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# A Modified VAPEPS Method for Predicting Vibroacoustic Response of Unreinforced Mass Loaded Honeycomb Panels

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# A MODIFIED VAPEPS METHOD FOR PREDICTING VIBROACOUSTIC RESPONSE OF UNREINFORCED MASS LOADED HONEYCOMB PANELS

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## SUMMARY

VAPEPS (VibroAcoustic Payload Environment Prediction System) is a computer program which is used to predict the vibroacoustic response of a structure. An alternate VAPEPS modeling technique, the NASA Lewis Method, is an improvement for modeling unreinforced mass loaded honeycomb panels. The NASA Lewis Method prediction is compared to the standard ASMS VAPEPS prediction, and the acoustic test data for three spacecraft panels. An analytical method of computing variance is presented and used to compute 95 percent confidence levels. These levels are compared to the standard VAPEPS confidence levels and to the envelope of the test data. As a result of using the new methodology suggested in this paper, both the mean prediction and the 95 percent confidence level prediction agree well with the test data in both spectral shape and magnitude. Therefore, the NASA Lewis Method prediction methodology may be used to define more realistic random vibration test levels.

E-4579

## INTRODUCTION

The VAPEPS (VibroAcoustic Payload Environment Prediction System) computer program, developed by Lockheed Missiles and Space Division and maintained by the Jet Propulsion Laboratory (JPL), performs vibroacoustic environmental response predictions based on Statistical Energy Analysis (SEA). The advantage of using VAPEPS as an analytical tool is it can be utilized early in the design process; SEA modeling does not require precise structural properties as does a finite element model. The VAPEPS vibroacoustic response predictions are used to specify random vibration test levels.

Typical spacecraft designs use honeycomb panel construction. The standard VAPEPS prediction for mass loaded honeycomb panels are found to be conservatively high from previous analysis done at NASA Lewis Research Center and in other reports [1,2]. To improve on this prediction, an alternative method called the NASA Lewis Method has recently been developed at NASA Lewis Research Center. Cambridge Collaborative, Inc. has been contracted to support NASA in this effort. This method is recommended for the modeling of unreinforced mass loaded honeycomb panels.

The major modifications employed in the NASA Lewis Method are:

(1) A new computation of the radiation efficiency
(2) A new computation for the coupling loss factors
(3) A new method for modeling nonstructural mass

These changes are utilized in the VAPEPS program.

The standard VAPEPS modeling method and theoretical prediction commands are presented. This is followed by a description of the NASA Lewis Method. The mean predictions from the NASA Lewis Method and the standard VAPEPS method are compared with the lognormal mean from measured test data for three spacecraft panels.

VAPEPS only provides a spatial average response prediction. In order to account for peak responses, confidence levels are calculated. The standard VAPEPS confidence levels are unrealistically high [1,2]. An alternate method, the NASA Lewis Lognormal 95/50 Method, is presented for computing confidence levels based on analytically determined response variance. The confidence levels from the NASA Lewis Lognormal 95/50 Method and the standard VAPEPS method are compared with the envelope of the test data. Finally, conclusions from the study are made.

## STANDARD VAPEPS MODELING AND PREDICTION

SEA model building is performed in the SEMOD processor (Statistical Energy MODeler) in VAPEPS [3]. The initial step in vibroacoustic modeling is to define the model elements. Elements are classified as either structural or acoustic elements. SEA element parameters are defined in VAPEPS in the ELNAME module. The PATHNAME command is used to connect the elements together.

Structural elements are characterized as structural panels, cylinders, and cones. To perform a vibroacoustic analysis, it is necessary to identify the material properties of the structural element including the mass density, Young's modulus, longitudinal wavespeed, and internal damping of the material.

Because of the requirement to keep the weight to strength ratio low in aerospace structures, many designs use honeycomb panel construction. In order to model a nonhomogeneous honeycomb structural panel with the VAPEPS software package, the honeycomb panel must first be converted to a single layer equivalent panel. The RUN=EQPL command in VAPEPS computes the equivalent structural properties: mass density (RHO), longitudinal wavespeed (CL), and Young's modulus (E), for an equivalent homogeneous structural panel. The equivalent structural properties are based on the simultaneous solution of bending stiffness, longitudinal wavespeed, and surface mass density from each layer. The RUN=EQPL command can account for lengthwise and widthwise stiffeners as part of the composition of the structure.

The structural SEA input parameters required for a VAPEPS vibroacoustic analysis are listed as follows:

(1) RHO mass density of the structural material
(2) RHOS surface mass density of the structural material
(3) ASMS nonstructural mass (component mass) on the structure
(4) H thickness of the structure
(5) D diameter (cylindrical and conical structures)
(6) BL length (cylindrical and conical structures)
(7) ALX typical sub-panel length
(8) ALY typical sub-panel width
(9) PATA total length of structural discontinuity
(10) AP surface area
(11) E Young's modulus of the structural material
(12) DLF damping loss factor = 2.0 * critical damping
(13) CL longitudinal wavespeed in the structural material
(14) CO velocity of sound in gaseous medium adjacent to the structure.

Nonstructural component mass mounted on the surface of a honeycomb panel has an attenuation affect on the response. The response prediction for a mass loaded honeycomb panel is computed by multiplying the response prediction for an unloaded panel by a scale factor:

$$S.F. = \frac{\text{STRUCTURAL MASS}}{\text{STRUCTURAL MASS + ASMS}} \tag{1}$$

where

S.F. is the scale factor

JPL has done significant research to improve the VAPEPS prediction methodology for nonstructural mass loading on honeycomb panels. Because of the inherent difficulty in determining how the nonstructural mass affects the modal density and stiffness properties of the honeycomb panel, most modeling methods fail to yield results that compare well with acoustic test data. However, the ASMS modeling method, the standard VAPEPS method for modeling nonstructural mass, is a conservative method.

Acoustic elements are air spaces inside the structure or the surrounding environment outside the structure. These elements can be described as either being reverberant or nonreverberant. To characterize the acoustic space, it is necessary to prescribe the mass density and speed of sound within the gaseous medium, and the volume of the acoustic space. VAPEPS requires the specification of these acoustic parameters to define an acoustic element:

(1) RHO mass density of the gaseous medium
(2) AP surface area exposed to the acoustic field
(3) V volume of the acoustic space
(4) AAC acoustic absorption coefficient of the surfaces exposed to the acoustic field
(5) CO speed of sound

An excitation element is the acoustic element which is the source of acoustic energy. The SETEXC (set excitation) is the command in VAPEPS to define the excitation element. The excitation spectrum is specified by the EXCITATION command and the associated 1/3 octave frequency range by the FREQUENCY command.

After the structural and acoustic elements have been defined, the next modeling step is to prescribe the connectivity between elements. A series of connection paths are listed in the "VAPEPS VOLUME II: USER'S MANUAL" [3], under chapter 11 Statistical Energy Modeler. While in the SEMOD processor, the PATHNAME command prompts the user for element connection information. Depending on the type of connectivity specified, the program has built in coupling loss factors which account for energy transfer between elements.

Once the elements, excitation spectrum, and energy paths have been determined, the next step is to execute the VAPEPS program. The order of execution of the VAPEPS commands to perform a vibroacoustic prediction is as follows:

(A) MDENS

(B) ATACALC

(C) ATACO

(D) CFAC

(E) TPRD

(F) POWER

The first command, MDENS, is used to calculate the modal density of each 1/3 octave frequency band. SEA theory computes response predictions based on the modal density. ATACALC generates the coupling loss factors used in transferring energy between elements. ATACO does the inversion of the coupling loss matrix and calculates the transfer functions. The next command, CFAC, is a means of indicating the engineering units used in the vibroacoustic analysis. The command TPRD performs the vibroacoustic prediction and generates the matrix of element responses. The POWER command generates a matrix of power flow between elements. This is a useful command to troubleshoot the model for inadequate energy connection path definition.

An example of a simple two element VAPEPS runstream, with comments, is presented in Fig. 1. The SEA model is composed of an external excitation acoustic element, EXTA, and a structural panel element, PL. The structural element is excited on both sides by the excitation acoustic space. The example model is designed to reveal the capabilities of the VAPEPS theoretical response prediction program. Table I lists the SEA example model excitations and responses. Table II lists the power flow through the model.

## NASA LEWIS METHOD

In order to more accurately predict the vibro-acoustic response of unreinforced mass loaded honeycomb panel structures with VAPEPS, the NASA Lewis Method was developed. This modeling method requires some deviation from the standard VAPEPS modeling mechanics described previously.

One of the main differences is the computation of the coupling loss factors based on a new definition of the radiation efficiency. The radiation efficiency formulation used in the NASA Lewis Method is adapted from recommendations from Cambridge Collaborative, Inc. to improve on the radiation efficiency within VAPEPS.

For frequencies less than the critical frequency, the radiation efficiency for the NASA Lewis Method is calculated:

$$\sigma_{rad} = (f/fc)^2 \quad \text{for} \quad f < fc \tag{2}$$

where

$\sigma_{rad}$ radiation efficiency

fc critical frequency

At and above the critical frequency, the radiation efficiency for the NASA Lewis Method is formulated:

$$\sigma_{rad} = 1.0 \quad \text{for} \quad f \geq fc \tag{3}$$

It should be noted that defining the radiation efficiency with the NASA Lewis Method eliminates the need to specify the PATA parameter. The PATA parameter, the total length of structural discontinuity which affects the bending wave pattern in the panel, is part of the Maidanik radiation efficiency [4] computation used in VAPEPS.

The NASA Lewis Method also conserves the important structural properties. These properties include conservation of panel mass, modal density, longitudinal wavespeed and critical frequency for an unloaded structure. Both the modal density and the critical frequency are directly proportional to the square root of the panel mass. Therefore, correctly specifying the panel mass is an integral part of the prediction methodology.

An outline of the NASA Lewis Method is given for modeling an unreinforced mass loaded honeycomb panel:

(Step 1) Determine the equivalent acoustic parameters of the honeycomb panel by using RUN=EQPL (Heqv, RHOeqv, RHOSeqv, Eeqv).

(Step 2) Model the structural panel in VAPEPS using the equivalent parameters.

(Step 3) Model component masses using ASMS (nonstructural mass) parameter.

(Step 4) Make theoretical prediction, listing the modal densities and critical frequency.

Steps 1 to 4 define the ASMS modeling method. Based on the modal density and critical frequency values computed in Steps 1 thru 4, a new set of equivalent modeling parameters are calculated for use in the NASA Lewis Method:

(Step 5) Heqv, the equivalent thickness computed in Step 1, is used in Steps 7 and 8. This value is chosen in order that the modal density and the critical frequency are conserved.

(Step 6) Compute the total mass, M

$$M = Mpanel + Mcomponent \tag{4}$$

$$M = RHOeqv * A * Heqv \tag{5}$$

where

| | |
|---|---|
| M | total mass |
| Mpanel | mass of the panel |
| Mcomponent | mass of the component |
| RHOeqv | equivalent panel density |
| Heqv | equivalent panel thickness |
| A | panel area |

(Step 7) Calculate the mass density, RHOeqv

$$RHOeqv = \frac{M}{(A * Heqv)} \tag{6}$$

(Step 8) Calculate the surface mass density, RHOSeqv

$$RHOSeqv = RHOeqv * Heqv \tag{7}$$

(Step 9) Calculate Young's modulus, Eeqv

$$Eeqv = (CL)^2 * RHOeqv \tag{8}$$

where

CL longitudinal wavespeed in the panel

(Step 10) Remodel structure based on the equivalent properties calculated from Eqs. (6), (7), and (8) and Heqv from Step 1. Reset ASMS = 0.0.

(Step 11) Compute a new set of coupling loss factors, based on the radiation efficiency defined by Eqs. (2) and (3).

The coupling loss from panel to acoustic space is:

$$\eta_{p;a} = \frac{\rho_a c_a}{2\pi f \ RHOS_{eqv}} \sigma_{rad} \tag{9}$$

where

| | |
|---|---|
| $\eta_{p;a}$ | coupling loss from panel to acoustic space |
| $\rho_a$ | density of gas in acoustic space |
| $c_a$ | speed of sound in acoustic space |
| $RHOS_{eqv}$ | surface mass density of the panel |

$\sigma_{rad}$ radiation efficiency

The coupling loss from acoustic space to panel is:

$$\eta_{a;p} = \frac{n(f)_p}{n(f)_a} \eta_{p;a} \qquad (10)$$

where

$\eta_{a;p}$ coupling loss from acoustic space to panel

$n(f)_p$ modal density of the panel (from Step 4)

$n(f)_a$ modal density of the acoustic space (from Step 4)

$\eta_{p;a}$ coupling loss from panel to acoustic space

(Step 12) Using RUN=CLFPUT [3], add the coupling loss factors to the ATA matrix. In a standard VAPEPS prediction, this matrix is generated by the ATACALC command. For the NASA Lewis Method, ATACALC is eliminated from the prediction scheme.

(Step 13) A theoretical prediction is completed by proceeding in the SEMOD processor with these steps:

(A) ATACO
(B) CFAC
(C) TPRD
(D) POWER

## COMPARISON OF NASA LEWIS METHOD PREDICTION WITH THE ASMS VAPEPS PREDICTION AND TEST DATA

The NASA Lewis Method and the standard ASMS VAPEPS method are used to model three spacecraft panels for comparison with acoustic ground test data. The three spacecraft panels represent typical honeycomb panel dimensions and component mass loadings. The boundary conditions for each of the panels is simply supported around the edges with no reinforcement across the panel surface.

The test data for Panels A and B was provided by JPL and RCA. The test data for Panel C was provided by the Naval Research Laboratory in Washington, D.C., as an SDIO spinoff.

Spacecraft Panel A has dimensions of 30" by 40" by 1" with a component mass to panel mass ratio of 16:1. During the acoustic ground test, thirteen accelerometers were instrumented across the surface of the panel. Based on the modal density requirement of at least one mode per 1/3 octave band [2], the lowest frequency for valid response prediction is 125 Hz. The critical frequency for the unloaded panel is 513 Hz.

Spacecraft Panel B has dimensions of 40" by 40" by 1" with a component mass to panel mass ratio of 23:1. During the acoustic ground test, nine accelerometers were instrumented across the surface of the panel. The minimum frequency for valid response prediction is 250 Hz. The critical frequency for the unloaded panel is 495 Hz.

Spacecraft Panel C has dimensions of 40" by 50" by 0.75" with a component mass to panel mass ratio of 2.75:1. During the acoustic ground test, three accelerometers were instrumented across the panel surface. The minimum frequency for valid response prediction is 250 Hz. The critical frequency for the unloaded panel is 666 Hz.

Figures 2 to 4 show a comparison of the NASA Lewis Method mean prediction, the ASMS mean prediction, and the statistical lognormal mean of the 1/3 octave accelerometer test data.

The NASA Lewis Method tends to predict the average response of an unreinforced mass loaded honeycomb panel well for a variety of mass loading cases. The mean value of the test data for Panel A is more statistically significant than for Panels B and C because of the larger number of accelerometers. The NASA Lewis Method matches the test data best for Panel A. For the case of Panels B and C, the NASA Lewis Method prediction follows the trend of the test data well, except at the higher frequencies.

As previously stated, the standard ASMS VAPEPS modeling method results in a conservative prediction in comparison with the test data. This is illustrated in Figs. 2, 3 and 4.

The NASA Lewis Method radiation efficiency formulation is an improvement on the ASMS VAPEPS radiation efficiency computation. As a result, the spectral shape of the NASA Lewis Method prediction closely matches the measured test data, particularly below the critical frequency. The NASA Lewis Method of calculating coupling loss factors and the method of modeling nonstructural mass improves the magnitude of the response prediction. These improvements are illustrated by comparing the mean predictions to the mean of the test data in Figs. 2, 3, and 4. Thus the NASA Lewis Method is recommended to model unreinforced mass loaded honeycomb panels.

## ADDING CONFIDENCE LEVELS TO THE NASA LEWIS METHOD PREDICTION AND THE ASMS VAPEPS PREDICTION

The final objective of the VAPEPS analysis is to establish component random vibration specification test levels. VAPEPS does not cover spatial variation responses. Peak responses are predicted statistically by adding a 95 percent confidence level to the VAPEPS average predicted response. The RUN=TPVL [3] command in VAPEPS computes a 95/50 confidence level based on the lognormal mean value and standard deviation. The standard VAPEPS equation to compute lognormal confidence levels is:

$$LN(n\%) = [LN(m) - 0.5LN(\sigma^2/m^2 + 1.0)] + s.f.*Kx\%*[LN(\sigma^2/m^2 + 1.0)]^{0.5} \qquad (11)$$

where

n% desired lognormal predicted response
m mean value predicted response

s.f. skew factor
LN natural logarithm
$\sigma$ standard deviation
Kx% constant relating the "x" percentile value to a multiple of the standard deviation for a normal distribution (for an infinite population)
$\sigma^2/m^2 = 4.1$
s.f. = 1.2

The simplified lognormal distribution equation for a 95th percentile (95/50) level (K95% = 1.65) using the default values is:

$$n95\% = 5.54 \bullet m$$

or (12)

$$n95\% = m + 7.4 \text{ db}$$

Previous research done at NASA Lewis Research Center indicates that the standard VAPEPS method for computing confidence levels results in unrealistically high prediction levels.

The default value for $\sigma^2/m^2 = 4.1$ is believed to be too large. As an alternative method to compute this value, Eq. (13) is utilized [5,6]. This equation forms the basis for the NASA Lewis Lognormal 95/50 Method.

$$\frac{\sigma^2}{m^2} = \left\{1 + \frac{\left[\frac{\langle\psi^4\rangle}{\langle\psi^2\rangle^2}\right]^2}{\pi\omega\eta n(\omega)}\right\}\left\{\frac{1}{1 + \frac{2\Delta a}{\pi\omega\eta}}\right\} \qquad (13)$$

where

$\sigma^2$ variance of mean-squared response

m mean-square response

$\Delta a$ analysis bandwidth

$\langle\psi\rangle$ mode shape average

$\eta$ internal panel damping

$n(\omega)$ panel modal density

The values for the modal density and the internal panel damping are obtained from the NASA Lewis Method analysis. The mode shape term was evaluated analytically from finite element models of mass loaded honeycomb panels. The results from Eq. (13) are averaged over the valid frequency range of response. This yields a $\sigma^2/m^2$ ratio of 0.74. This agrees well with the actual test data, whose average ratio is 0.80. Substituting this value into Eq. (11) results in:

$$n95\% = 3.3 * m$$

or (14)

$$n95\% = m + 5.2 \text{ dB}$$

Equation (14) is the NASA Lewis Lognormal 95/50 Method.

The NASA Lewis Lognormal 95/50 Method adds 5.2 dB to the mean predicted response, while the standard VAPEPS method adds 7.4 dB. The NASA Lewis Lognormal 95/50 Method is a less conservative method for adding confidence to the mean prediction.

The NASA Lewis Lognormal 95/50 Method confidence level (Eq. 14) is computed for the NASA Lewis Method mean prediction. The standard VAPEPS (RUN=TPVL) 95 percent confidence level (Eq. 12) is calculated for the ASMS VAPEPS method mean prediction. A comparison of the NASA Lewis Lognormal 95/50 Method and the standard VAPEPS confidence level prediction is made with the envelope of the test data for the three spacecraft panels in Figs. 5 thru 7. The NASA Lewis Lognormal 95/50 Method compares better to the envelope of the test data than does the standard VAPEPS method. Efforts to further improve the calculation of the confidence levels are in progress.

## CONCLUSIONS

Statistical Energy Analysis, as executed by VAPEPS, is a proven method for predicting the vibroacoustic response of a structure. The NASA Lewis Method, as presented in this paper, is the recommended method for predicting the mean vibroacoustic response for unreinforced mass loaded honeycomb panels.

The NASA Lewis Method improves on the spectral shape and magnitude of the response prediction. The improvement in the spectral shape of the response prediction is due to the NASA Lewis Method radiation efficiency computation, particularly below the critical frequency. The improvement in the magnitude of the response prediction is due to the method of modeling component mass and the computation of the coupling loss factors. This method also conserves the panel mass, modal density, longitudinal wavespeed and critical frequency. The end result is the NASA Lewis Method yields predictions which match the test data well. The prediction magnitude is typically within a factor of 3 of the test data and the spectral shape of the prediction follows the trend of the test data. The standard VAPEPS method overpredicts the lognormal mean of the test data by a factor of 10 to 50 and does not follow the test data trend below the critical frequency.

The NASA Lewis Lognormal 95/50 Method confidence level adds 5.2 dB to the mean predicted response. The standard VAPEPS confidence level adds 7.4 dB to the mean predicted response. The NASA Lewis Lognormal 95/50 Method gives a more realistic prediction from which to base component vibration test specification levels. Work is in progress to further improve the calculation of the confidence levels.

## REFERENCES


1. Beck, C.J., "Comparison of VAPEPS Prediction with IUS Vibroacoustic Data," 59th Shock and Vibration Symposium, Vol. 1, SANDIA REPORT SAND88-2473C, DOE, 1988, pp. 155-186.

2. Salzberg, A.A., "Validation of LACE Spacecraft Vibroacoustic Prediction Model," Journal of Environmental Sciences, Vol. 32, No. 1, Jan./Feb. 1989.

3. Park, D.M., "Vibroacoustic Payload Environment Prediction System (VAPEPS), Vol. II: VAPEPS Users's Manual," draft version, Lockheed Missiles and Space Company, Sunnyvale, CA, 1987.

4. Maidanik, G., "Response of Ribbed Panels to Reverberant Acoustic Fields," Journal of the Acoustical Society of America, Vol. 34, No. 6, June 1962, pp. 809-826.

5. SEAM User's Manual, Version 1.86, Cambridge Collaborative, Inc., Cambridge, MA, 1986.

6. Lyon, R.H., "Statistical Analysis of Power Injection and Response in Structures and Rooms," Journal of the Acoustical Society of America, Vol. 45, No. 3, Mar. 1969, pp. 545-565.

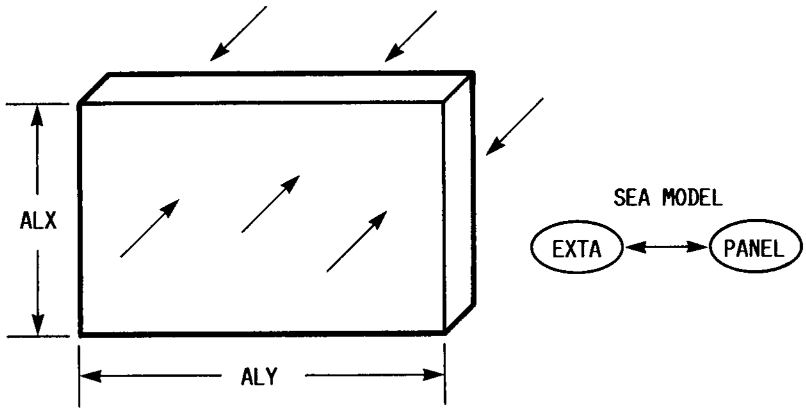

TABLE I. - OUTPUT EXCITATIONS AND RESPONSES FOR SEA EXAMPLE MODEL

| Frequency, Hz | EXTA, dB | PL, $G^2/Hz^{-1}$ $(x10^{-1})$ |
|---|---|---|
| 40.0 | 125.0 | 1.0297 |
| 50.0 | 129.4 | 2.7244 |
| 63.0 | 130.0 | 2.5599 |
| 80.0 | 132.5 | 4.0232 |
| 100.0 | 133.0 | 4.3297 |
| 125.0 | 135.4 | 3.6463 |
| 160.0 | 134.0 | 2.1224 |
| 200.0 | 135.5 | 3.1009 |
| 250.0 | 135.0 | 2.4847 |
| 315.0 | 136.7 | 3.1800 |
| 400.0 | 138.0 | 3.9896 |
| 500.0 | 139.8 | 6.1662 |
| 630.0 | 135.6 | 2.0879 |
| 800.0 | 134.4 | 1.5791 |
| 1000.0 | 133.0 | 1.2861 |
| 1250.0 | 132.7 | 1.3187 |
| 1600.0 | 131.0 | 1.0470 |
| 2000.0 | 130.2 | 1.3326 |

TABLE II. - OUTPUT POWER FLOW FOR SEA EXAMPLE MODEL

[Percent power flow per path for element PL.]

| Frequency, Hz | PL PL, percent | EXTA PL, percent | PL EXTA, percent |
|---|---|---|---|
| 40.0 | -94.95 | 100.00 | -5.05 |
| 50.0 | -94.38 | 100.00 | -5.62 |
| 63.0 | -93.73 | 100.00 | -6.27 |
| 80.0 | -92.98 | 100.00 | -7.02 |
| 100.0 | -92.20 | 100.00 | -7.80 |
| 125.0 | -95.19 | 100.00 | -4.81 |
| 160.0 | -94.48 | 100.00 | -5.52 |
| 200.0 | -93.72 | 100.00 | -6.28 |
| 250.0 | -92.81 | 100.00 | -7.19 |
| 315.0 | -91.67 | 100.00 | -8.33 |
| 400.0 | -90.19 | 100.00 | -9.81 |
| 500.0 | -88.40 | 100.00 | -11.60 |
| 630.0 | -85.91 | 100.00 | -14.09 |
| 800.0 | -82.20 | 100.00 | -17.80 |
| 1000.0 | -76.83 | 100.00 | -23.17 |
| 1250.0 | -67.60 | 100.00 | -32.40 |
| 1600.0 | -45.65 | 100.00 | -54.35 |
| 2000.0 | -8.52 | 100.00 | -91.48 |




```
SEMOD 9,bulk                        \activates SEMOD processor
ELNAME                              \activates element ID processor
EXTA,1                              \identifies EXTA element. acoustic space
p*                                  \identifies input of parameters
DESC='ACOUSTIC EXCITATION OF PANEL' \description of element
RHO=1.15e-07
CO=1.32e+04
VOL=7.52e+07
AP=1.12e+06
AAC=0.010
done                                \indicates end of EXTA element ID
PL,3                                \identifies Pl element, plate
p*                                  \identifies input of parameters
DESC= 'NORTH EAST panel/asms        \description of element
RHO=4.633E-05
CL=1.916E+05
H=0.2487
AP=1124.0
ALX=36.25
ALY=31.0
DLF=0.05
E=1.703e+07
PATA=134.5
RHOS=1.152E-04
ASMS=0.1228
PIVOTFRQ=250.0
done                                \indicates end of PL element ID
list                                \list element parameter information
done                                \end of element ID processor
SETEXC EXTA                         \define external excitation element,
EXTA
EXCITATION                          \define excitation spectrum
FREQUENCY                           \define frequency regime
PATHNAME                            \activates energy pathname processor
EXTA,PL,1                           \energy path connecting EXTA to PL
DONE                                \exit path definition
LIST                                \list pathname definition
done                                \exit pathname processor
MDENS 40.0,2000.0                   \calc. modal density/specify freq. range
ATACALC                             \calculate ata's
ATACO                               \compute coefficient matrix/trans. func.
CFAC 7,1,4                          \define conversion units
TPRD                                \do theoretical prediction
POWER                               \calculate power flows
LIST RESP                           \list theoretical response values
LIST POWER                          \list power flows
LIST DENS                           \list modal densities
LIST CRIT                           \list critical frequencies
done                                \exit SEMOD processor
RUN=TPVK 9, bulk 9, plat 0.95       \compute 95 percent confidence levels
```

FIGURE 1. - EXAMPLE SEA MODEL RUNSTREAM.

PANEL A

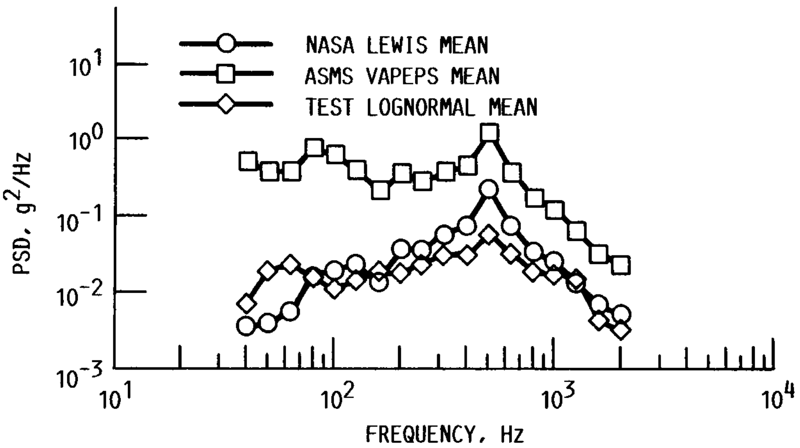



FIGURE 2. - COMPARISON OF NASA LEWIS METHOD MEAN PREDICTION, ASMS VAPEPS MEAN PREDICTION, AND ACOUSTIC GROUND TEST DATA FOR PANEL A.

PANEL B

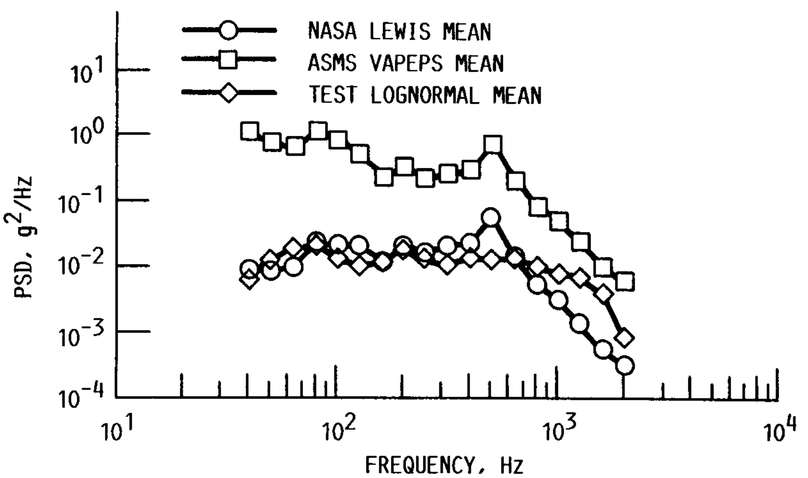



FIGURE 3. - COMPARISON OF NASA LEWIS METHOD MEAN PREDICTION, ASMS VAPEPS MEAN PREDICTION, AND ACOUSTIC GROUND TEST DATA FOR PANEL B.

PANEL C

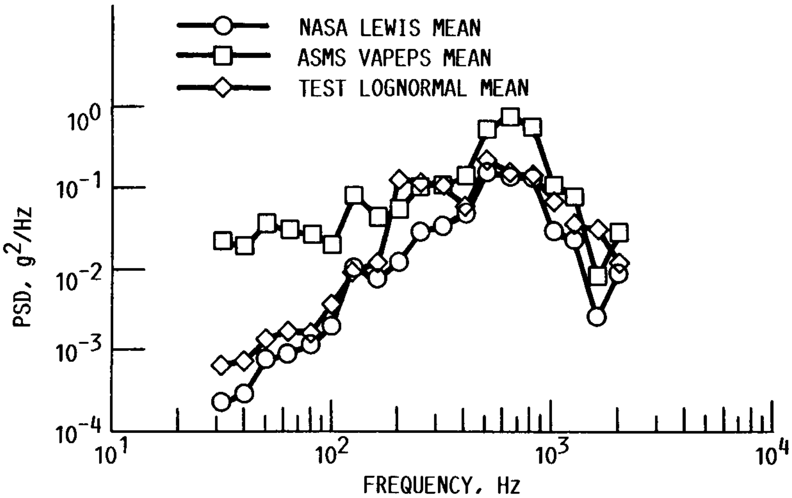



FIGURE 4. - COMPARISON OF NASA LEWIS METHOD MEAN PREDICTION, ASMS VAPEPS MEAN PREDICTION, AND ACOUSTIC GROUND TEST DATA FOR PANEL C. DATA PROVIDED BY THE NAVAL RESEARCH LABORATORY IN WASHINGTON, D.C. AS AN SDIO SPINOFF.

PANEL A

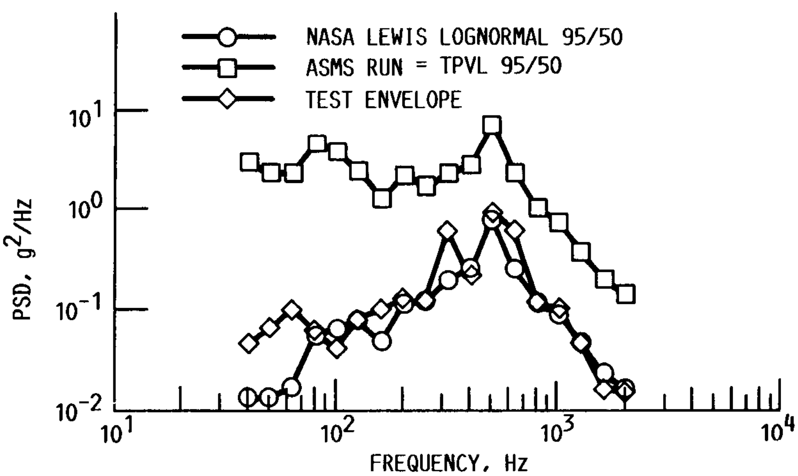



FIGURE 5. - COMPARISON OF NASA LEWIS LOGNORMAL 95/50 PREDICTION, VAPEPS RUN = TPVL 95/50 PREDICTION AND ACOUSTIC GROUND TEST DATA FOR PANEL A.

PANEL B

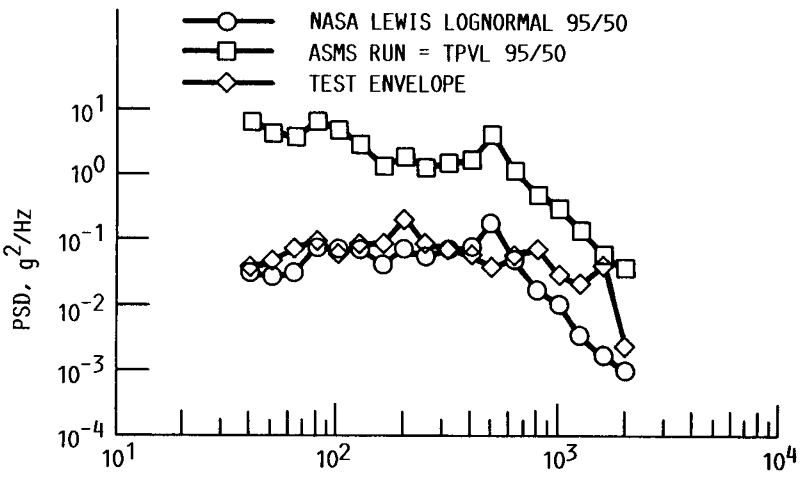



FIGURE 6. - COMPARISON OF NASA LEWIS LOGNORMAL 95/50 PREDICTION, VAPEPS RUN = TPVL 95/50 PREDICTION, AND ACOUSTIC GROUND TEST DATA FOR PANEL B.

PANEL C

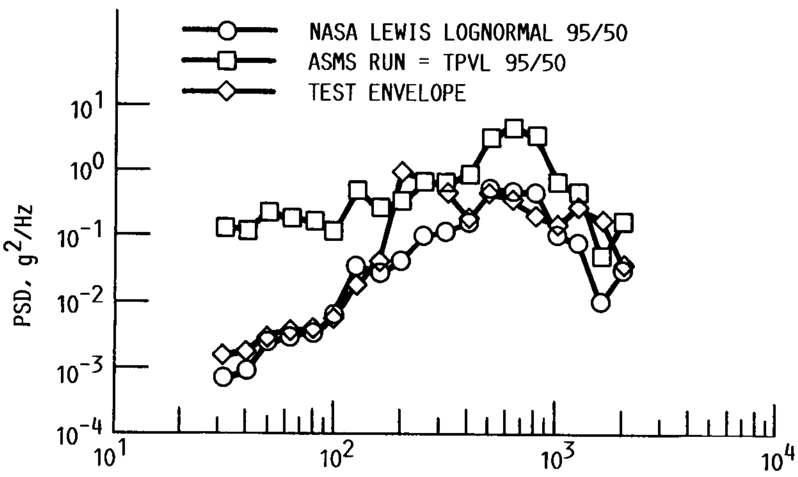



FIGURE 7. - COMPARISON OF NASA LEWIS LOGNORMAL 95/50 PREDICTION, VAPEPS RUN = TPVL 95/50 PREDICTION, AND ACOUSTIC GROUND TEST DATA FOR PANEL C. DATA PROVIDED BY THE NAVAL RESEARCH LABORATORY IN WASHINGTON, D.C. AS A SDIO SPINOFF.

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16. Abstract

VAPEPS (VibroAcoustic Payload Environment Prediction System) is a computer program which is used to predict the vibroacoustic response of a structure. An alternate VAPEPS modeling technique, the Modified NASA Lewis Method, is an improvement for modeling unreinforced mass loaded honeycomb panels. The Modified NASA Lewis Method prediction is compared to the standard ASMS VAPEPS prediction, and the acoustic test data for three spacecraft panels. An analytical method of computing variance is presented and used to compute 95 percent confidence levels. These levels are compared to the standard VAPEPS confidence levels and to the envelope of the test data. As a result of using the new methodology suggested in this paper, both the mean prediction and the 95 percent confidence level prediction agree well with the test data in both spectral shape and magnitude. Therefore, the Modified NASA Lewis Method prediction methodology may be used to define more realistic random vibration test levels.

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