variance $10^{22}$ | 84.13% Prob. Level 1/3 OBSPL dB | 97.73% Prob. Level 1/3 OBSPL dB | 99.87% Prob. Level 1/3 OBSPL dB |
|---|---|---|---|---|---|
| 12.5 | | | | | |
| 16 | | | | | |
| 20 | | | | | |
| 25 | | | | | |
| 31.5 | | | | | |
| 40 | | | | | |
| 50 | | | | | |
| 63 | | | | | |
| 80 | | | | | |
| 100 | | | | | |
| 125 | | | | | |
| 160 | | | | | |
| 200 | | | | | |
| 250 | 120.1 | 380.00 | 125.3 | 128.9 | 133.1 |
| 315 | 125.3 | 6700.00 | 131.2 | 134.9 | 139.3 |
| 400 | 116.2 | 37.00 | 120.6 | 123.9 | 128.1 |
| 500 | | | | | |
| 630 | | | | | |
| 800 | | | | | |
| 1000 | | | | | |
| 1250 | | | | | |
| 1600 | | | | | |
| 2000 | | | | | |
| 2500 | | | | | |
| OAL | | | | | |

* dB re. 20 $\mu N/m^2$
Variance of mean square pressure ratio $(psi^2/p_{ref}^2)$

Levels in these freq. bands < lift-off levels

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Table 18 - OV-102 Flight Data Analysis
Worst-Case Zone Average Levels of Maximum Transonic Levels

| 1/3 OB Cent. Freq. Hz | STS-1 1/3 OBSPL dB | STS-1 Zone | STS-2 1/3 OBSPL dB | STS-2 Zone | STS-3 1/3 OBSPL dB | STS-3 Zone | STS-4 1/3 OBSPL dB | STS-4 Zone | Average 1/3 OBSPL dB |
|---|---|---|---|---|---|---|---|---|---|
| 250 | 120.0 | B | 124.8 | C | 122.5 | B | 124.4 | C | 122.9 |
| 315 | 130.0 | B | 129.7 | C | 129.5 | B | 128.0 | B | 129.3 |
| 400 | 118.0 | B | 120.1 | C | 118.0 | B | 119.5 | C | 118.9 |

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* dB re. 20 $\mu N/m^2$

Table 19 -

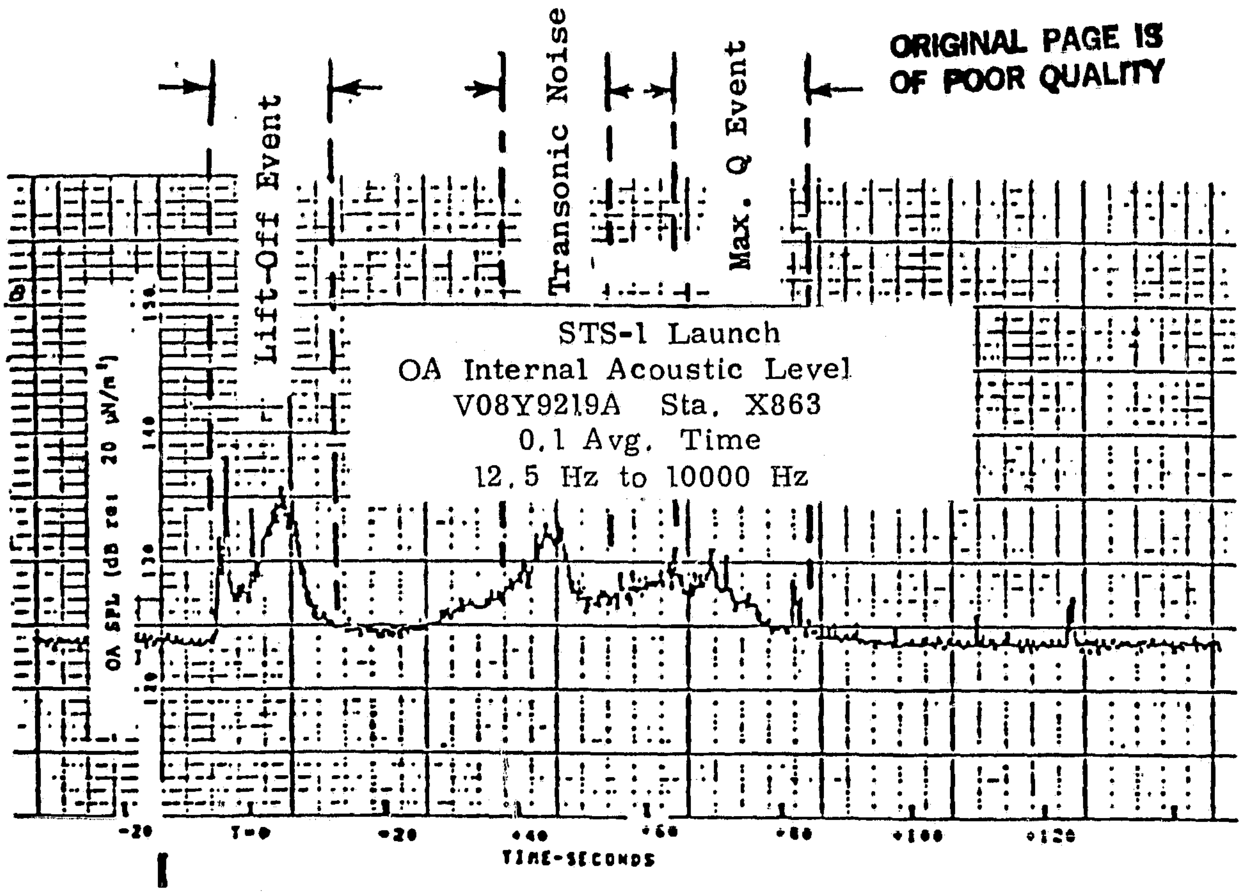


Recommended Payload Acoustic Flight Levels
(based on empty STS Cargo Bay)

| Center Frequency (Hz) | Sound Pressure Level (dB re. 20 μN/m²) Without Transonic Level | With Transonic Level |
|---|---|---|
| 1/3 Octave | 1/3 Octave | 1/3 Octave |
| 25 | 119 | 119 |
| 32 | 122 | 122 |
| 40 | 125 | 125 |
| 50 | 127.5 | 127.5 |
| 63 | 128.5 | 128.5 |
| 80 | 129 | 129 |
| 100 | 129 | 129 |
| 125 | 129 | 129 |
| 160 | 128.5 | 129 |
| 200 | 127.5 | 129 |
| 250 | 127 | 129 |
| 315 | 126 | 129 |
| 400 | 125 | 127.5 |
| 500 | 124 | 125.5 |
| 630 | 123 | 124 |
| 800 | 121.5 | 122 |
| 1000 | 120 | 120 |
| 1250 | 118.5 | 118.5 |
| 1600 | 116.5 | 116.5 |
| 2000 | 115 | 115 |
| 2500 | 113 | 113 |
| 3150 | 111.5 | 111.5 |
| 4000 | 109.5 | 109.5 |
| 5000 | 108 | 108 |
| 6300 | 106 | 106 |
| 8000 | 104.5 | 104.5 |
| 10000 | 103 | 103 |
| OVERALL | 139 | 139.5 |
| MIN. DURATION | 15 seconds | 30 seconds |

## APPENDIX A

## PAYLOAD BAY INTERNAL SOUND PRESSURES MEASUREMENTS FROM STS-1 THROUGH STS-4 LIFT-OFF AND TRANSONIC FLIGHT



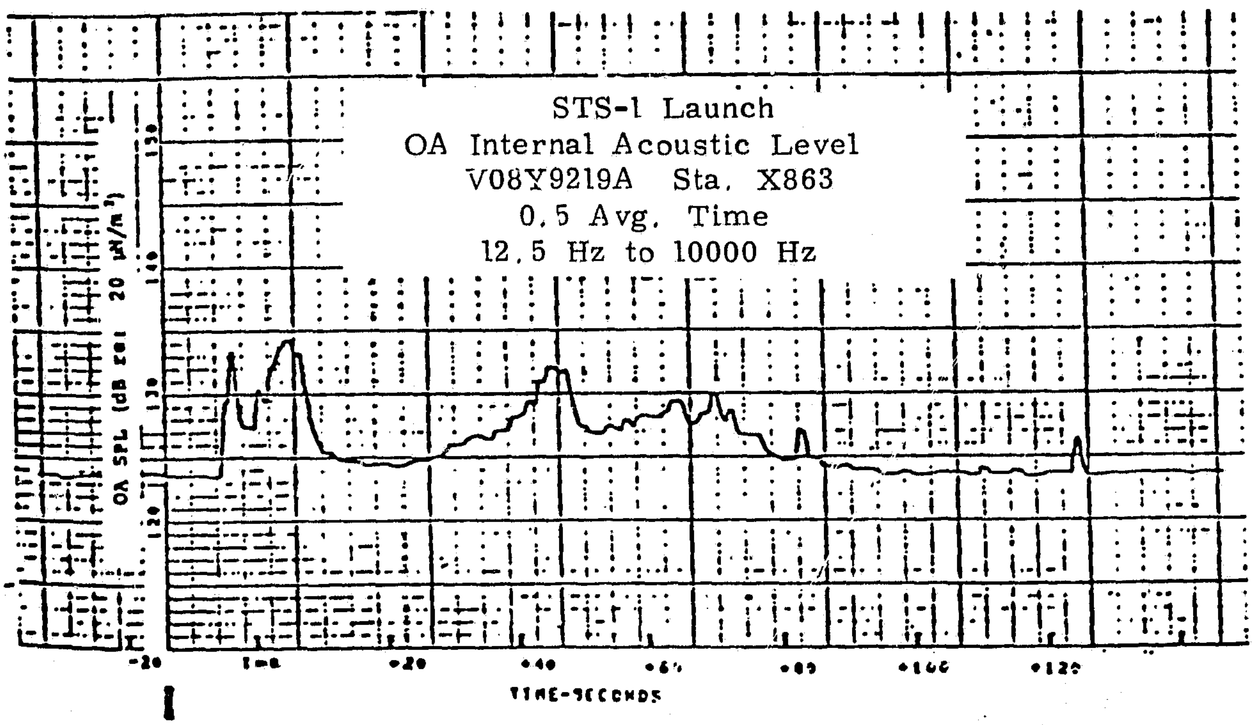




Figure A.1 - Example of **Overall Level Time History**
**Microphone V08Y9219A**

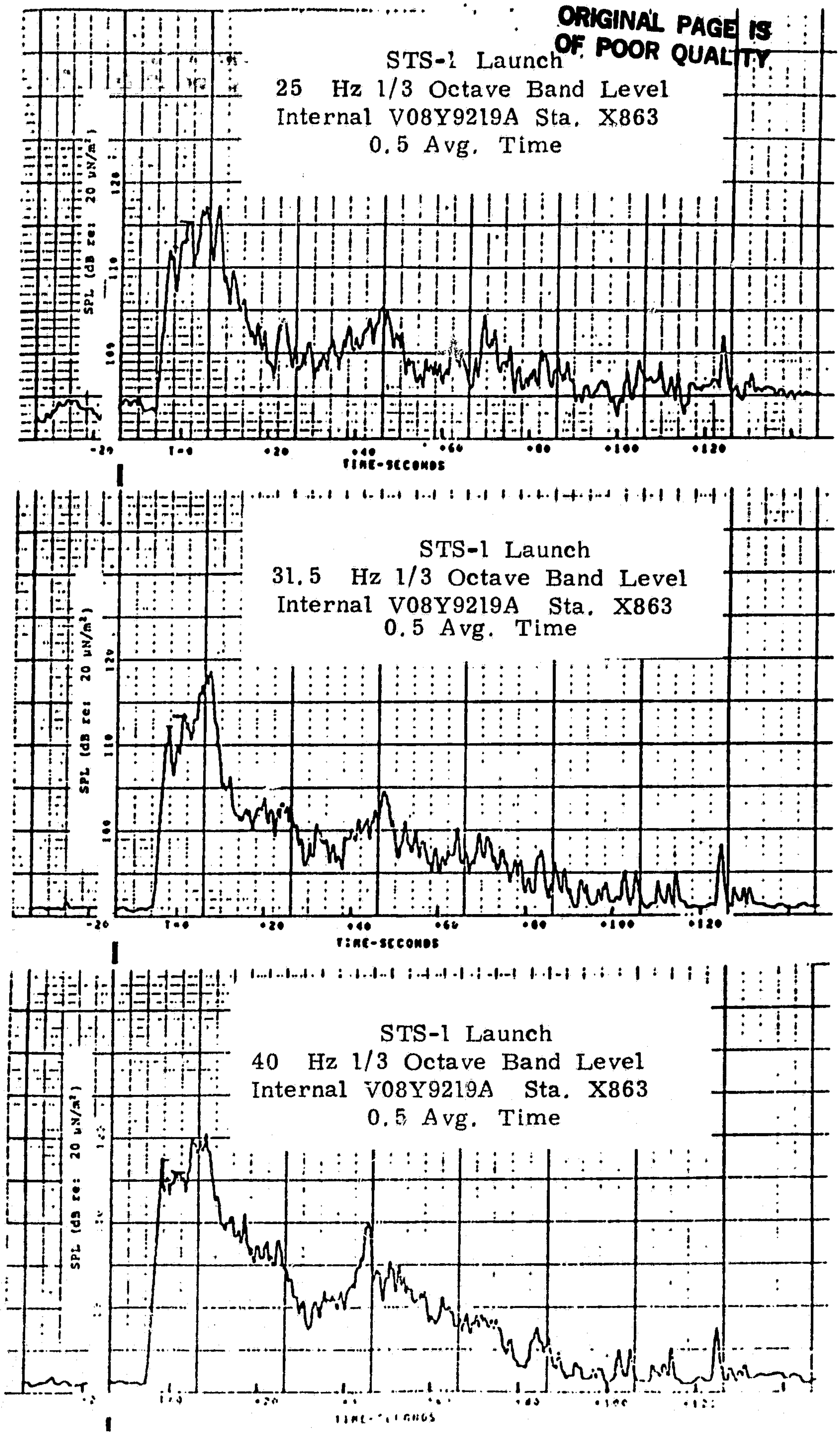



Figure A.2 - Example of One-Third Octave Band Level Time History
Microphone V08Y9219A

Table A.1 - Significant Event Times of Flight Profile

| Event Nomenclature | Time Segment, sec. | | | |
|---|---|---|---|---|
| | STS - 1 | STS - 2 | STS - 3 | STS - 4 |
| Lift-off (SSME ignition through SRB ignition and maximum exhaust deflection effects) | T-6 to T+12 | T-6 to T+12 | T-6 to T+12 | T-6 to T+12 |
| Transonic noise | T+38 to T+55 | T+30 to T+55 | T+30 to T+55 | T+30 to T+55 |
| Max. Q (Maximum dynamic pressure) | T+64 to T+84 | T+60 to T+84 | T+60 to T+84 | T+60 to T+84 |

# APPENDIX A.1

# STS-1 FLIGHT DATA

| I.D. | X | Y | Z |
|---|---|---|---|
| I 1 | 576 | 4 | 423 |
| I 2 | 863 | -91 | 381 |
| I 3 | 1307 | 11.5 | 400 |
| I 4 | 1039 | 0 | 427 |

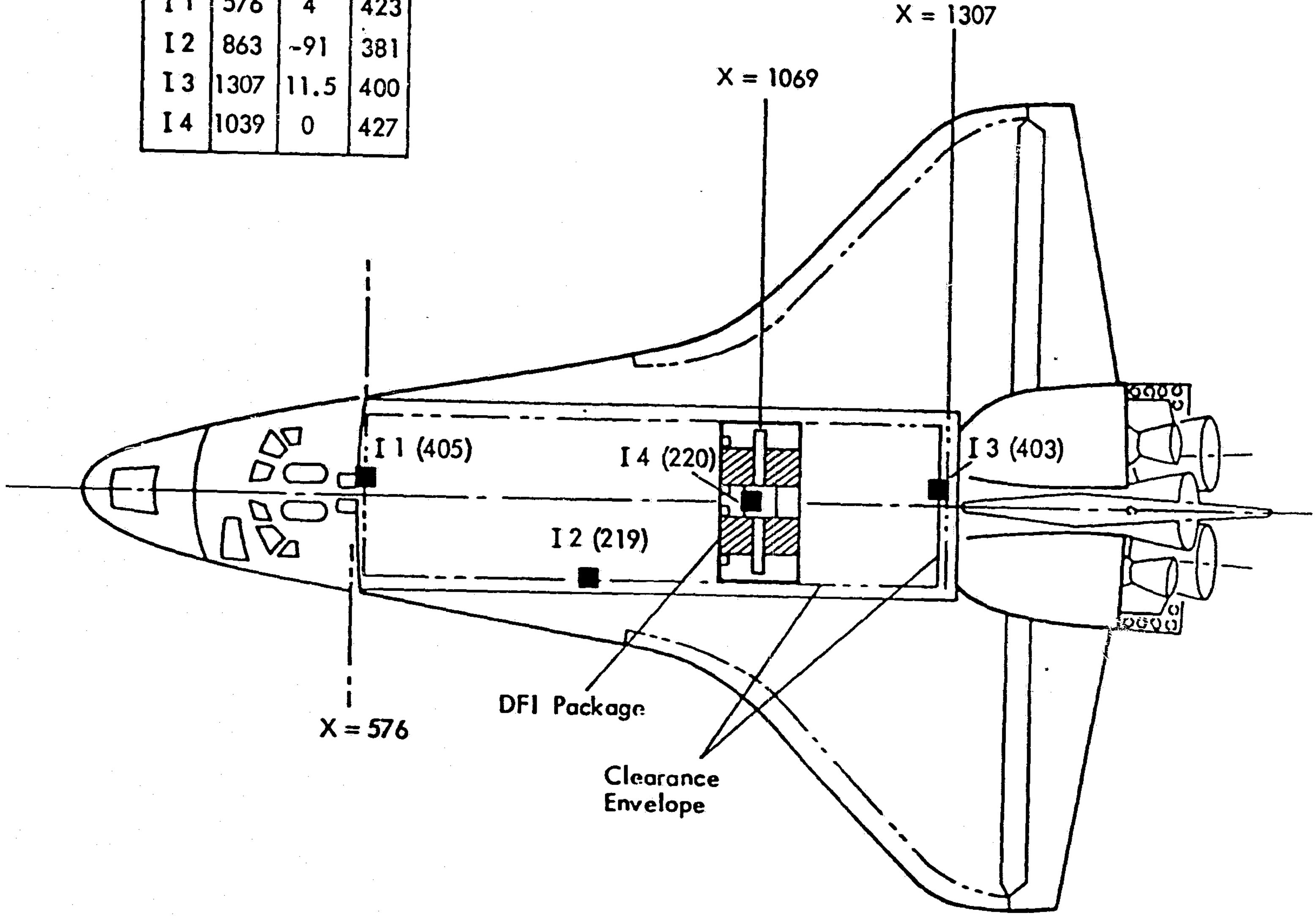



Figure A.1.1 - Internal Microphone Locations for STS-1

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Table A.1.1 - Summary of Microphone Locations For STS-1

| General Location | BBN Code | NASA Code | Station Number | | | Frequency Range* |
|---|---|---|---|---|---|---|
| | | | X | Y | Z | |
| Bay Structure | I1 | V08Y9405A | 576 | +4 | 423 | A |
| | I2 | V08Y9219A | 863 | -100 | 381 | A |
| | I3 | V08Y9403A | 1306 | +12 | 400 | A |
| DFI Payload | I4 | V08Y9220A | 1049 | 0 | 427 | A |

*A-20 Hz to 8kHz; B-5 Hz to 2kHz

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Table A.1.2 - Measured Sound Pressure Levels in Payload Bay
STS-1 Lift-Off

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | | | | | |
| 12.5 | 117.1 | 109.1 | 116.1 | 111.0 | | | | | |
| 16 | 120.1 | 116.1 | 114.1 | 120.0 | | | | | |
| 20 | 117.1 | 114.1 | 112.1 | 114.0 | | | | | |
| 25 | 116.1 | 114.1 | 111.1 | 115.0 | | | | | |
| 31.5 | 116.1 | 116.2 | 109.1 | 113.0 | | | | | |
| 40 | 122.1 | 117.2 | 109.1 | 115.0 | | | | | |
| 50 | 123.1 | 118.3 | 111.1 | 118.0 | | | | | |
| 63 | 127.1 | 120.4 | 112.1 | 119.0 | | | | | |
| 80 | 124.2 | 124.6 | 119.2 | 121.0 | | | | | |
| 100 | 123.2 | 123.8 | 121.2 | 122.0 | | | | | |
| 125 | 123.2 | 126.2 | 121.2 | 121.0 | | | | | |
| 160 | 122.3 | 123.7 | 122.3 | 121.0 | | | | | |
| 200 | 122.3 | 121.0 | 121.3 | 123.0 | | | | | |
| 250 | 120.4 | 122.0 | 122.3 | 122.0 | | | | | |
| 315 | 118.7 | 120.0 | 120.6 | 120.0 | | | | | |
| 400 | 117.1 | 119.0 | 117.9 | 116.0 | | | | | |
| 500 | 115.6 | 118.0 | 115.3 | 114.0 | | | | | |
| 630 | 112.9 | 117.0 | 116.4 | 111.7 | | | | | |
| 800 | 114.0 | 115.0 | 111.7 | 109.4 | | | | | |
| 1000 | 112.8 | 115.0 | 108.7 | 108.0 | | | | | |
| 1250 | 111.8 | 115.0 | 106.8 | 109.3 | | | | | |
| 1600 | 111.7 | 113.8 | 107.8 | 110.3 | | | | | |
| 2000 | 111.6 | 111.4 | 108.8 | 109.0 | | | | | |
| 2500 | 110.0 | 111.3 | 109.4 | 108.4 | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate

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Table A.1.3 - Measured Sound Pressure Levels in Payload Bay
STS-1 Transonic

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | | | | | |
| 12.5 | | | | | | | | | |
| 16 | | | | | | | | | |
| 20 | | | | | | | | | |
| 25 | | | | | | | | | |
| 31.5 | * | * | * | * | | | | | |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 63 | | | | | | | | | |
| 80 | | | | | | | | | |
| 100 | | | | | | | | | |
| 125 | | | | | | | | | |
| 160 | | | | | | | | | |
| 200 | | | | | | | | | |
| 250 | 118.4 | 120.0 | 113.3 | 117.5 | | | | | |
| 315 | 124.2 | 130.0 | 113.6 | 120.0 | | | | | |
| 400 | 114.1 | 118.0 | 111.9 | 112.0 | | | | | |
| 500 | | | | | | | | | |
| 630 | | | | | | | | | |
| 800 | * | * | * | * | | | | | |
| 1000 | | | | | | | | | |
| 1250 | | | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 μN/m²

Corrected for instrumentation noise / reflection effect when appropriate

Levels in these freq. bands < Lift-off levels

# APPENDIX A.2

# STS-2 FLIGHT DATA

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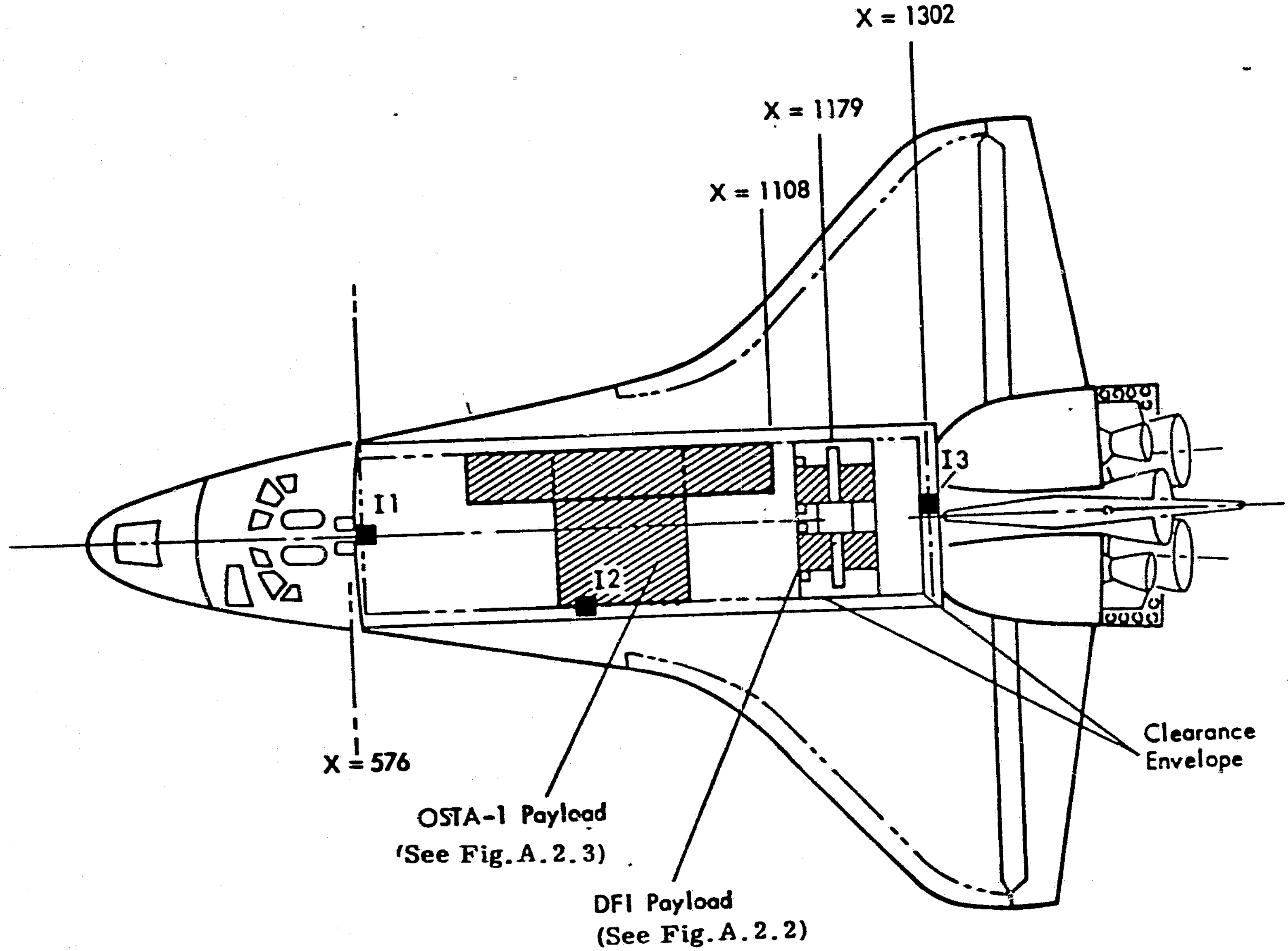


Figure A.2.1 - Payload Bay Configuration for STS-2

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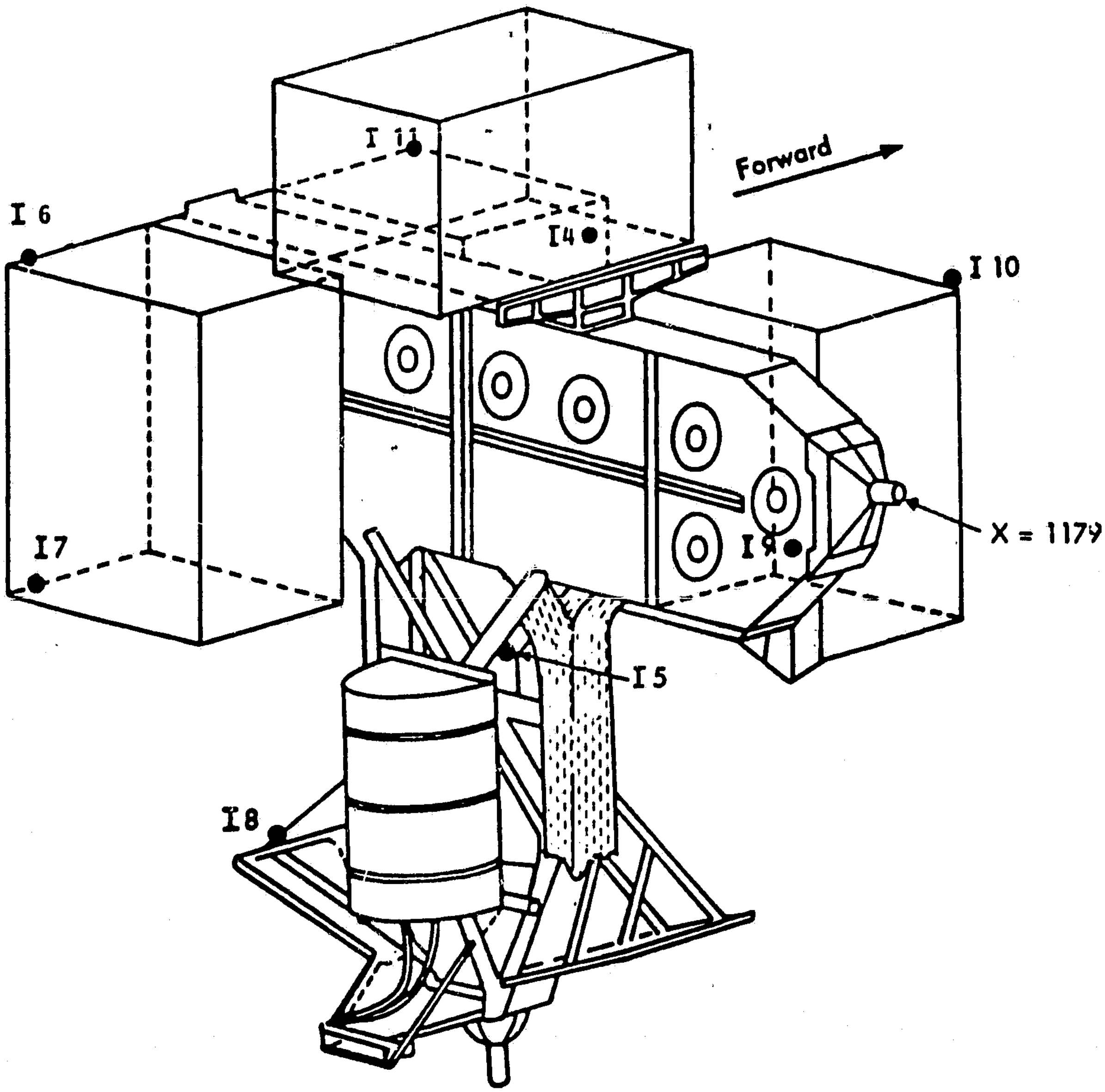


Figure A.2.2 - Microphone Locations on DFI Payload for STS-2

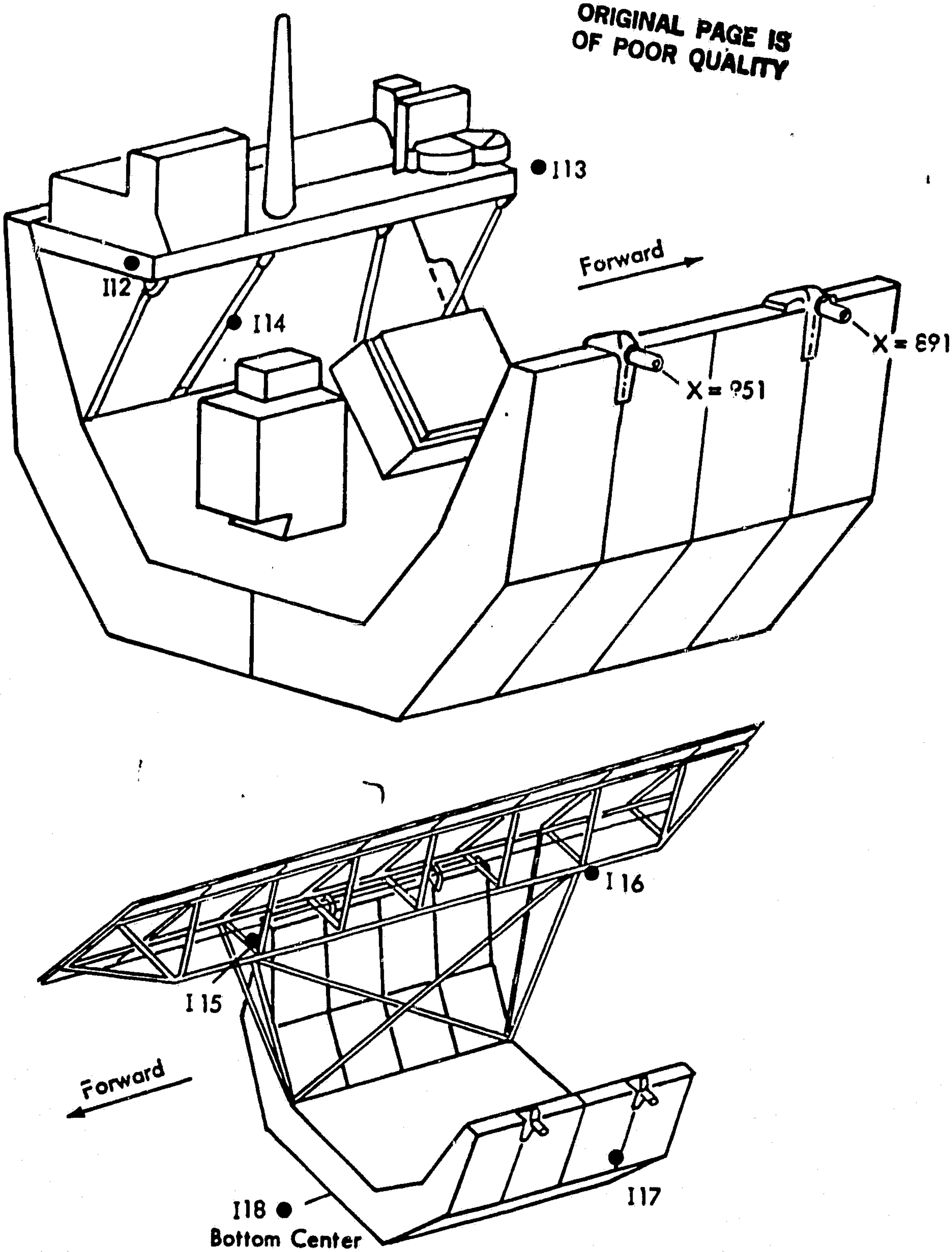


Figure A.2.3 - Microphone Locations on OSTA-1 Payload for STS-2

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Table A.2.1 - Summary of Microphone Locations For STS-2

| General Location | BBN Code | NASA Code | Station Number X | Y | Z | Frequency Range* |
|---|---|---|---|---|---|---|
| Bay Structure | I1 | V08Y9405A | 576 | +4 | 423 | A |
| | I2 | V08Y9219A | 863 | -100 | 381 | A |
| | I3 | V08Y9403A | 1306 | +12 | 400 | A |
| DFI Payload | I4 | V08Y9220A | 1159 | 0 | 427 | A |
| | I5 | V08Y9279A | 1192 | +15 | 384 | B |
| | I6 | V08Y9277A | 1219 | -68 | 432 | B |
| | I7 | V08Y9281A | 1219 | -68 | 384 | A |
| | I8 | V08Y9278A | 1194 | -44 | 328 | B |
| | I9 | V08Y9276A | 1139 | +20 | 384 | B |
| | I10 | V08Y9280A | 1139 | +68 | 432 | A |
| | I11 | V08Y9275A | 1139 | -68 | 432 | B |
| OSTA Payload | I12 | V08Y9253A | 978 | -29 | 410 | B |
| | I13 | V08Y9252A | 864 | -29 | 410 | B |
| | I14 | V08Y9254A | 951 | -45 | 394 | B |
| | I15 | V08Y9257A | 832 | +29 | 427 | A |
| | I16 | V08Y9258A | 1001 | +29 | 427 | A |
| | I17 | V08Y9256A | 951 | -85 | 398 | B |
| | I18 | V08Y9255A | 951 | 0 | 326 | B |

*A-20 Hz to 8kHz; B-5 Hz to 2kHz

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Table A.2.2 - Measured Sound Pressure Levels in Payload Bay
STS-2 Lift-Off

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | I5 9279 | I6 9277 | I7 9281 | I8 9278 | I9 9276 |
| 12.5 | 116.1 | 109.1 | 114.1 | 109.0 | 116.2 | 116.0 | 116.0 | 117.0 | 111.0 |
| 16 | 120.1 | 113.6 | 115.1 | 107.0 | 112.0 | 115.6 | 116.0 | 114.0 | 104.0 |
| 20 | 116.6 | 112.1 | 111.6 | 105.0 | 108.0 | 112.0 | 111.5 | 109.0 | 109.0 |
| 25 | 117.6 | 115.7 | 112.6 | 113.5 | 110.1 | 112.0 | 112.0 | 109.7 | 114.6 |
| 31.5 | 118.6 | 116.7 | 109.1 | 115.0 | 112.0 | 114.0 | 110.0 | 114.0 | 113.0 |
| 40 | 123.1 | 120.2 | 111.6 | 114.0 | 117.0 | 117.0 | 112.5 | 117.5 | 117.0 |
| 50 | 124.6 | 120.8 | 112.1 | 117.0 | 115.0 | 120.0 | 115.0 | 116.7 | 117.0 |
| 63 | 126.6 | 124.9 | 113.6 | 117.0 | 118.0 | 119.0 | 115.0 | 119.0 | 117.0 |
| 80 | 126.7 | 125.1 | 118.7 | 121.0 | 119.0 | 123.0 | 120.0 | 122.0 | 118.0 |
| 100 | 125.2 | 124.8 | 118.2 | 122.0 | 121.0 | 122.5 | 123.0 | 124.0 | 120.5 |
| 125 | 123.7 | 124.2 | 120.2 | 122.0 | 123.0 | 120.0 | 123.0 | 124.0 | 121.6 |
| 160 | 122.3 | 123.7 | 122.3 | 122.0 | 121.0 | 118.0 | 119.5 | 122.0 | 123.0 |
| 200 | 125.3 | 123.0 | 121.8 | 123.5 | 124.5 | 120.0 | 121.0 | 121.5 | 122.5 |
| 250 | 121.4 | 124.0 | 122.3 | 122.5 | 122.0 | 121.4 | 119.0 | 122.0 | 120.0 |
| 315 | 119.7 | 120.0 | 121.6 | 119.0 | 119.8 | 121.0 | 120.0 | 119.0 | 119.0 |
| 400 | 117.1 | 118.0 | 117.9 | 117.0 | 116.6 | 118.0 | 116.5 | 118.0 | 119.0 |
| 500 | 116.6 | 118.0 | 114.8 | 115.0 | 114.0 | 116.0 | 114.8 | 117.0 | 118.0 |
| 630 | 112.9 | 116.0 | 117.9 | 112.0 | 114.0 | 115.9 | 115.0 | 117.5 | 118.0 |
| 800 | 113.0 | 114.5 | 110.2 | 112.5 | 110.2 | 111.0 | 112.0 | 117.0 | 118.0 |
| 1000 | 112.0 | 114.0 | 108.0 | 110.0 | 110.0 | 110.0 | 109.0 | 117.4 | 119.0 |
| 1250 | 111.0 | 111.0 | 106.0 | 110.0 | 109.0 | 109.0 | 108.0 | 117.0 | 119.0 |
| 1600 | 109.0 | 111.0 | 105.1 | | | | 106.2 | | |
| 2000 | 109.0 | 111.0 | 106.1 | | | | 105.5 | | |
| 2500 | 108.0 | 111.0 | 106.0 | | | | 105.0 | | |
| OAL | | | | | | | | | |

* dB re. 20 μN/m$^2$
Corrected for instrumentation noise / reflection effect when appropriate

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Table A.2.3 - Measured Sound Pressure Levels in Payload Bay
STS-2 Lift-Off

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I10 9280 | I11 9275 | I12 9253 | I13 9252 | I14 9254 | I15 9257 | I16 9258 | I17 9256 | I18 9255 |
| 12.5 | 108.0 | 109.5 | 111.1 | 108.8 | 110.7 | 106.4 | 112.6 | 113.5 | 110.0 |
| 16 | 106.0 | 104.0 | 117.1 | 113.6 | 117.9 | 111.9 | 118.0 | 118.1 | 118.0 |
| 20 | 108.8 | 111.0 | 115.0 | 113.7 | 115.6 | 112.8 | 114.8 | 115.5 | 119.2 |
| 25 | 114.0 | 115.0 | 114.8 | 117.1 | 112.0 | 117.6 | 113.5 | 117.0 | 118.0 |
| 31.5 | 116.0 | 117.1 | 116.4 | 115.0 | 116.2 | 113.9 | 115.0 | 120.7 | 117.0 |
| 40 | 116.8 | 120.0 | 117.0 | 119.0 | 119.0 | 115.0 | 115.0 | 122.8 | 118.5 |
| 50 | 118.0 | 121.0 | 120.0 | 121.0 | 121.1 | 121.0 | 117.0 | 128.8 | 123.5 |
| 63 | 120.0 | 121.0 | 121.9 | 121.0 | 122.7 | 123.0 | 120.0 | 128.0 | 121.4 |
| 80 | 120.0 | 122.0 | 122.0 | 122.0 | 123.6 | 122.0 | 120.5 | 128.5 | 125.2 |
| 100 | 122.0 | 124.1 | 123.0 | 122.0 | 125.0 | 122.7 | 123.0 | 125.6 | 124.0 |
| 125 | 120.0 | 123.0 | 123.0 | 122.8 | 124.0 | 125.0 | 123.0 | 130.4 | 126.0 |
| 160 | 121.0 | 123.0 | 122.0 | 122.8 | 121.4 | 124.4 | 123.5 | 128.5 | 122.5 |
| 200 | 122.0 | 123.0 | 124.0 | 122.2 | 121.4 | 123.0 | 125.0 | 130.0 | 123.8 |
| 250 | 123.0 | 123.5 | 122.0 | 121.5 | 119.9 | 122.6 | 124.0 | 127.3 | 120.0 |
| 315 | 121.0 | 122.7 | 121.2 | 121.0 | 117.9 | 120.0 | 120.0 | 125.6 | 120.5 |
| 400 | 120.0 | 120.0 | 120.0 | 117.8 | 116.7 | 117.8 | 120.0 | 123.5 | 116.8 |
| 500 | 119.0 | 118.5 | 119.1 | 117.0 | 115.8 | 116.0 | 118.8 | 122.0 | 115.5 |
| 630 | 115.0 | 116.0 | 117.5 | 115.0 | 114.0 | 114.8 | 116.6 | 119.0 | 113.8 |
| 800 | 113.0 | 114.2 | 118.0 | 111.3 | 112.0 | 112.3 | 114.5 | 117.8 | 112.1 |
| 1000 | 110.0 | 113.0 | 120.0 | 109.2 | 113.0 | 111.0 | 112.0 | 119.0 | 111.0 |
| 1250 | 110.0 | 113.0 | 120.0 | 109.0 | 113.0 | 109.0 | 111.0 | 119.0 | 111.0 |
| 1600 | 109.0 | | | | | 108.3 | 109.5 | | |
| 2000 | 108.0 | | | | | 106.3 | 108.7 | | |
| 2500 | 108.0 | | | | | 106.0 | 108.0 | | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate

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Table A.2.4 - Measured Sound Pressure Levels in Payload Bay
STS-2 Transonic

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | I5 9279 | I6 9277 | I7 9281 | I8 9278 | I9 9276 |
| 12.5 | | | | | | | | | |
| 16 | | | | | | | | | |
| 20 | | | | | | | | | |
| 25 | | | | | | | | | |
| 31.5 | * | * | * | * | * | * | * | * | * |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 63 | | | | | | | | | |
| 80 | | | | | | | | | |
| 100 | | | | | | | | | |
| 125 | | | | | | | | | |
| 160 | | | | | | | | | |
| 200 | | | | | | | | | |
| 250 | 118.4 | 124.0 | 114.3 | 116.5 | 116.0 | 111.0 | 111.0 | 115.0 | 120.0 |
| 315 | 124.2 | 130.0 | 113.6 | 119.0 | 117.0 | 115.0 | 114.0 | 119.0 | 122.0 |
| 400 | 113.1 | 120.0 | 110.9 | 112.0 | 114.0 | 110.0 | 112.0 | 117.0 | 116.0 |
| 500 | | | | | | | | | |
| 630 | | | | | | | | | |
| 800 | * | * | * | * | * | * | * | * | * |
| 1000 | | | | | | | | | |
| 1250 | | | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate
Levels in these freq. bands < Lift-off levels

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Table A.2.5 - Measured Sound Pressure Levels in Payload Bay
STS-2 Transonic

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I10 9280 | I11 9275 | I12 9253 | I13 9252 | I14 9254 | I15 9257 | I16 9258 | I17 9256 | I18 9255 |
| 12.5 | | | | | | | | | |
| 16 | | | | | | | | | |
| 20 | | | | | | | | | |
| 25 | | | | | | | | | |
| 31.5 | * | * | * | * | * | * | * | * | * |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 63 | | | | | | | | | |
| 80 | | | | | | | | | |
| 100 | | | | | | | | | |
| 125 | | | | | | | | | |
| 160 | | | | | | | | | |
| 200 | | | | | | | | | |
| 250 | 115.0 | 116.5 | 124.0 | 120.0 | 119.5 | 117.0 | 121.0 | 130.0 | 115.5 |
| 315 | 117.0 | 121.0 | 125.0 | 123.0 | 122.0 | 120.0 | 122.0 | 136.0 | 117.0 |
| 400 | 116.0 | 117.0 | 119.0 | 115.0 | 114.0 | 116.0 | 118.0 | 125.0 | 114.0 |
| 500 | | | | | | | | | |
| 630 | | | | | | | | | |
| 800 | * | * | * | * | * | * | * | * | * |
| 1000 | | | | | | | | | |
| 1250 | | | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate
Levels in these freq. bands < Lift-off levels

# APPENDIX A.3

# STS-3 FLIGHT DATA

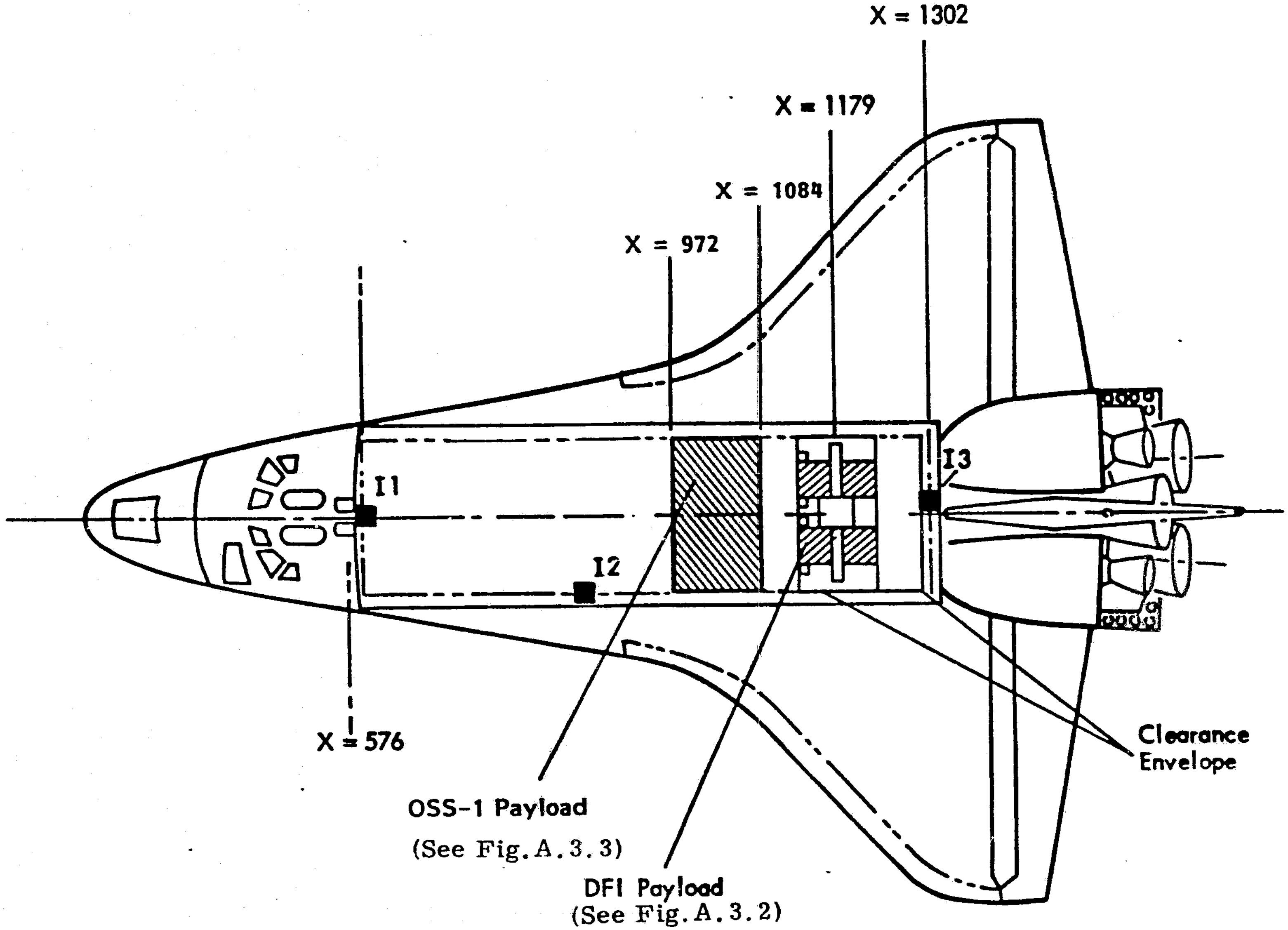


Figure A.3.1 - Payload Bay Configuration for STS-3

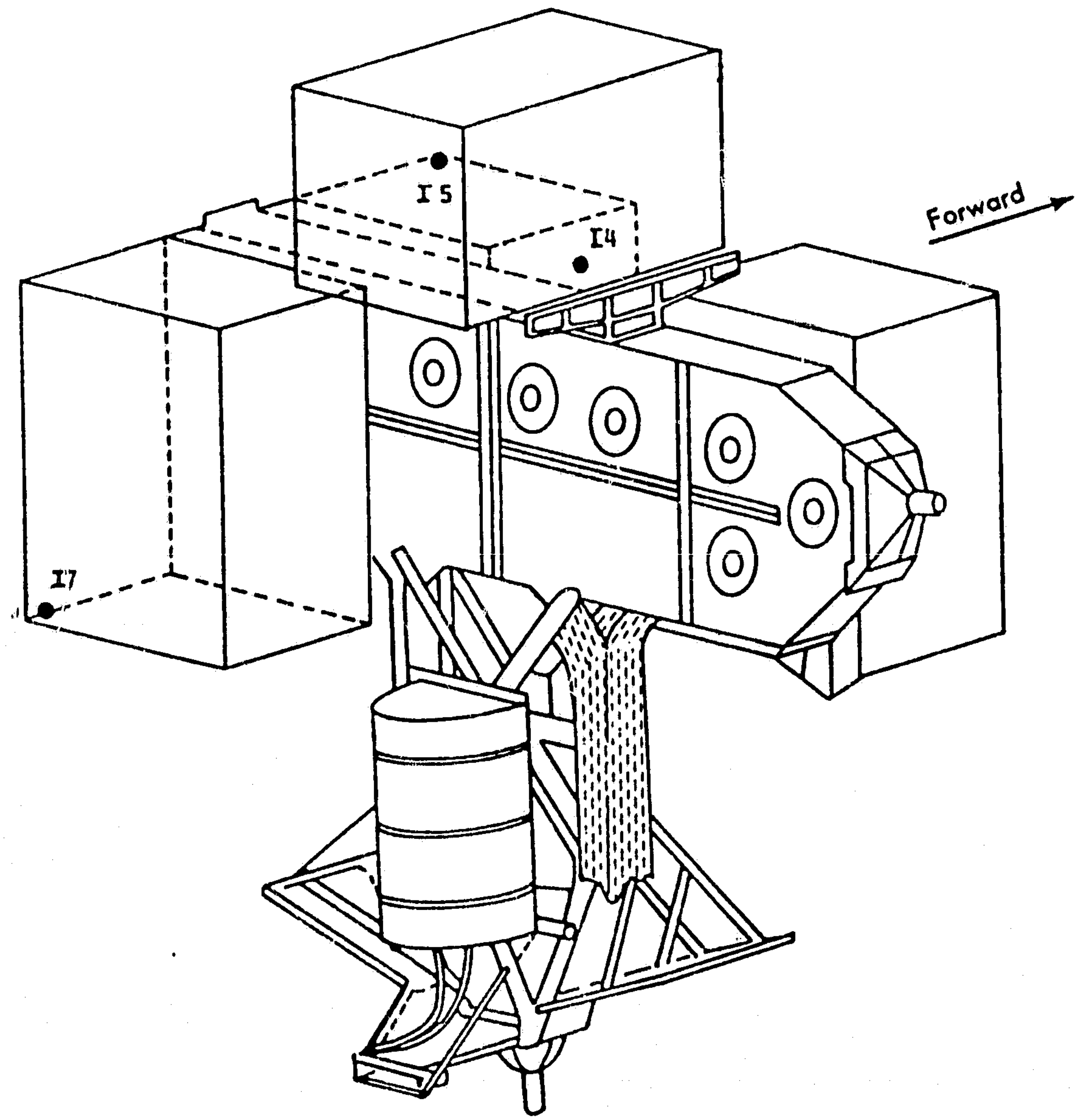


Figure A.3.2 - Microphone Locations on DFI Payload for STS-3

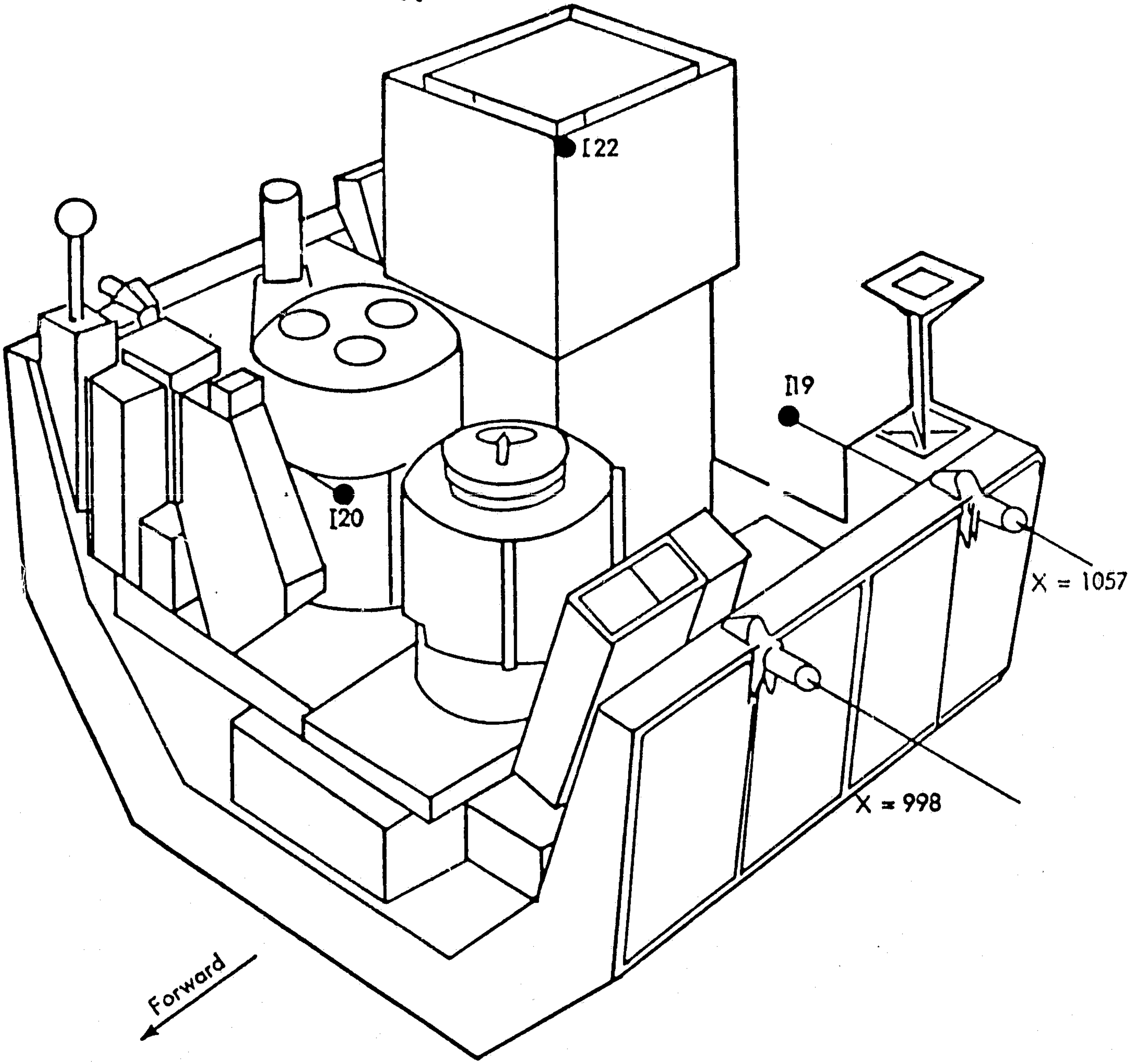


Figure A.3.3 - Microphone Locations on OSS-1 Payload for STS-3

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Table A.3.1 - Summary of Microphone Locations for STS-3

| General Location | BBN Code | NASA Code | Station Number X | Station Number Y | Station Number Z | Frequency Range* |
|---|---|---|---|---|---|---|
| Bay Structure | I1 | V08Y9405A | 576 | +4 | 423 | A |
| | I2 | V08Y9219A | 863 | -100 | 381 | A |
| | I3 | V08Y9403A | 1306 | +12 | 400 | A |
| DFI Payload | I4 | V08Y9220A | 1159 | 0 | 427 | A |
| | I5 | V08Y9275A | 1139 | -68 | 432 | B |
| | I7 | V08Y9281A | 1219 | -68 | 384 | A |
| OSS-1 Payload | I19 | V08Y9232A | 1060 | -35 | 419 | B |
| | I20 | V08Y9234A | 976 | 11 | 409 | A |
| | I22 | V08Y9231A | 1032 | -10 | 471 | B |

* A - 20 Hz to 8 kHz; B - 5 Hz to 2 kHz

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Table A.3.2 - Measured Sound Pressure Levels in Payload Bay
STS-3 Lift-Off

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | I5 9275 | I7 9281 | I19 9232 | I20 9234 | I22 9231 |
| 12.5 | 119.1 | 110.6 | 117.1 | 115.0 | 114.0 | 118.0 | 112.0 | 110.0 | 114.0 |
| 16 | 119.1 | 111.6 | 113.1 | 110.0 | 109.0 | 113.0 | 114.0 | 117.0 | 116.0 |
| 20 | 120.6 | 111.6 | 111.1 | 108.0 | 110.0 | 111.0 | 111.0 | 114.0 | 113.0 |
| 25 | 119.1 | 116.6 | 118.1 | 120.0 | 120.0 | 116.0 | 122.0 | 114.0 | 121.0 |
| 31.5 | 119.0 | 115.7 | 110.1 | 115.0 | 118.0 | 113.0 | 115.0 | 113.0 | 114.0 |
| 40 | 124.1 | 119.7 | 112.1 | 118.0 | 119.0 | 113.0 | 118.0 | 119.0 | 117.0 |
| 50 | 127.1 | 120.3 | 115.1 | 119.0 | 119.0 | 115.0 | 122.0 | 119.0 | 122.0 |
| 63 | 127.1 | 125.9 | 117.1 | 119.0 | 124.0 | 119.0 | 122.5 | 122.0 | 126.0 |
| 80 | 127.2 | 126.6 | 119.2 | 120.0 | 123.0 | 120.0 | 121.5 | 124.0 | 124.0 |
| 100 | 126.2 | 125.8 | 121.2 | 122.0 | 124.0 | 126.0 | 119.0 | 124.0 | 126.0 |
| 125 | 122.2 | 128.2 | 119.2 | 121.0 | 123.0 | 123.0 | 119.5 | 123.0 | 128.0 |
| 160 | 124.3 | 124.2 | 121.3 | 124.0 | 124.0 | 120.0 | 122.0 | 120.0 | 127.0 |
| 200 | 124.3 | 123.5 | 120.3 | 124.0 | 123.0 | 123.0 | 120.0 | 122.0 | 127.0 |
| 250 | 121.4 | 122.5 | 121.3 | 123.0 | 123.0 | 120.0 | 122.0 | 121.0 | 126.0 |
| 315 | 119.7 | 121.0 | 121.6 | 120.0 | 123.0 | 120.0 | 120.0 | 118.0 | 123.0 |
| 400 | 117.1 | 120.0 | 117.9 | 118.0 | 120.0 | 117.0 | 117.5 | 116.0 | 121.0 |
| 500 | 115.6 | 119.0 | 115.3 | 114.0 | 118.0 | 115.0 | 115.0 | 116.0 | 119.0 |
| 630 | 113.9 | 119.0 | 116.4 | 110.0 | 116.0 | 115.0 | 113.0 | 114.0 | 117.0 |
| 800 | 114.0 | 116.5 | 110.7 | 110.0 | 114.0 | 113.0 | 112.0 | 111.0 | 117.0 |
| 1000 | 113.0 | 115.0 | 108.0 | 108.0 | 113.0 | 110.0 | 111.0 | 111.0 | 116.0 |
| 1250 | 112.0 | 115.0 | 108.0 | 108.0 | 112.0 | 107.0 | 110.0 | 110.0 | 115.0 |
| 1600 | 110.0 | 113.5 | 107.0 | 107.0 | | 107.0 | | 108.0 | |
| 2000 | 109.0 | 113.0 | 106.0 | 106.0 | | 107.0 | | 107.0 | |
| 2500 | 110.0 | 113.0 | 105.0 | 105.0 | | 106.0 | | 107.0 | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate

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Table A.3.3 - Measured Sound Pressure Levels in Payload Bay
STS-3 Transonic

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | I5 9275 | I7 9281 | I19 9232 | I20 9234 | I22 9231 |
| 12.5 | | | | | | | | | |
| 16 | | | | | | | | | |
| 20 | | | | | | | | | |
| 25 | | | | | | | | | |
| 31.5 | * | * | * | * | * | * | * | * | * |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 63 | | | | | | | | | |
| 80 | | | | | | | | | |
| 100 | | | | | | | | | |
| 125 | | | | | | | | | |
| 160 | | | | | | | | | |
| 200 | | | | | | | | | |
| 250 | 118.9 | 122.5 | 111.3 | 113.5 | 116.0 | 110.0 | 113.0 | 114.5 | 115.0 |
| 315 | 125.2 | 129.5 | 111.6 | 113.0 | 117.0 | 111.0 | 116.0 | 121.0 | 117.0 |
| 400 | 113.6 | 118.0 | 111.9 | 111.0 | 115.0 | 112.0 | 117.5 | 114.5 | 114.0 |
| 500 | | | | | | | | | |
| 630 | | | | | | | | | |
| 800 | * | * | * | * | * | * | * | * | * |
| 1000 | | | | | | | | | |
| 1250 | | | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate
Levels in these freq. bands < Lift-off levels

# APPENDIX A.4

# STS-4 FLIGHT DATA

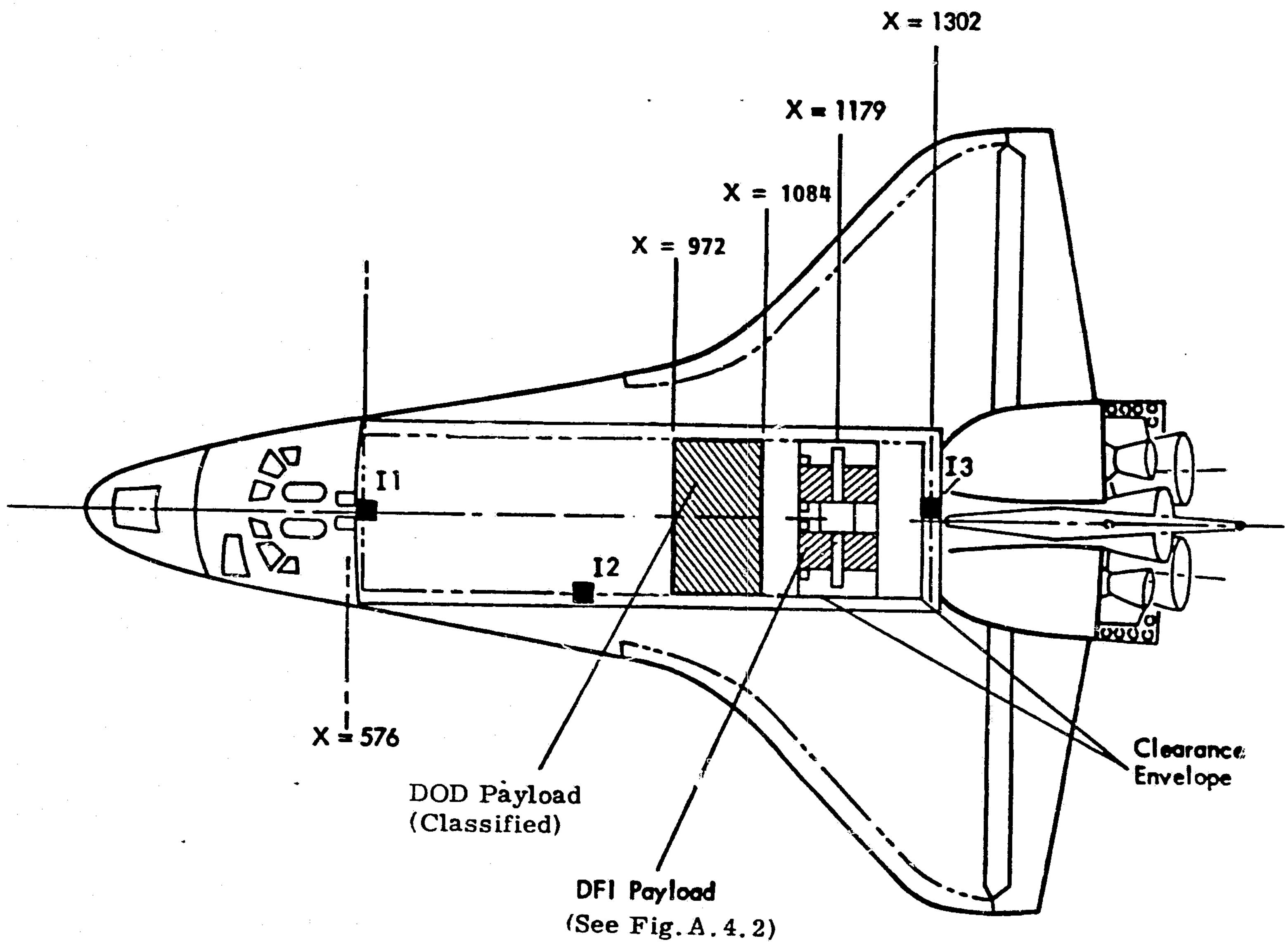


Figure A.4.1 - Payload Bay Configuration for STS-4

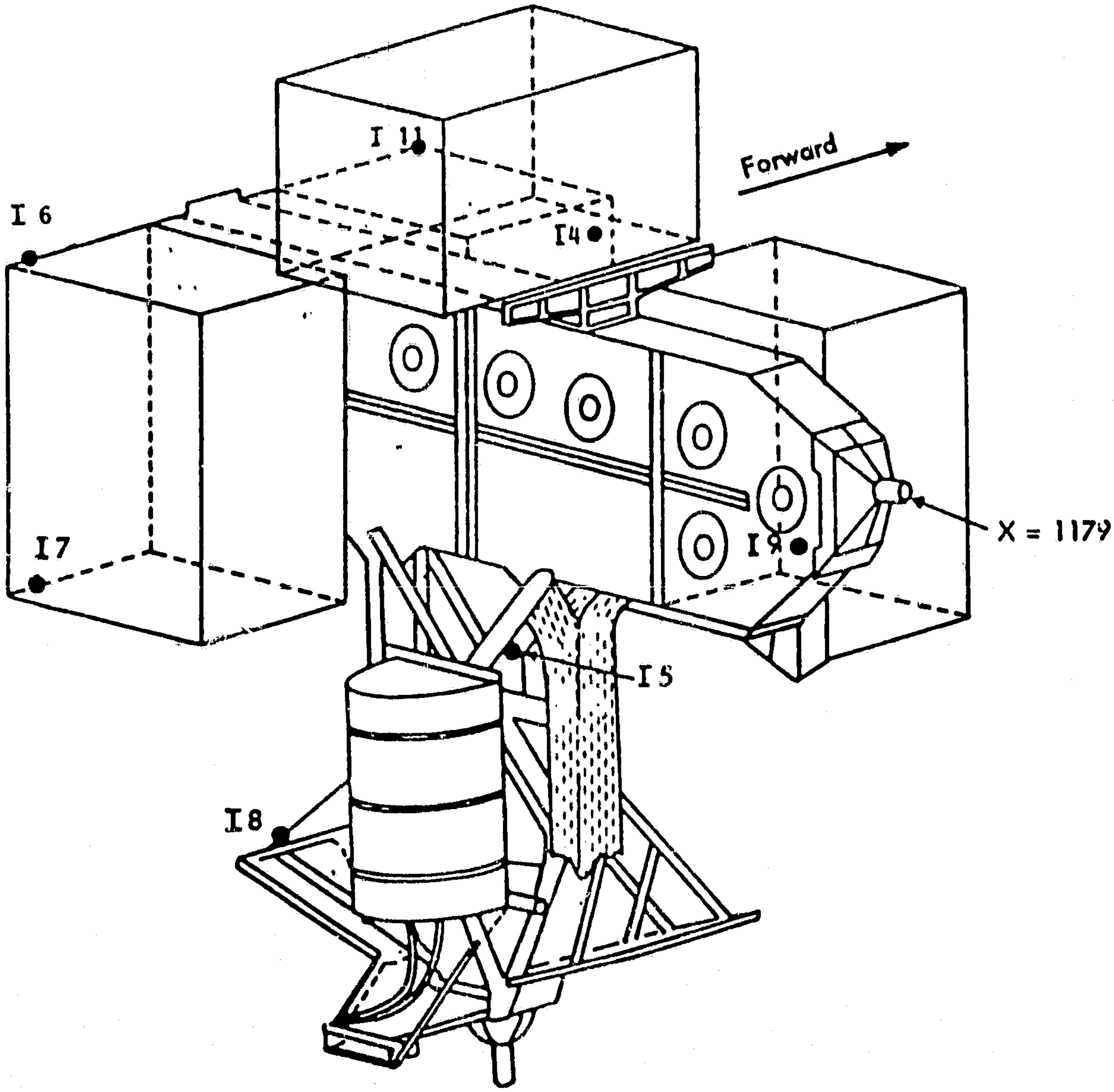


Figure A.4.2 - Microphone Locations on DFI Payload for STS-4

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Table A.4.1 - Summary of Microphone Locations For STS-4

| General Location | BBN Code | NASA Code | Station Number X | Y | Z | Frequency Range* |
|---|---|---|---|---|---|---|
| Bay | I1 | V08Y9405A | 576 | +4 | 423 | A |
| Structure | I2 | V08Y9219A | 863 | -100 | 381 | A |
| | I3 | V08Y9403A | 1306 | +12 | 400 | A |
| DFI | I4 | V08Y9220A | 1159 | 0 | 427 | A |
| Payload | I5 | V08Y9279A | 1192 | +15 | 384 | B |
| | I6 | V08Y9277A | 1219 | -68 | 432 | A |
| | I7 | V08Y9281A | 1219 | -68 | 384 | B |
| | I8 | V08Y9278A | 1194 | -44 | 328 | B |
| | I9 | V08Y9276A | 1139 | +20 | 384 | A |
| | I11 | V08Y9275A | 1139 | -68 | 432 | B |
| DOD Payload (Classified) | I23 | V08Y9642A | | | | B |

*A-20 Hz to 8kHz; B-5 Hz to 2kHz

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Table A.4.2 - Measured Sound Pressure Levels in Payload Bay
STS-4 Lift-Off

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | I5 9279 | I6 9277 | I7 9281 | I8 9278 | I9 9276 |
| 12.5 | 116.9 | 108.5 | 115.4 | 112.0 | 117.0 | 116.7 | 117.7 | 118.4 | 114.5 |
| 16 | 120.1 | 116.1 | 114.6 | 105.9 | 111.2 | 114.8 | 115.2 | 112.9 | 107.9 |
| 20 | 115.9 | 112.1 | 112.9 | 105.2 | 105.6 | 110.8 | 111.1 | 108.4 | 105.7 |
| 25 | 115.9 | 115.5 | 111.5 | 111.6 | 107.4 | 111.2 | 111.2 | 109.9 | 112.3 |
| 31.5 | 118.7 | 116.6 | 107.6 | 112.5 | 109.3 | 112.3 | 110.1 | 112.3 | 111.7 |
| 40 | 123.6 | 119.2 | 107.2 | 116.4 | 112.8 | 113.7 | 111.2 | 114.0 | 115.3 |
| 50 | 124.0 | 121.5 | 110.9 | 116.8 | 112.0 | 118.3 | 112.1 | 115.1 | 117.3 |
| 63 | 127.7 | 123.5 | 113.0 | 118.4 | 120.2 | 120.8 | 117.3 | 120.3 | 119.1 |
| 80 | 126.9 | 124.2 | 117.2 | 120.1 | 119.8 | 120.6 | 119.3 | 123.7 | 117.9 |
| 100 | 123.8 | 122.2 | 119.6 | 122.3 | 119.7 | 121.9 | 123.1 | 122.0 | 121.3 |
| 125 | 124.2 | 123.6 | 119.2 | 121.4 | 121.0 | 120.2 | 122.2 | 122.6 | 121.1 |
| 160 | 123.0 | 123.2 | 122.2 | 120.5 | 121.2 | 119.5 | 119.4 | 121.4 | 121.7 |
| 200 | 124.0 | 124.4 | 120.8 | 122.6 | 122.6 | 121.5 | 120.2 | 120.9 | 122.0 |
| 250 | 120.6 | 124.2 | 120.2 | 122.2 | 120.8 | 121.7 | 118.9 | 121.1 | 121.9 |
| 315 | 118.3 | 121.2 | 120.0 | 119.0 | 117.3 | 120.6 | 120.0 | 117.5 | 119.0 |
| 400 | 115.3 | 120.6 | 117.0 | 117.5 | 115.5 | 117.9 | 115.5 | 116.5 | 117.6 |
| 500 | 115.3 | 120.9 | 114.6 | 114.2 | 113.9 | 115.9 | 114.3 | 115.0 | 115.7 |
| 630 | 113.1 | 119.3 | 116.5 | 111.5 | 113.9 | 115.0 | 115.3 | 115.7 | 112.8 |
| 800 | 113.3 | 116.9 | 109.4 | 109.5 | 109.8 | 110.3 | 111.1 | 112.6 | 110.0 |
| 1000 | 112.8 | 115.6 | 106.5 | 108.6 | 110.1 | 108.0 | 108.7 | 110.8 | 108.3 |
| 1250 | 112.1 | 115.5 | 106.9 | 107.9 | 110.0 | 106.6 | 107.8 | 111.0 | 107.0 |
| 1600 | 110.8 | 114.5 | 105.9 | 107.4 | | 106.1 | | | 106.5 |
| 2000 | 110.3 | 114.1 | 106.3 | 107.6 | | 105.9 | | | 106.3 |
| 2500 | 110.0 | 114.2 | 106.0 | 108.0 | | 105.7 | | | 106.9 |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$.
Corrected for instrumentation noise / reflection effect when appropriate

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Table A.4.3 - Measured Sound Pressure Levels in Payload Bay
STS-4 Lift-Off

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I11 9275 | I23 9642 | | | | | | | |
| 12.5 | 113.3 | 111.3 | | | | | | | |
| 16 | 108.7 | 117.6 | | | | | | | |
| 20 | 110.2 | 116.1 | | | | | | | |
| 25 | 115.5 | 113.2 | | | | | | | |
| 31.5 | 115.6 | 118.4 | | | | | | | |
| 40 | 118.6 | 118.7 | | | | | | | |
| 50 | 119.7 | 120.7 | | | | | | | |
| 63 | 123.4 | 122.5 | | | | | | | |
| 80 | 121.4 | 123.0 | | | | | | | |
| 100 | 122.3 | 121.2 | | | | | | | |
| 125 | 121.3 | 123.6 | | | | | | | |
| 160 | 122.9 | 123.8 | | | | | | | |
| 200 | 124.5 | 124.2 | | | | | | | |
| 250 | 122.9 | 120.7 | | | | | | | |
| 315 | 121.5 | 119.9 | | | | | | | |
| 400 | 119.2 | 119.3 | | | | | | | |
| 500 | 117.1 | 117.7 | | | | | | | |
| 630 | 115.4 | 117.6 | | | | | | | |
| 800 | 113.4 | 115.5 | | | | | | | |
| 1000 | 112.6 | 115.5 | | | | | | | |
| 1250 | 112.6 | 114.0 | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 μN/m²
Corrected for instrumentation noise / reflection effect when appropriate

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Table A.4.4 - Measured Sound Pressure Levels in Payload Bay
STS-4 Transonic

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I1 9405 | I2 9219 | I3 9403 | I4 9220 | I5 9279 | I6 9277 | I7 9281 | I8 9278 | I9 9276 |
| 12.5 | | | | | | | | | |
| 16 | | | | | | | | | |
| 20 | | | | | | | | | |
| 25 | | | | | | | | | |
| 31.5 | * | * | * | * | * | * | * | * | * |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 63 | | | | | | | | | |
| 80 | | | | | | | | | |
| 100 | | | | | | | | | |
| 125 | | | | | | | | | |
| 160 | | | | | | | | | |
| 200 | | | | | | | | | |
| 250 | 118.7 | 121.8 | 112.9 | 112.1 | 110.9 | 110.2 | 109.5 | 112.8 | 116.8 |
| 315 | 121.0 | 128.0 | 112.4 | 114.3 | 112.9 | 109.1 | 110.8 | 113.5 | 118.3 |
| 400 | 111.6 | 118.8 | 109.5 | 109.8 | 110.9 | 108.1 | 108.7 | 110.5 | 112.8 |
| 500 | | | | | | | | | |
| 630 | * | * | * | * | * | * | * | * | * |
| 800 | | | | | | | | | |
| 1000 | | | | | | | | | |
| 1250 | | | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 $\mu N/m^2$
Corrected for instrumentation noise / reflection effect when appropriate
Levels in these freq. bands < Lift-off levels

Table A.4.5 - Measured Sound Pressure Levels in Payload Bay
STS-4 Transonic

| 1/3 OB Cent. Freq. Hz | One-Third Octave Band Sound Pressure Levels (dB) by Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I11 9275 | I23 9642 | | | | | | | |
| 12.5 | | | | | | | | | |
| 16 | | | | | | | | | |
| 20 | | | | | | | | | |
| 25 | | | | | | | | | |
| 31.5 | * | * | | | | | | | |
| 40 | | | | | | | | | |
| 50 | | | | | | | | | |
| 63 | | | | | | | | | |
| 80 | | | | | | | | | |
| 100 | | | | | | | | | |
| 125 | | | | | | | | | |
| 160 | | | | | | | | | |
| 200 | | | | | | | | | |
| 250 | 114.5 | 124.4 | | | | | | | |
| 315 | 113.4 | 123.0 | | | | | | | |
| 400 | 111.0 | 119.5 | | | | | | | |
| 500 | | | | | | | | | |
| 630 | | | | | | | | | |
| 800 | * | * | | | | | | | |
| 1000 | | | | | | | | | |
| 1250 | | | | | | | | | |
| 1600 | | | | | | | | | |
| 2000 | | | | | | | | | |
| 2500 | | | | | | | | | |
| OAL | | | | | | | | | |

* dB re. 20 μN/$m^2$
Corrected for instrumentation noise / reflection effect when appropriate
Levels in these freq. bands < Lift-off levels

# APPENDIX B

# SURFACE REFLECTION CORRECTIONS

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APPENDIX B

SURFACE REFLECTION CORRECTIONS

The surface reflection problem relates to the fact that on all STS flights, the bulkhead microphones (I1 and I3) were mounted very close to the bulkhead surface; I1 was 0.066m (2.6 in.) from the forward bulkhead and I3 was 0.046m (1.8 in.) from the aft bulkhead. The sidewall microphone (I2) was also mounted close to the orbiter structure. It can be anticipated that the measurements made by these microphones located close to large surfaces will include significant reflection effects.

The increase in sound pressure levels in a reverberant enclosure due to surface reflections has been evaluated by Waterhouse [1]. An extension of those results to include the effects of surface absorption leads to the relationship by Piersol [2].

$$\overline{p_x^2} \,/\, \overline{p_o^2} = \frac{(1+a^2)}{2} + \frac{a}{kx} \sin kx \cos (kx + \phi) \qquad \text{(B.1)}$$

where:

$\overline{p_x^2}$ = mean square pressure x meters from the reflecting surface,

$\overline{p_o^2}$ = space averaged mean square pressure in the enclosure,

$a^2$ = $1 - \alpha$ where $\alpha$ = absorption coefficient,

$k$ = $2\pi f/c$ where c = speed of sound,

$\phi$ = phase shift of reflected waves.

Again, Eq (B.1) assumes a highly reverberant (diffuse) noise field which will not be fully representative of the noise field inside the payload bay at all frequencies. At the lower frequencies (below 30 Hz or so), the bay levels will be dominated by standing waves, while at the higher frequencies where surface absorption values are large (above 250 Hz or so), the sound pressure levels near reflecting surfaces will not be diffuse. At the higher frequencies, the lack of a diffuse field implies that the predictions of Eq (B.1) yield only crude approximations.

Based on the assumption of no phase shift of reflected waves and that amplitude changes are due to absorption only, the contribution of surface reflections in the various measurements of interest can be predicted using Eq

(B.1) with the results shown in table B.1. The negative correction factors predicted by Eq (B.1) are assumed zero for the purpose of correcting the measurements from STS flights. With this assumption the measurement results from microphones I1 through I3 were corrected.

References:

1. R.V. Waterhouse, "Inteference Patterns in Reverberant Sound Fields," Journal of the Acoustical Society of America, Vol. 27, No. 2, pp. 247-258, March 1955.

2. A.G. Piersol, "Bias Error Corrections for Acoustic Data From Space Shuttle FRF and STS-1 through STS-3", BBN Report 4547, Bolt Beranek and Newman Inc., Canoga Park, California, December 1981.

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## TABLE B.1 SURFACE REFLECTION CORRECTIONS

| 1/3 O.B. CENTER FREQ. (HZ.) | FORWARD BULKHEAD I1 | SIDE I2 | AFT BULKHEAD I3 |
|---|---|---|---|
| 12.5 | 2.9 | 2.9 | 2.9 |
| 16 | 2.9 | 2.9 | 2.9 |
| 20 | 2.9 | 2.9 | 2.9 |
| 25 | 2.9 | 2.9 | 2.9 |
| 31.5 | 2.9 | 2.8 | 2.9 |
| 40 | 2.9 | 2.8 | 2.9 |
| 50 | 2.9 | 2.7 | 2.9 |
| 63 | 2.9 | 2.6 | 2.9 |
| 80 | 2.8 | 2.4 | 2.8 |
| 100 | 2.8 | 2.2 | 2.8 |
| 125 | 2.8 | 1.8 | 2.8 |
| 160 | 2.7 | 1.3 | 2.7 |
| 200 | 2.7 | 0.5 | 2.7 |
| 250 | 2.6 | -0.5 | 2.7 |
| 315 | 2.3 | -1.5 | 2.4 |
| 400 | 1.9 | -1.5 | 2.1 |
| 500 | 1.4 | -0.8 | 1.7 |
| 630 | 1.1 | -0.5 | 1.6 |
| 800 | 0.6 | 0 | 1.3 |
| 1000 | 0 | 0 | 1.0 |
| 1250 | -0.9 | 0 | 0.5 |
| 1600 | -1.8 | 0 | -0.3 |
| 2000 | -1.9 | 0 | -1.3 |
| 2500 | -1.0 | 0 | -1.9 |
| 3150 | -0.4 | 0 | -1.7 |
| 4000 | -1.1 | 0 | -0.7 |

# APPENDIX C

# INSTRUMENTATION BACKGROUND NOISE

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# APPENDIX C

## INSTRUMENTATION BACKGOUND NOISE

In many cases of acoustic data acquisition and reduction, the valid frequency range of the measured data is often limited by the effects of "instrumentation background" noise. The microphone measurements on the STS-1 through STS-4 flights were acquired via a Frequency Modulation (FM) multiplex system with a frequency bandwidth of either 2000 Hz or 8000 Hz. In almost all the flight measurements the acoustic data were contaminated by background noise above a certain frequency depending upon the data acquisition frequency bandwidth.

In figures C.1 and C.2 the presence of background noise contaminating an one-third octave band spectrum is characterized by the sudden reversal of increased spectrum levels which follows a trend similar in slope to the "noise floor" spectrum. This criteria was adopted in determining the valid frequency range for the acoustic data. Applying this criteria, the valid cut off frequency for the 2000 Hz and 8000 Hz bandwidth data was estimated to be 1000 Hz and 2000 Hz, respectively.

The one-third octave band levels were further edited for background noise based on the following procedures:

a. If the maximum level during flight is at least 10 dB above the background noise, no correction is applied to the data.

b. If the maximum level during flight is at least 3 dB but less than 10 dB above the background noise, the data are corrected for background noise using the relationship,

$$\text{corrected dB} = 10 \log\left[10^{(dB_r/10)} - 10^{(dB_b/10)}\right] \tag{1}$$

where $dB_r$ is the sound pressure level as read during flight and $dB_b$ is the background noise level.

c. If the maximum level during flight is less than 3 dB above the background noise, the data are considered too contaminated by noise to be useful and are discarded.

This method of correcting for background noise assumes that the signal designated as "background" has a constant level independent of flight events. The validity of the assumption is not known precisely for the present situation, but appears to be supported by the close similarity in background noise level measured at pre-SSME engine ignition time event at T-20 sec.

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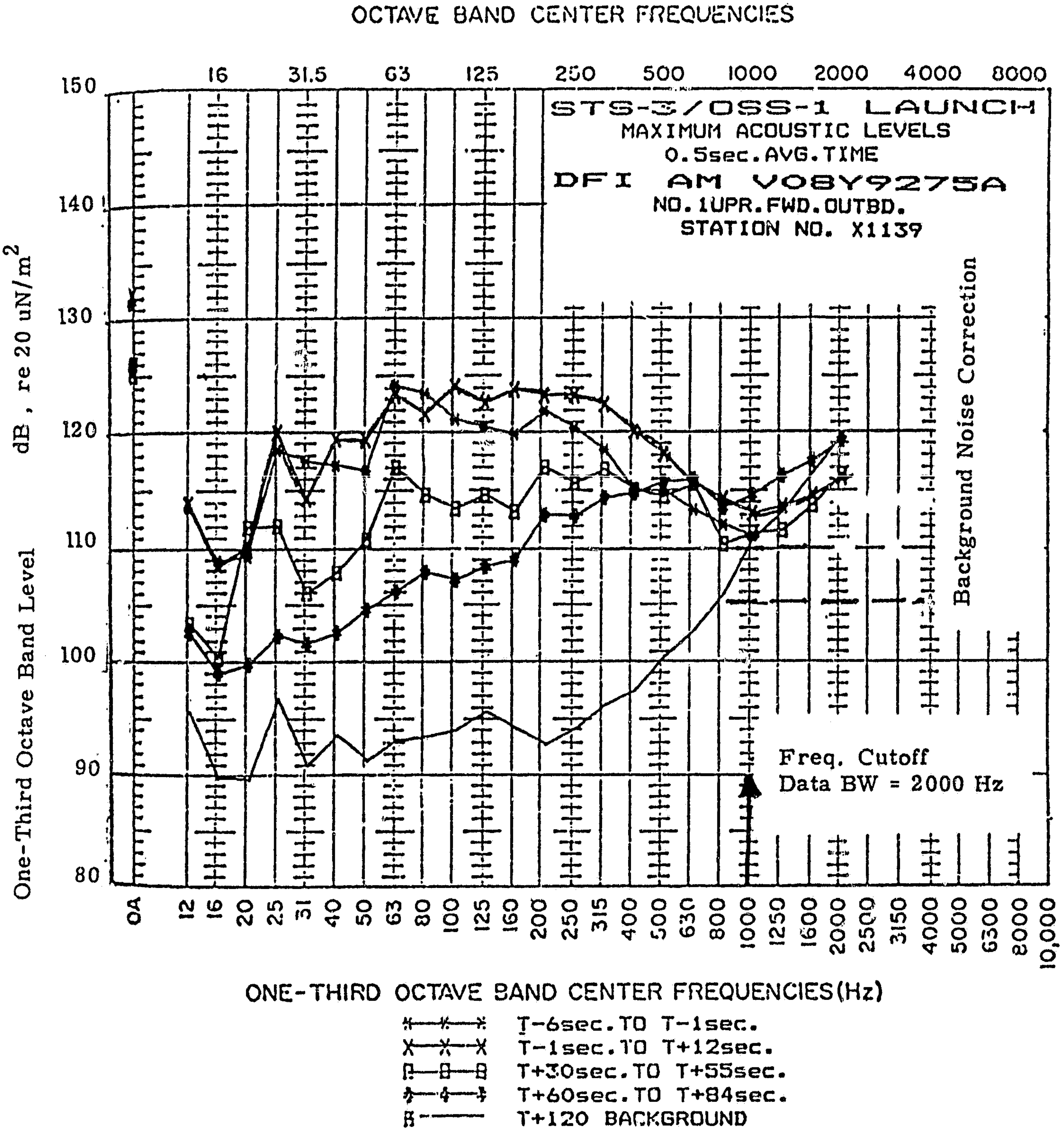


Figure C.1 - Example of Instrumentation Background Noise Effect on 2000 Hz Bandwidth Data

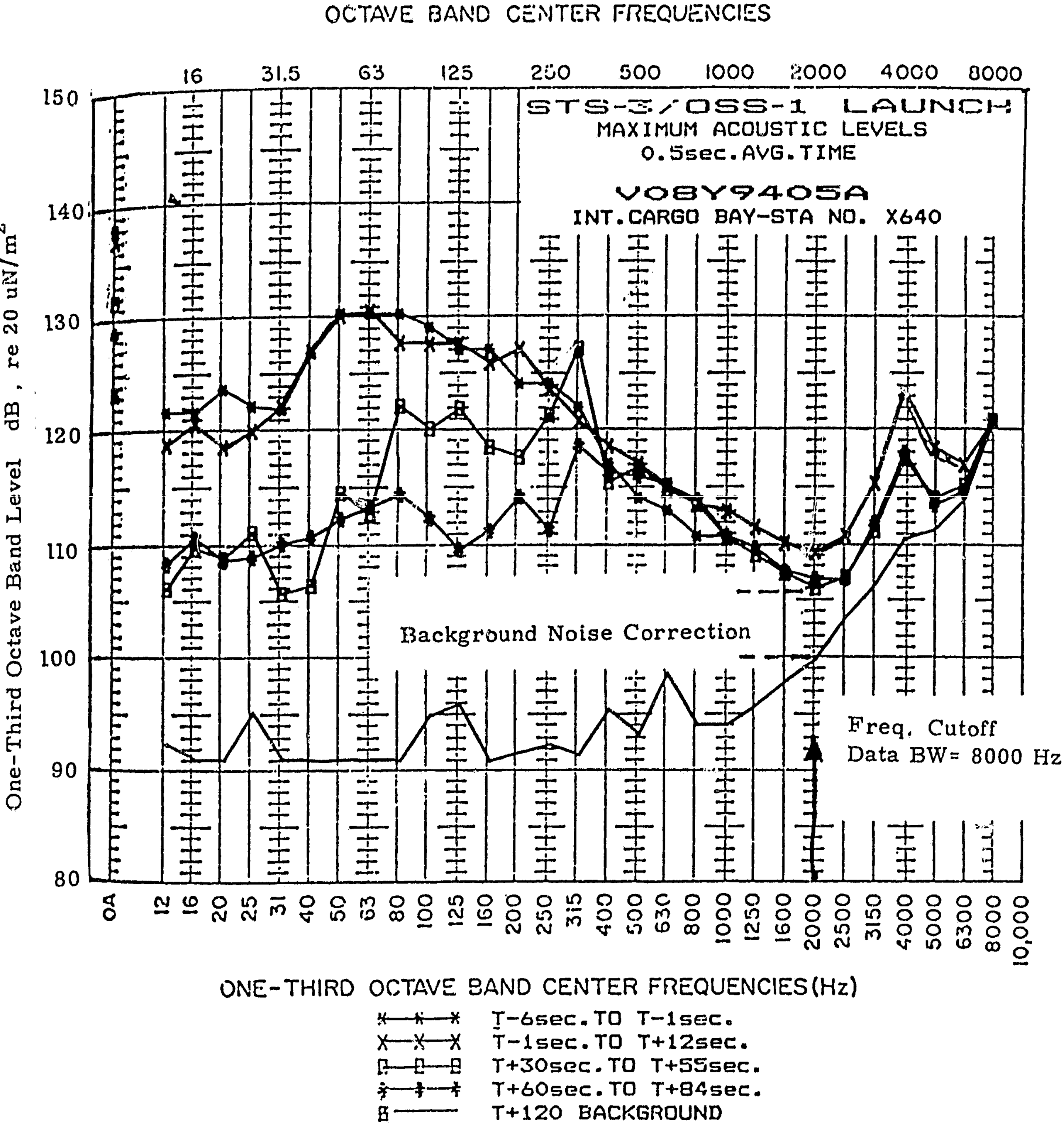


Figure C.2 - Example of Instrumentation Background Noise Effect on 8000 Hz Bandwidth Data