N83-25769

NASA Contractor Report 159956

SPACE SHUTTLE PAYLOAD BAY ACOUSTICS PREDICTION STUDY

VOLUME IIIA ADDENDUM TO COMPUTER USERS' MANUAL

J.F. Wilby

E.G. Wilby

BOLT BERANEK AND NEWMAN INC.
Canoga Park, California 91303

Contract No. NAS5-26570

January 1983

NASA

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 SUMMARY

Since the publication of the Computer Users' Manual for PACES, the analytical model has been validated by means of measured data from the first three shuttle lift-offs. During the validation process, new information became available and five changes have been made to the input data and the computer program. Three changes affect the user. They are:-

(a) A revision to the recommended exterior sound pressure levels (See Section 3.0)

(b) A revision to the recommended payload bay acoustic absorption coefficients (See Section 4.0)

(c) A revision to the vertical station datum for the payload bay (See Section 5.0).

The two other changes do not involve the user. The changes are associated with the output of confidence limits for the predicted space-average sound pressure levels in the payload bay, and a modification to the analytical representation of the payload bay door. The changes are discussed briefly in this Addendum to the Computer Users' Manual.

2.0 INTRODUCTION

2.1 General

The PACES (Payload Acoustics Environment for Shuttle) computer program, developed from the analytical model described in [1], provides a means of predicting the sound levels in the payload bay of the Space Shuttle orbiter vehicle at lift-off. The development of the analytical model included a number of validation tests involving the OV-101 test vehicle and one-fifth and one-quarter scale models. This development process is described in Volumes I, II, IV and V of NASA Contractor Report CR-159956 [1]. Volume III of the same report consists of a users' manual for the PACES computer program.

Subsequent to the publication of NASA CR-159956 in March 1980, acoustic measurements were made on the exterior of the orbiter vehicle and in the payload bay during lift-off for the first three shuttle launches [2-4] designated STS-1, STS-2 and STS-3. Data from these launches were analyzed [5-7] with the purpose of validating the PACES computer program under actual launch conditions and with an essentially empty payload bay. The results of these analyses indicated several ways in which the accuracy of the predictions could be improved either by modifying input data to the program, by changing assumptions adopted in the computation process, or by additions to the computer program output. These improvements are discussed in this report, which is an addendum to the computer users' manual (Volume III of [1]).

2.2 Computer Program Modifications

It should be emphasized that the modifications to the PACES computer program do not involve changes to the analytical model.

Rather they consist of modifications to the manner in which computations are performed or updates made to the input data. The modifications are:-

(a) Revisions to the recommended exterior sound pressure level to take into account actual lift-off measurements.

(b) Revisions to recommended acoustic absorption coefficients for the payload and payload bay to take into account the use of TCS material on the forward and aft bulkheads, and thermal insulation material on payload surfaces.

(c) Change of the reference Z station used in the computer program to allow for the application of PACES to payloads with a diameter of 15 feet (the maximum permissible within the payload envelope).

(d) Provision of confidence limits for the estimated space-average sound pressure levels in the payload bay.

(e) Changes to the assumptions adopted in the representation of the dynamic characteristics of the payload bay door.

The modifications have a small impact on the tasks performed by the user. Items (a) and (b) simply replace values recommended previously on the basis of information available before the first launch of the Space Shuttle. Item (c) corrects an error in the Z datum contained in PACES. Item (d) is an addition to the computer program to provide the automatic output of confidence limits for all predicted space-average sound pressure levels. Finally, item (e) constitutes a change to the structural data package, which is outside the control of the user.

In summary, the user should note items (a), (b) and (c) before preparing an input data package for PACES. The user has no control over items (d) and (e). Users of PACES should still refer to Volume III of [1] as the program manual. The present addendum is presented solely as a supplement to Volume III.

3.0 EXTERIOR SOUND PRESSURE LEVELS

In Section 5.1 of Volume III cards 8 through 31 define the space-average sound pressure level spectra (in one-third octave frequency bands) on the exterior of the payload bay. The exterior surfaces are divided into six areas -- payload bay door, forward and aft regions of the bottom, forward and aft regions of the sidewall, and the aft bulkhead at X = 1307. Space-average sound levels are required for each area. The data for the cards are to be selected by the user but, on page 29 of Volume III, the user is referred to recommended levels provided in Volume II.

Since the publication of Volumes II and III, measurements made during STS-1, STS-2 and STS-3 indicate that the exterior levels given in Volume II (and based on 6.4% scale model tests) do not match the actual lift-off values. Consequently the recommended exterior sound pressure levels have been modified by averaging data from STS-2 and STS-3 launches. (Data from STS-1 have been excluded because the ramp water injection system was changed following STS-1 launch). The resulting sound presssure level spectra are plotted in Figure 1 and tabulated in Table 1. The spectra contain measured data for the frequency range 12.5 Hz to 1600 Hz. Data at higher frequencies were excluded because of signal contamination. Thus the spectra were extrapolated from 1600 Hz to 4000 Hz by inspection.

It is recommended that the spectra contained in Figure 1 and Table 1 now be used as data input to PACES, in place of values given in Volume II.

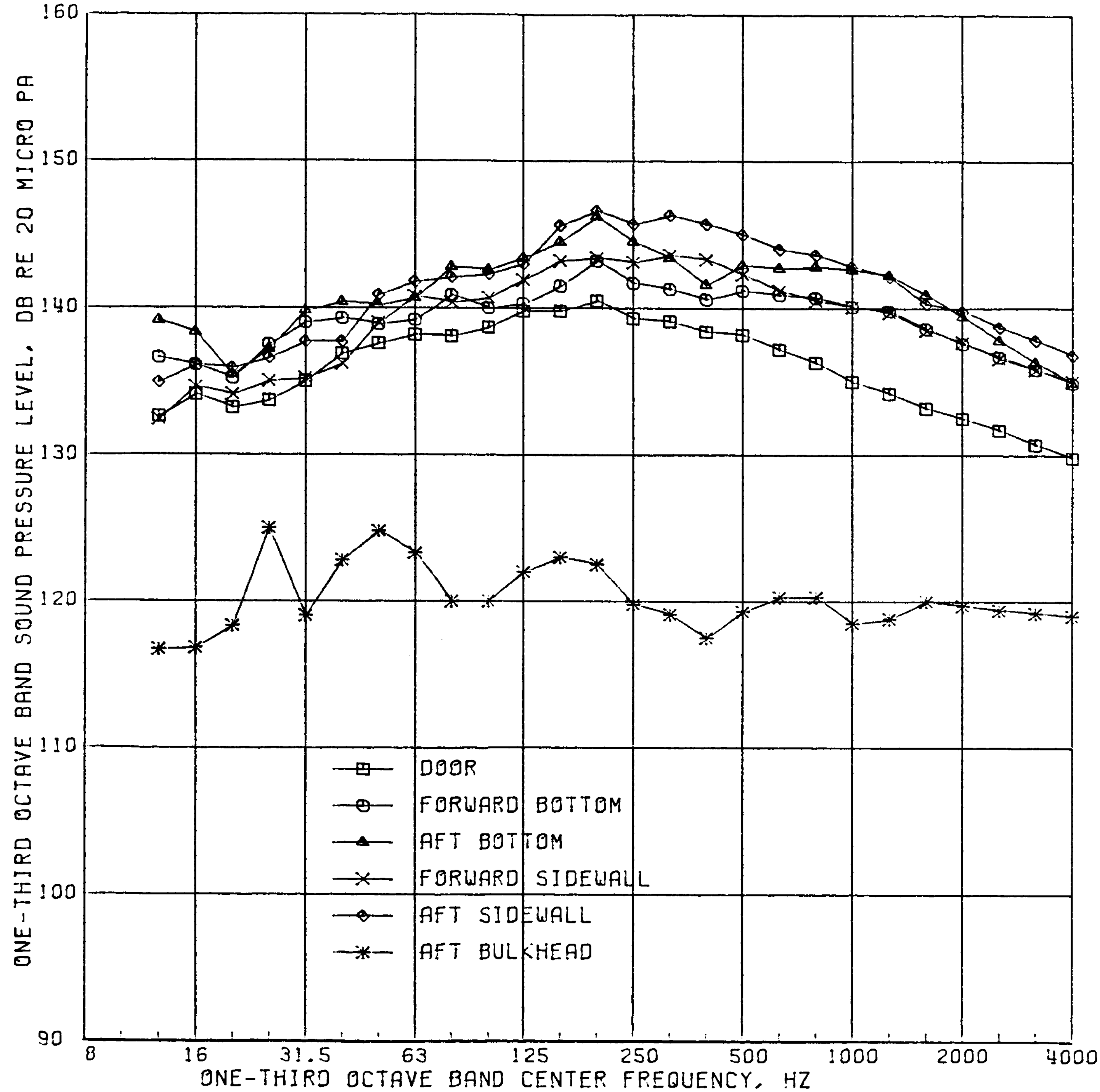

FIGURE 1. EXTERNAL SOUND PRESSURE LEVELS ON DIFFERENT STRUCTURAL REGIONS (AVERAGE OF STS-2 AND STS-3 DATA)

Table 1. Estimated External Space-Average Sound Pressure Levels*

Frequency Hz	One-Third Octave Band Sound Pressure Level, dB re 20 μPa					
	Door	Fwd Bottom STA 582-1191	Aft Bottom STA-1191-1307	Fwd Sidewall STA 582-1040	Aft Sidewall STA 1040-1307	Aft Bulkhead
12.5	132.6	136.6	139.1	132.4	134.9	116.7
16.0	134.1	136.1	138.3	134.6	136.1	116.8
20.0	133.2	135.2	135.4	134.1	135.9	118.3
25.0	133.7	137.5	137.2	135.0	136.6	125.0
31.5	135.0	139.0	139.8	135.2	137.7	119.0
40.0	136.9	139.3	140.4	136.2	137.7	122.8
50.0	137.6	138.9	140.2	139.0	140.9	124.8
63.0	138.2	139.2	140.7	140.8	141.8	123.3
80.0	138.1	140.9	142.8	140.4	142.1	120.0
100.0	138.7	140.0	142.6	140.7	142.3	120.0
125.0	139.8	140.3	143.4	141.9	143.0	122.0
160.0	139.8	141.5	144.5	143.2	145.6	123.0
200.0	140.5	143.2	146.2	143.4	146.6	122.5
250.0	139.3	141.7	144.5	143.1	145.7	119.8
315.0	139.1	141.3	143.4	143.6	146.3	119.1
400.0	138.4	140.6	141.6	143.3	145.7	117.5
500.0	138.2	141.2	142.9	142.3	145.0	119.3
630.0	137.2	140.9	142.7	141.2	144.0	120.3
800.0	136.3	140.7	142.8	140.5	143.6	120.3
1000.0	135.0	140.1	142.6	140.1	142.8	118.5
1250.0	134.2	139.8	142.2	139.7	142.1	118.8
1600.0	133.2	138.6	140.9	138.5	140.3	120.0
2000.0	132.5	137.6	139.4	137.7	139.8	119.7
2500.0	131.7	136.7	137.8	136.6	138.7	119.4
3150.0	130.7	135.8	136.3	135.8	137.8	119.2
4000.0	129.8	134.9	134.9	135.0	136.8	119.0

* Based on Results from STS-2 and STS-3

4.0 ACOUSTIC ABSORPTION COEFFICIENTS

In Section 5.1 of Volume III, Payload Cards 4 + 3n through 3 + 27n constitute n sets of 24 cards which define the acoustic absorption coefficient spectra for the six surfaces of each sub-volume. Also, Payload Cards 4 + 28n through 3 + 32n constitute a set of 4n cards which define the absorption coefficient spectra for the non-bounding payload surfaces in the n sub-volumes. Values of the absorption coefficients are to be selected by the user.

Table 6 of Volume II provides absorption coefficients estimated for the payload and payload bay surfaces. The table has now been revised to allow for the TCS material which is installed on the forward (X = 582) and aft (X = 1307) bulkheads. Also, allowance is made for the possible use of thermal insulation material (referred to here under the generic TPS designation) on surfaces of the payload. Use of such material on payloads was observed for the early shuttle launches. Revised absorption coefficient spectra are given in Table 2 for the payload bay surfaces, and in Table 3 for payload surfaces.

In the case of the payload, two extreme conditions are presented. One extreme refers to a payload which has no surfaces treated with TCS (or equivalent) material, and the other is associated with payloads for which all the surface area is treated with TCS material. Table 3 provides absorption coefficient data for both conditions, with α_o referring to surfaces without TCS and α_t to surfaces with TCS material.

Should the payload be only partially covered by TCS material, an average absorption coefficient $\bar{\alpha}$ can be estimated by:-

$$\bar{\alpha} = \frac{\alpha_o S_o + \alpha_t S_t}{S_o + S_t} \qquad (1)$$

In Eq.(1) S_o and S_t are, respectively, the areas of the surfaces without and with TCS material. Values of α_o and α_t are obtained from Table 3.

Table 2. Estimated Absorption Coefficients for Payload Bay

Frequency (Hz)	Door	Bulkhead	Sidewall & Bottom (Base)	Sidewall with TCS			Bottom with TCS			TCS Beneath Payload
				STA582-919	STA919 1307	Average	STA582-919	STA919-1307	Average	
12.5	0.100	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
16		0.043	0.040	0 043	0.065	0.054	0.043	0.065	0.054	0.065
20		0.045	0.040	0.045	0.090	0.068	0.045	0.090	0.068	0.090
25		0.048	0.040	0.048	0.114	0.081	0.048	0.114	0.081	0.115
31.5		0.050	0.040	0.050	0.140	0.095	0.050	0.140	0.095	0.140
40		0.055	0.040	0.055	0.140	0.098	0.060	0.140	0.100	0.140
50		0.060	0.040	0.060	0.145	0.103	0.065	0.145	0.105	0.145
63		0.065	0.040	0.065	0.150	0.108	0.075	0.155	0.115	0.155
80		0.075	0.050	0.075	0.165	0.120	0.095	0.170	0.133	0.170
100		0.085		0.085	0.180	0.133	0.110	0.195	0.153	0.205
125		0.100		0.100	0.200	0.150	0.125	0.230	0.178	0.260
160		0.105		0.105	0.240	0.173	0.140	0.280	0.210	0.360
200		0.115		0.115	0.280	0.198	0.165	0.375	0.270	0.500
250		0.125		0.125	0.370	0.248	0.220	0.480	0.350	0.570
315		0.210		0.210	0.460	0.335	0.310	0.540	0.425	0.605
400		0.305		0.305	0.505	0.405	0.415	0.565	0.490	0.615
500		0.400		0.400	0.525	0.463	0.480	0.570	0.525	0.615
630		0.400		0.400	0.530	0.465	0.505	0.570	0.538	0.595
800		0.400		0.400	0.530	0.465	0.520	0.570	0.545	0.570
1000		0.400		0.400	0.520	0.460	0.530	0.565	0.548	0.550
1250		0.400		0.400	0.510	0.455	0.535	0.560	0.548	0.530
1600		0.400		0.400	0.505	0.453	0.535	0.550	0.543	0.510
2000		0.400		0.400	0.490	0.445	0.535	0.540	0.538	0.500
2500		0.395		0.395	0.470	0.433	0.525	0.530	0.525	0.490
3150		0.390		0.390	0.455	0.423	0.520	0.520	0.520	0.480
4000		0.390		0.390	0.430	0.410	0.510	0.510	0.510	0.470

Table 3. Estimated Absorption Coefficients for Payload Surfaces

Frequency (Hz)	Absorption Coefficient	
	Payload Without TCS α_o	Payload With TCS α_t
12.5	0.175	0.175
16		
20		
25		
31.5		
40		
50		
63		
80		
100		
125		
160		
200		0.175
250		0.220
315		0.310
400		0.415
500		0.480
630		0.505
800		0.520
1000		0.530
1250		0.535
1600		0.535
2000		0.535
2500		0.525
3150		0.520
4000	0.175	0.510

5.0 VERTICAL STATION DATUM

Payload Cards 4 through 3+n define the volume, dimensions and locations of the n active subvolumes which describe the region surrounding a payload. Columns 51-60 of each card define the Volume K Z-axis locator D2(K), where D2(K) is the distance (in inches) that the top surface of the subvolume indexed K lies below a given vertical station datum. The datum is given as Z = 488 in Volume III of [1] but since this location lies within the maximum available payload envelope the value is being changed to Z = 493. This vertical station coincides with the lower surface of the radiators at the payload bay centerline (Y=0), and provides a static clearance of 3.0 inches between the radiators and the payload envelope with a 90.0 inch radius centered at Z = 400.

The instructions regarding the definition of D2(K) should now read: D2(K) is the distance (inches) that the deformed top surface of the subvolume indexed K lies below the vertical station designated 493, when measured on the Y=0 axis.

6.0 CONFIDENCE INTERVALS

Analysis of the sound levels measured in the payload bay during lift-off for STS-1, -2 and -3 has provided 95% confidence intervals for each one-third octave band in the frequency range 12.5 to 630 Hz. These confidence intervals which are given in Table 4, have been applied directly to all space-average sound pressure levels predicted by PACES. Confidence intervals for frequency bands above 630 Hz have been estimated by taking average values for the one-third octave bands in the frequency range 160 to 630 Hz. These extrapolated values (-3.3 dB and +1.9 dB) are also shown in Table 4.

The inclusion of 95% confidence intervals in PACES does not involve any additional effort on the part of the user. The confidence intervals are specified in the first eight cards of the DATA-STRUCTURE package, and they are to be considered as part of that fixed input package. To accommodate this additional data, the number of data cards in the DATA-STRUCTURE package (see page 29 of Volume III [1]) has been increased to 346 (Cards 32-377) and the card defining the number of payload configuration input data packages (see page 30 of Volume III [1]) has been changed from Card 370 to Card 378.

The new output from PACES, showing the upper and lower 95% confidence limits, provides an indication of the statistical variability of payload bay sound levels from location to location and from launch to launch. Further details on the measured variations in payload bay sound levels can be found in [5-7].

Table 4. Confidence Intervals for Space-Average Sound Pressure Levels Predicted by PACES

Frequency (Hz)	95% Confidence Intervals (dB)	
	Lower	Upper
12.5	-2.5	+1.5
16	-1.5	+1.1
20	-1.9	+1.4
25	-3.7	+2.0
31.5	-2.5	+1.5
40	-1.7	+1.2
50	-3.1	+1.8
63	-1.7	+1.3
80	-3.5	+1.9
100	-2.1	+1.4
125	-5.6	+2.3
160	-3.3	+1.8
200	-3.7	+2.0
250	-3.0	+1.7
315	-3.2	+1.8
400	-3.2	+1.9
500	-3.3	+1.9
630	-3.1	+1.9
800	-3.3	+1.9
1000	-3.3	+1.9
1250	-3.3	+1.9
1600	-3.3	+1.9
2000	-3.3	+1.9
2500	-3.3	+1.9
3150	-3.3	+1.9
4000	-3.3	+1.9

7.0 ANALYTICAL MODEL FOR PAYLOAD BAY DOOR

The analytical model for the dynamic response of the payload bay door includes the calculation of joint acceptance functions which describe the coupling between the excitation field and the structure. Of particular interest is the average joint acceptance function for progressive wave excitation. This is discussed in Section 4.2.3.1 of Volume II [1], where on the basis of ground tests on the OV-101 test vehicle (Volume IV of [1]), the band average joint acceptance function $\langle j^2_{MN} \rangle$ is taken as the upper envelope of values calculated for stiffened and unstiffened door structures.

Comparisons between measured and estimated sound levels for the payload bay for STS-1, STS-2 and STS-3 [5-7] show that the predicted values are, on the average, 3.5 dB too high at frequencies above 160 Hz. Since the analytical model indicates that the door is the dominant transmission path it is appropriate to modify the joint acceptance model for the door. The modification places more emphasis on the unstiffened door characteristics, making the model more consistent with that for other structural regions of the payload bay. The modified joint acceptance spectrum is shown in Figure 2, where it is compared with the model shown in Figure 14 of Volume II [1].

When the revised door joint acceptance function is used for the door, the predicted space-average sound pressure levels for the payload bay show very good agreement with lift-off data. Comparisons for STS-1, STS-2 and STS-3 are shown in Figures 3 through 5. The figures also contain 95% confidence limits for the STS-2 and STS-3 data and 90% confidence limits for STS-1. (In the latter case 95% confidence limits were not determined because of the very small number of data points). The revised joint acceptance function is now incorporated into the PACES computer program. The change affects only the high frequency calculations in the analysis, since the low frequency calculations do not utilize $\langle j^2_{MN} \rangle$.

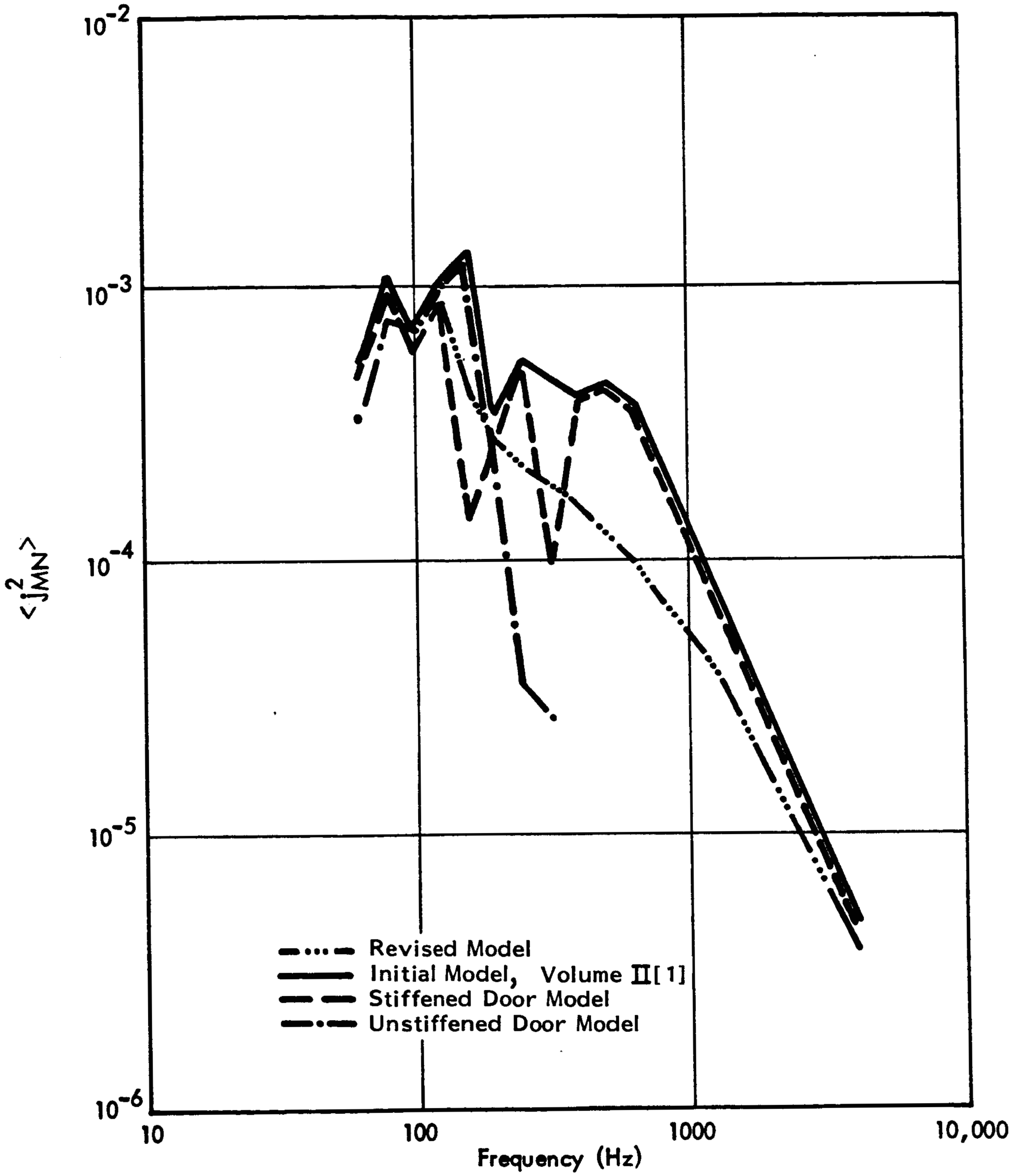

FIGURE 2. BAND AVERAGE JOINT ACCEPTANCES FOR PAYLOAD BAY DOOR WITH PROGRESSIVE WAVE EXCITATION

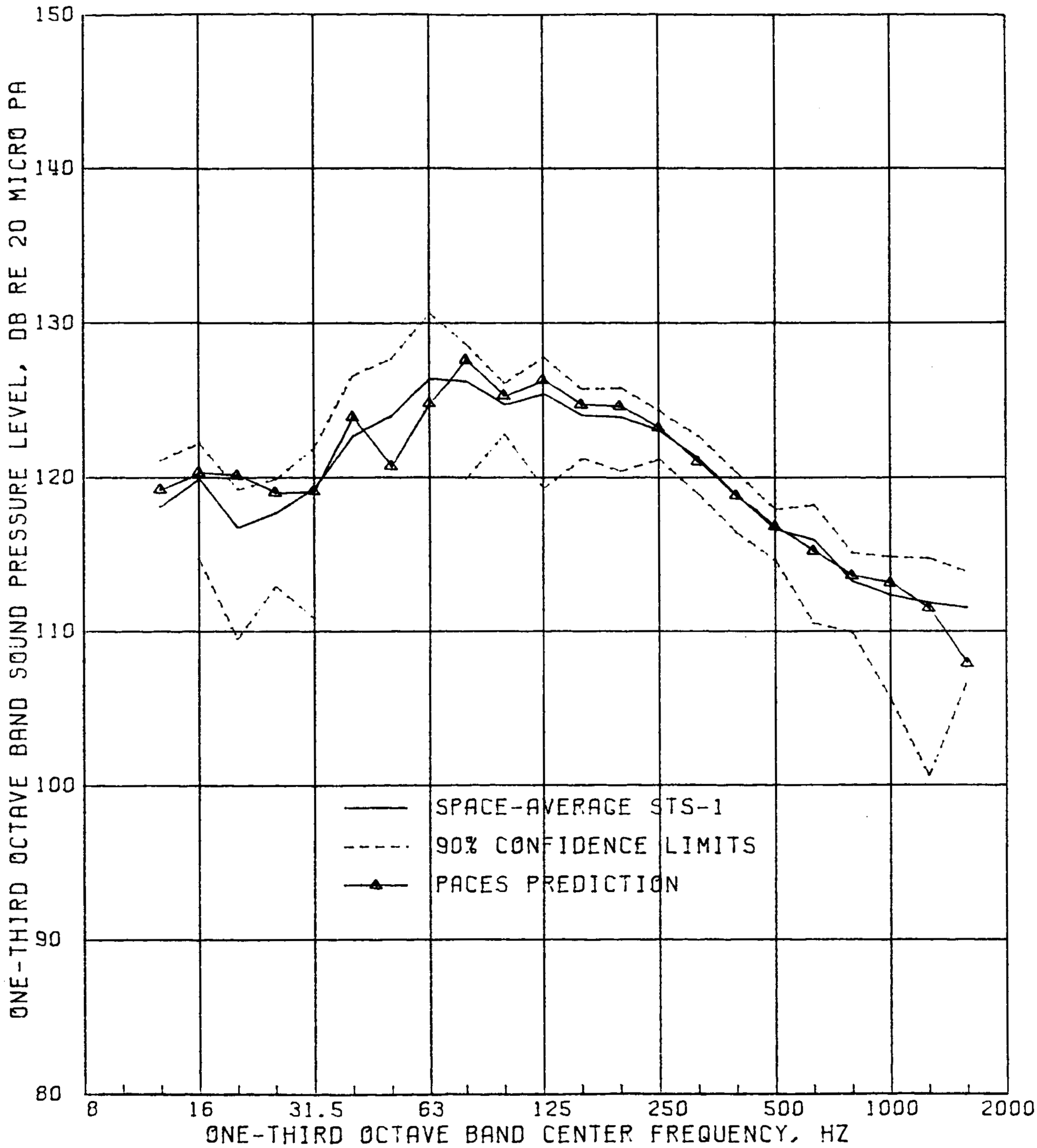

FIGURE 3. COMPARISON OF PREDICTED AND MEASURED SPACE-AVERAGE SOUND PRESSURE LEVELS FOR PAYLOAD BAY OF STS-1

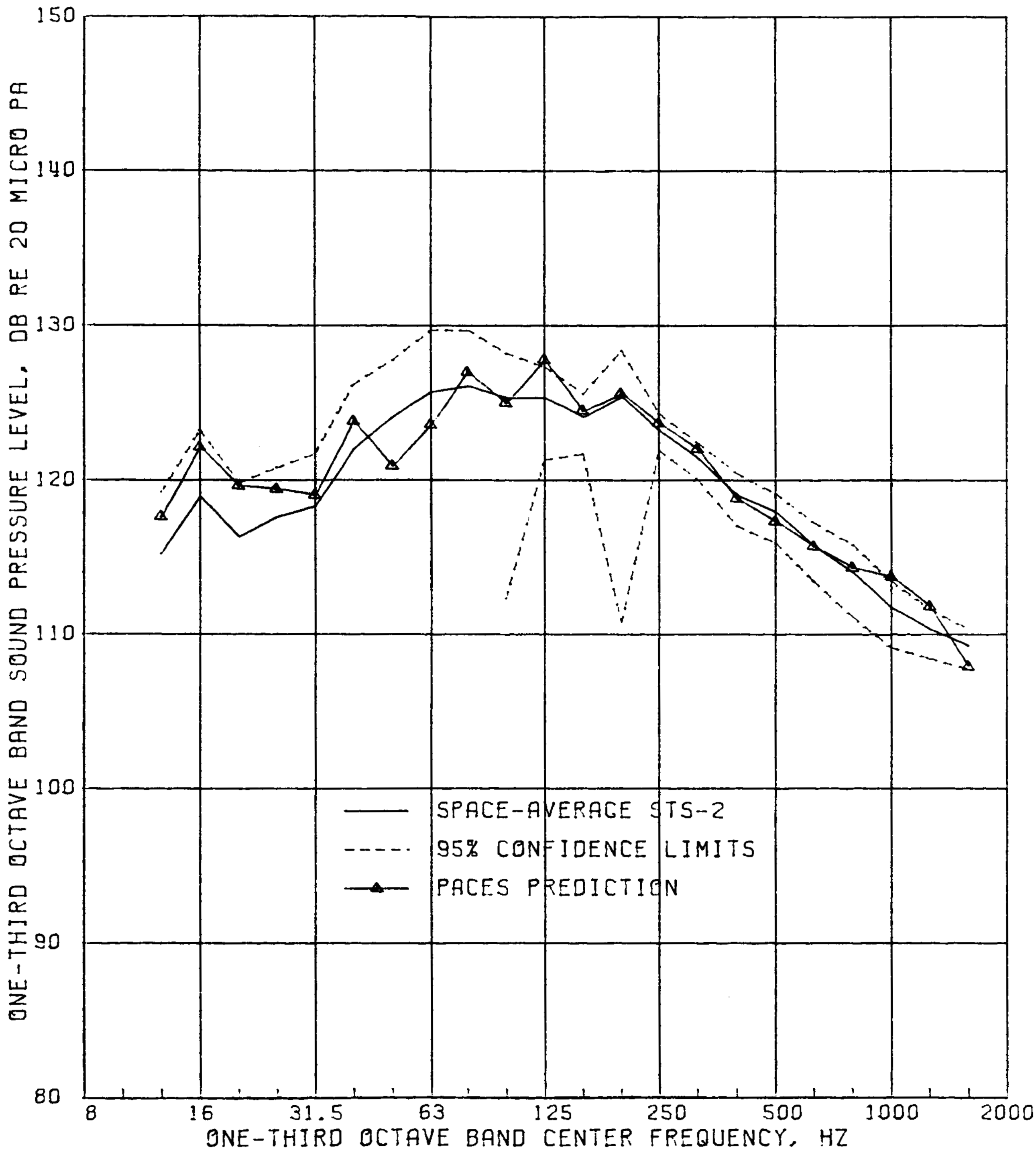

FIGURE 4. COMPARISON OF PREDICTED AND MEASURED SPACE-AVERAGE SOUND PRESSURE LEVELS FOR PAYLOAD BAY OF STS-2

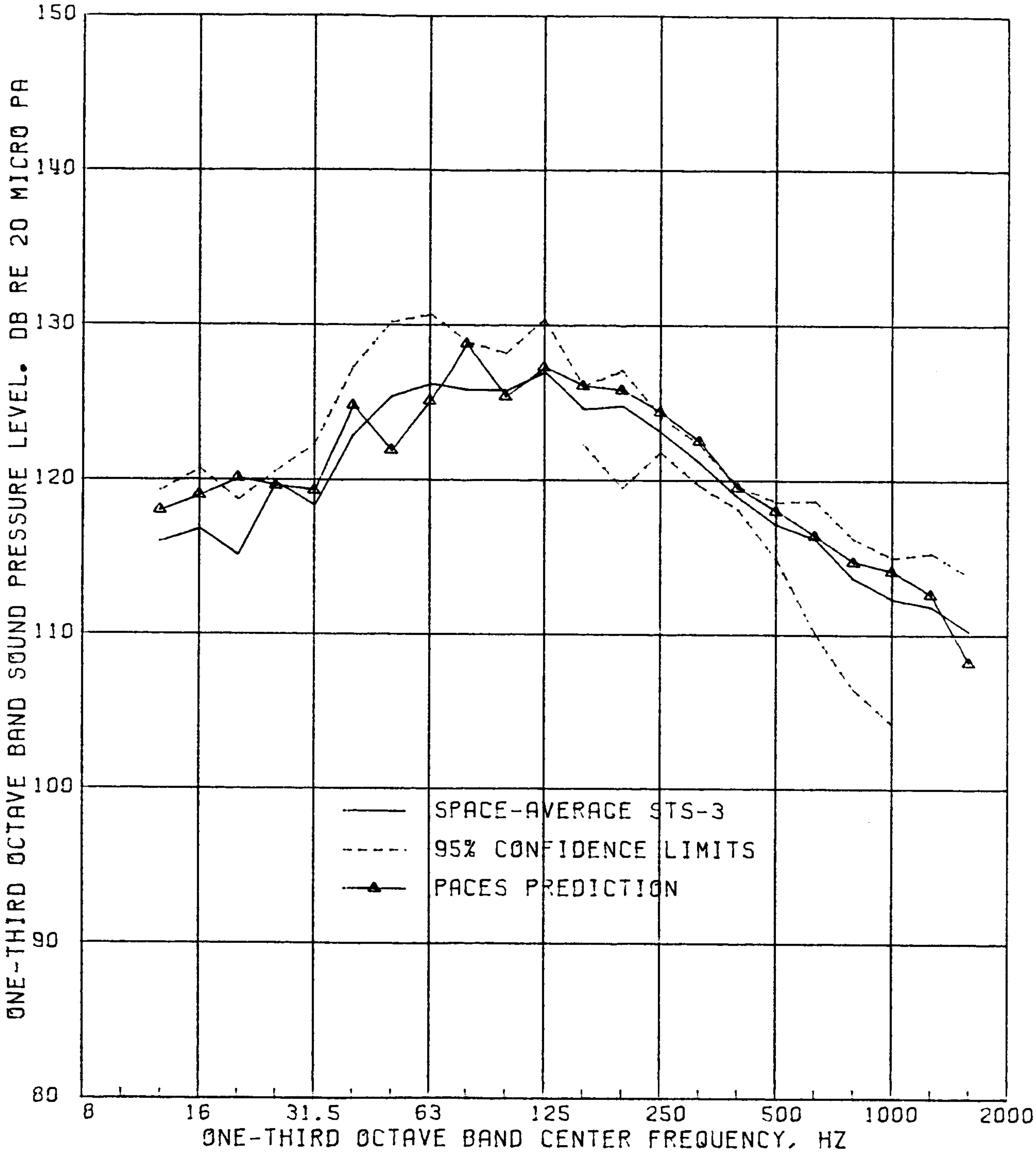

FIGURE 5. COMPARISON OF PREDICTED AND MEASURED SPACE-AVERAGE SOUND PRESSURE LEVELS FOR PAYLOAD BAY OF STS-3

8.0 DISCUSSION

The preceding sections have presented information to the user of PACES in a fairly concise manner. Thus it is useful now to discuss certain aspects of the prediction procedure.

Payload Bay Vents:-

In principle, the analytical model associated with PACES assumes that the eight vents in the sidewalls of the payload bay are closed at lift-off. In practice, however, the PACES computer program computes space-average sound levels for the payload bay with vents open.

There are two reasons for making this assertion. Firstly, the analytical model contained in PACES has been modified slightly, as described in Section 7, so that there is good agreement between measurements and predictions for STS-1 through STS-3 lift-offs. Since the payload bay vents were open during those lift-offs, the PACES computations implicitly assume that the vents are open.

Secondly, a simplified analysis of noise transmission through the vents was performed in [5]. The analysis suggested that, at frequencies below 400 Hz, opening the vents would increase the space-average sound levels in the payload bay by less than 2 dB, although as the frequency increased above 400 Hz the effect became larger. It was observed, however, that the accuracy of the predictions was highly sensitive to the accuracy with which the exterior sound pressure levels could be described for the vent locations. Unfortunately, these exterior sound pressure levels could, in practice, be estimated only approximately because of the absence of microphones on the mid-fuselage side-wall. Furthermore, the vents have a complicated geometry being composed of a box-like cavity with a non-uniform depth and a porous filter for the transmitting area. These factors cannot be modeled very accurately. Because of these uncertainties, and the relatively small effects predicted for the vents, the influence of the vents was assumed to be negligible except, perhaps, for payload surfaces which are close to an open vent.

Confidence Intervals:-

The 95% confidence intervals presented with the PACES predictions for various subvolume space-average sound levels were determined from statistical studies of acoustic measurements made in the orbiter payload bay during STS-1, STS-2 and STS-3 lift-offs. Hence the confidence intervals represent uncertainties due to possible sampling errors in the acoustic measurements used to verify the PACES computer model as opposed to derived error estimates for the analytical model itself. Since the analytical model has been modified to provide relatively close agreement with the space-average levels measured on STS-1 through STS-3, it is believed that the noted confidence intervals can be used as a first order estimate for possible errors in the PACES predictions. For example, the upper limit of the 95% confidence interval can be interpreted as an upper bound on the PACES space-average estimates in a given subvolume for design and test purposes.

It should be emphasized that the PACES predictions with confidence intervals apply only to the space-average level in a given subvolume and not to the acoustic pressures at individual locations within that subvolume. Analysis of the data from STS-1 through STS-3 has shown that the acoustic pressures at individual locations in an essentially empty bay may be substantially higher or lower than the space-average level, and fall well outside the noted confidence intervals. This is demonstrated in Figures 6 and 7 taken from [7]. The two figures were derived from an analysis of the combined data from STS-1 through

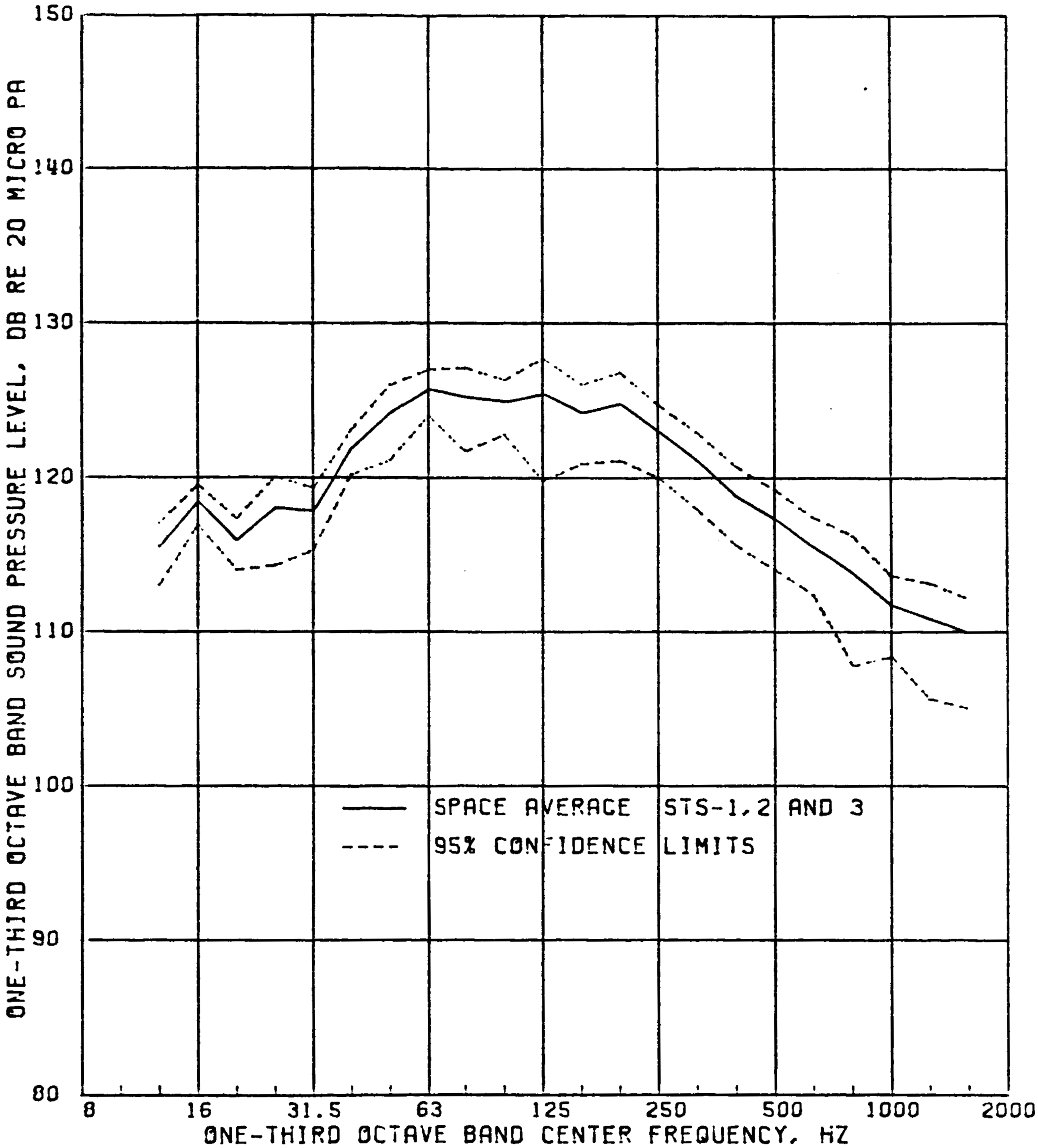

FIGURE 6. SPACE-AVERAGE AND 95% CONFIDENCE LIMITS FOR MEASURED SOUND PRESSURE LEVELS IN PAYLOAD BAY AT LIFT-OFF (STS-1, STS-2, AND STS-3)

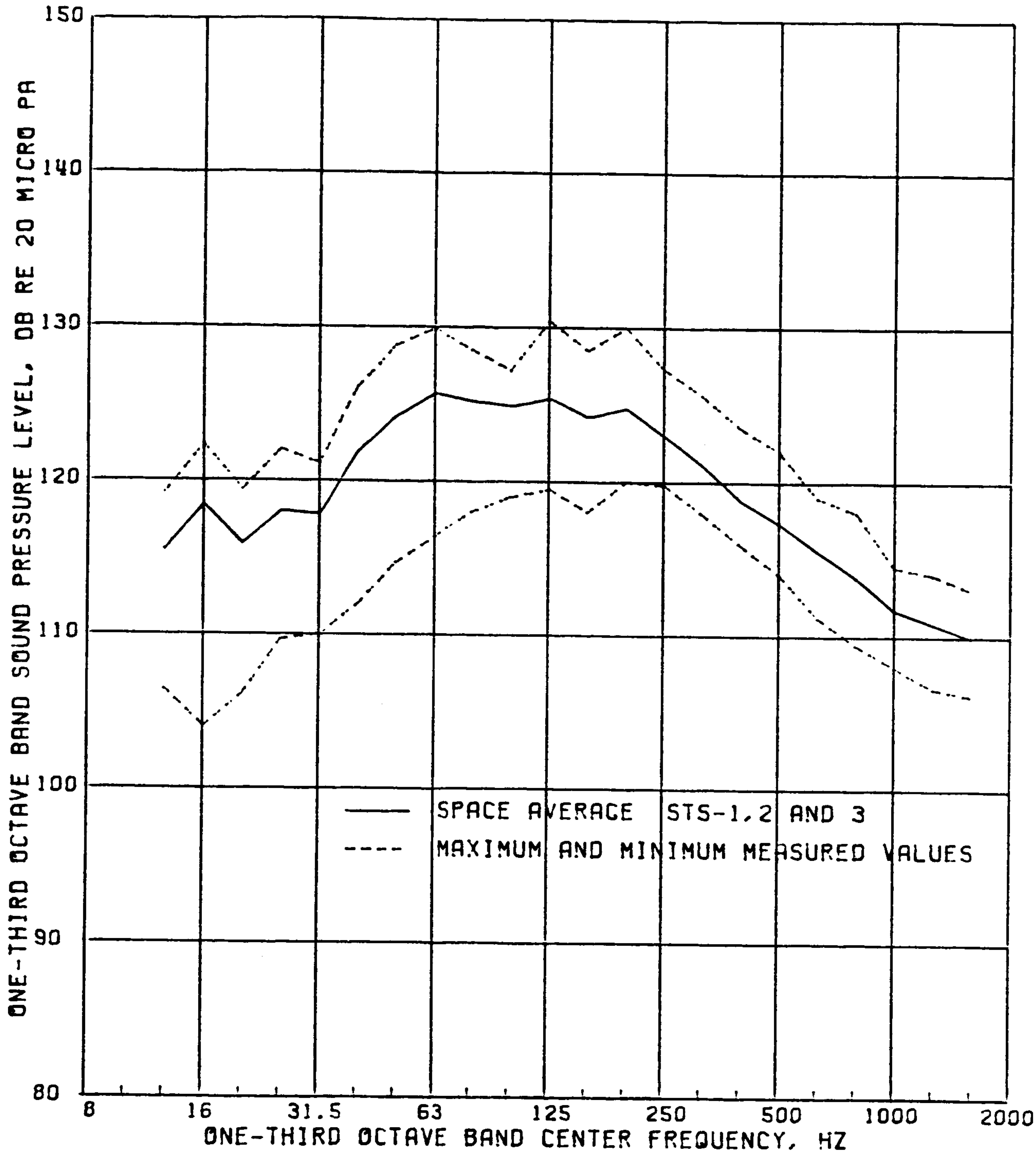

FIGURE 7. SPACE-AVERAGE AND RANGE OF VALUES FOR MEASURED SOUND PRESSURE LEVELS IN PAYLOAD BAY AT LIFT-OFF (STS-1, STS-2, AND STS-3)

STS-3. Figure 6 shows the space-average level and the 95% confidence limits, whereas Figure 7 shows the space-average with the corresponding maximum and minimum values. This difference between the 95% confidence interval and the range of measured data might influence the selection of design criteria and/or test levels for specific components of a payload.

It should also be emphasized that the confidence intervals contained in PACES were derived from measurements in an empty, or almost empty, payload bay. The assumption is made in PACES that the same confidence intervals can be applied to subvolumes surrounding payloads. The validity of this assumption can be justified by reference to Volume V of [1] which contains an analysis of measurements from the one-quarter scale model tests. Confidence limits calculated for space-average sound levels in subvolumes around model payloads have values which are similar to those measured for STS-1 through STS-3. Thus it is deemed appropriate to apply the confidence limits computed for STS-1 through STS-3 to all subvolumes in the payload bay.

Modeling of Subvolumes:-

One of the more difficult tasks imposed on the user is that of modeling the space around a given payload. Problems involved with the modeling received considerable attention during the development of the PACES computer program and discussion can be found in Volumes II, III and V of [1] as well as in [6] and [7]. It is worthwhile, however, to reiterate some of the more important aspects of the modeling process.

The analytical model developed for PACES envisages the space around a payload in terms of a group of coupled subvolumes excited by a number of different structural components. Ideally, each subvolume should be capable of supporting a standing wave system, each boundary of a subvolume being made up partly of an absorbing and reflecting surface and partly of a transmitting opening. There should be an actual, physical, reflecting surface on each of the six boundaries of each subvolume. Problems arise where these conditions cannot be met. Since the model assumes that all subvolumes extend the full width of the payload bay, from sidewall to sidewall, boundary condition problems are associated with the yz and xy planes perpendicular to the x- (longitudinal) and z- (vertical) axes, respectively.

Consider first the xy plane. The recommended approach for modeling a subvolume around a payload section which projects only a small area on the xy plane is to utilize a single subvolume surrounding the payload section, with the payload section represented as a sound-absorbing surface within the subvolume. Representations of this type are shown as Subvolume 1 in Figures 39 and 40 of Volume II [1].

The main problem arises when considering the yz plane perpendicular to the x-axis. In this case it is possible that the user will have no alternative but to select subvolumes which have no physical surfaces at the forward or aft boundaries. The only longitudinal acoustic modes which can be set up in such subvolumes will be those associated with the change in impedance at an area change. The user should, however, make every effort to avoid subvolumes of this type. For example, when the payload is small, no attempt should be made to form multiple subvolumes where these are not appropriate. PACES cannot be used to estimate the spatial variation of the payload bay sound pressure level by arbitrarily dividing the bay into several subvolumes. In this example, the payload bay should be modeled as a single subvolume containing a non-bounding, sound-absorbing payload, as is shown in Figure 38 of Volume II [1].

While some criterion regarding payload volume as a percentage (say 10%) of the total bay volume could be used as a guideline in deciding whether or not to select a single-volume representation, the decision on subvolume modeling should really depend on whether or not the payload occupies a significant fraction of the payload bay cross-sectional area at some longitudinal station, thereby constituting a physical reflecting boundary.

Given the selection of a single volume surrounding a non-bounding payload, any estimate of the spatial variation of sound pressure level in the payload bay would have to be made on the basis of data contained in [5] through [7] and in Figure 7.

The most difficult representation is that associated with annular-type subvolumes, such as Subvolume 5 in Figure 39 or Subvolume 7 in Figure 40 of Volume II [1], around large diameter payload sections. Similar problems occur for subvolumes beneath payload pallets, but these regions are usually less critical than those above payloads because most of the acoustic power is transmitted through the payload bay doors.

PACES allows three options for subvolumes of this type. The option is specified by the user on Payload Card 3. Code 1 identifies the subvolume as being regular and active. This is the code used for most subvolumes. Code 2 specifies the subvolumes as being inactive. Such a subvolume acts solely as a transmitter of acoustic power between subvolumes; an inactive subvolume cannot accept acoustic power from outside the payload bay. Finally, Code 3 identifies an irregular, active subvolume. An irregular subvolume accepts acoustic power form outside the orbiter but only in frequency bands above (but not including) the band containing the lowest resonance frequency of the subvolume. The irregular, active subvolume is the model recommended for annular-type subvolumes on the basis of results from the one-quarter scale model tests (Volume V of [1]).

Even with these options available within PACES, the user should be alert to any large changes in predicted sound levels at low frequencies when a payload is introduced. There are two reasons why these large changes should be treated with caution. Firstly, the model might introduce strong subvolume acoustic modes which cannot, in practice, be supported by open ends of an annular subvolume. Secondly, the modeling of the payload bay as a series of subvolumes will exclude from the model low frequency modes of the empty bay. In practice the presence of the payload may interfere with, but not eliminate, these modes. It is recommended that, if the user suspects that either of these effects is occurring in the low frequencies, additional computations be performed with different codes or dimensions for the subvolumes, or with a different subdivision of the space around the payload, for example a single subvolume with a non-bounding payload.

Finally, it should be noted that there has not yet been an opportunity to validate PACES for a payload bay with payload under actual launch conditions. The only validations performed for actual lift-off conditions have been for payload bays which are essentially empty.

REFERENCES

1. A.G. Piersol et al, "Space Shuttle Payload Bay Acoustics Prediction Study, Volumes I-V", NASA CR-159956, March 1980.

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

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

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

5. J.F. Wilby et al, "An Evaluation of Space Shuttle STS-1 Payload Bay Acoustic Data and Comparison with Predictions", BBN Report 4738, February 1982.

6. J.F. Wilby et al, "An Evaluation of Space Shuttle STS-2 Payload Bay Acoustic Data and Comparison with Predictions", BBN Report 4748, August 1982.

7. J.F. Wilby et al, "An Evaluation of Space Shuttle STS-3 Payload Bay Acoustic Data and Comparison with Predictions", BBN Report 4959, September 1982.

BIBLIOGRAPHIC DATA SHEET

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-159956		

4. Title and Subtitle	5. Report Date
SPACE SHUTTLE PAYLOAD BAY ACOUSTICS PREDICTION STUDY - VOLUME IIIA - ADDENDUM TO COMPUTER USERS' MANUAL	JANUARY 1983
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
J. F. Wilby, E. G. Wilby	5063
9. Performing Organization Name and Address	10. Work Unit No.
BOLT BERANEK AND NEWMAN INC. 21120 Vanowen Street P.O. Box 633 Canoga Park, California 91305	11. Contract or Grant No. NAS5-26570
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Goddard Space Flight Center Greenbelt, Maryland 20771 Technical Monitor: F. J. On, Code 731.1	FINAL
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A computer program PACES (Payload Acoustic Environment for Shuttle) was developed under Contract NAS5-22832 to calculate space-average sound levels in the payload bay of the Space Shuttle Orbiter Vehicle. A computer users' manual for PACES is provided in Volume III of this Contractor Report. Since the publication of the report in March 1980 there has been an opportunity to compare predicted sound levels with values measured during the lift-off of STS-1, -2 and -3. In addition, modifications have been made to the exterior sound pressure levels and payload bay absorption coefficients, utilizing information obtained from the three lift-offs. Consequently, recommended values contained in Volume II input data to PACES have been revised. This addendum to Volume III presents the modifications concerned with the use of PACES.

17. Key Words (Selected by Author(s))	18. Distribution Statement
SPACE SHUTTLE PAYLOAD BAY PAYLOAD LIFT-OFF NOISE COMPUTER PROGRAM OPERATION	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
UNCLASSIFIED	UNCLASSIFIED	28	

*For sale by the National Technical Information Service, Springfield, Virginia 22151.

GSFC 25-44 (10/77)