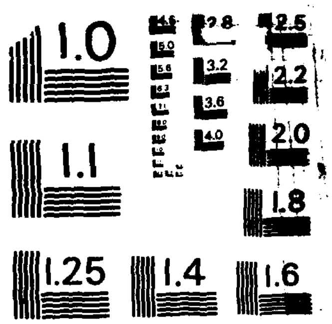
AD-A190 611 WAVE PROPAGATION AND DYNAMICS OF LATTICE STRUCTURES(U) 1/1
WEA CAMBRIDGE MA J H WILLIAMS 01 OCT 87
AFOSR-TR-87-1777 F49620-85-C-0148
UNCLASSIFIED F/G 22/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A190 611

DTIC FILE COPY

DTIC SELECTE JAN 19 1988 D

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for Public Release; Distribution Unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- 87-1777
6a. NAME OF PERFORMING ORGANIZATION: WEA	6b. OFFICE SYMBOL (If applicable)
7a. NAME OF MONITORING ORGANIZATION: AFOSR	
6c. ADDRESS (City, State and ZIP Code): P.O. Box 260, MIT Branch, Cambridge, MA 02139	7b. ADDRESS (City, State and ZIP Code): Same as 8C
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Air Force Office of Scientific Research	8b. OFFICE SYMBOL (If applicable): AFOSR/NA
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: F49620-85-C-0148	
8c. ADDRESS (City, State and ZIP Code): Bld 410, Bolling AFB, D.C. 20332	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
61102F	2302	B1	

11. TITLE (Include Security Classification) Wave Propagation and Dynamics of Lattice Structures (Unclassified)

12. PERSONAL AUTHOR(S) James H. Williams, Jr.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM 01 Sept 85 TO 30 Sept 87	87, October, 1	8

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Wave Propagation, Dynamic Failure, Lattice Structures, Large Space Structures

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

One of the most attractive structural configurations for large space structures (LSS) for outer space applications is the repetitive lattice concept. Achieving the operational requirements of such structures will necessitate considerable knowledge of the dynamics, control, materials and nondestructive evaluation (NDE) of these structural systems. Wave propagation analyses provide potentially valuable perspectives from which to consider this broad range of analysis, design and synthesis issues.

The theoretical and experimental results of a two-year research program on the wave propagation and dynamics of LSS are briefly reviewed. Potential benefits of wave propagation analyses in the vibration, parameter identification, dynamic failure, control and NDE of lattice structures have been identified and are summarized in this report.

(Keywords:

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Anthony K. Amos	22b. TELEPHONE NUMBER (Include Area Code): 202/767-4937 — 22c. OFFICE SYMBOL: AFOSR/NA

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

87 12 29 284

AFOSR-TR- 87-1777

ACKNOWLEDGMENTS

The Air Force Office of Scientific Research (Project Monitor, Dr. Anthony K. Amos) is gratefully acknowledged for its support of this research.

INTRODUCTION

Many papers and reports may be found in the literature on the concepts, design, analysis and potential uses of lattice structures in outer space. Such structures include large antennae, solar power systems and habitable stations for support of space colonies.

Currently, both deployable and erectable concepts are being investigated for the implementation of lattice structures. Also, investigations of size considerations indicate that small antennae ranging from tens of meters in span to solar power collectors ranging up to several thousand meters have been proposed. Such structural sizes along with stringent operational requirements will require considerable information of dynamics, control, materials, nondestructive evaluation (NDE), environmental effects and wave propagation relating to their design and analysis.

Much has been written on the theoretical aspects of the control of such structures. Also, a large number of vibration analyses have been undertaken. However, despite a distinct recognition of the importance of wave propagation in many of the control, vibration and NDE investigations, very little can be found on wave propagation in large space structures (LSS). The major goal of this program was to pursue the development of several aspects of wave propagation analyses in LSS.

ACCOMPLISHMENTS

A number of theoretical and experimental analyses have been undertaken. Some of these efforts have been documented in reports and some as yet remain undocumented in formal reports. The formally documented accomplishments will be described briefly.

As indicated above, the focus of our investigations has been the wave propagation of broadband and narrow-band signals in lattice structures for outer space applications. Theoretical and experimental analyses which have resulted in formal reports are listed here.

1. Theoretical formulations of the input-output relations for arbitrary pairs of locations on periodic structures have been initiated. In this formulation, we have used (and are continuing to use) a transfer matrix technique for analyzing periodic structures which can be modeled as one-dimensional continua, two-dimensional rectangular trusses and three-dimensional tetrahedral trusses. The elements in these structures are capable of transmitting longitudinal, shear and flexural waves. Our efforts on this topic have resulted in reports* as follows:

   - J.H. Williams, Jr., H.K. Yeung and R.J. Nagem, "Joint Coupling Matrices for Wave Propagation in Large Space Structures", AFOSR/WEA Technical Report, April 1986

   - J.H. Williams, Jr., R.J. Nagem and H.K. Yeung, "Wave-Mode Coordinates and Scattering Matrices for Wave Propagation in Large Space Structures", AFOSR/WEA Technical Report, October 1986.

* Reports written on this topic and other topics that were published on an earlier contract are relevant but are not listed here. For the listing of those reports, refer to J.H. Williams, Jr., "Wave Propagation and Dynamics of Lattice Structures", AFOSR/WEA Final Report, October 1985.

2. The dynamic properties of two two-dimensional lattice structures have been investigated both analytically, using the NASTRAN finite element code and transfer matrices, and experimentally, using an HP Fourier analyzer. The natural frequencies obtained via the three approaches were compared and shown to agree within seven percent of each other. These results are reported in a document as follows:

- J.H. Williams, Jr. and R.J. Nagem, "Computation of Natural Frequencies of Planar Lattice Structures", AFOSR/WEA Technical Report, March 1987.

More recently, this work has been extended to consider the nondestructive detection of damage and is reported as follows:

- J.H. Williams, Jr. and R.J. Nagem "Natural Frequencies and Structural Integrity Assessment of Damaged Lattice Structure", AFOSR/WEA Technical Report, April 1987.

Further, in these efforts we have collaborated with colleagues at Stanford University and Virginia Polytechnic Institute and State University. In fact, both 5-bay and 22-bay lattice structures which we have fabricated and tested have been sent to colleagues at Stanford for testing.

3. In lattice structures where the signal propagation is dominated by longitudinal waves, we hope to develop general closed-form expressions for the input-output relations of arbitrary pairs of locations of the structure. This type of analysis requires the reckoning of each wave front which leaves joint i and arrives at joint j, having undergone a series of reflections and transmissions at each intervening joint encountered along the way. Such an approach may be called a "wave summation analysis". We have been able to duplicate these results

using wave-mode coordinates. Our efforts thus far on this topic have resulted in a report as follows:

- J.H. Williams, Jr., R.J. Nagem and H.K. Yeung, "Comparison of Wave-Mode Coordinate and Pulse Summation Methods", AFOSR/WEA Technical Report, December 1986.

4. The wave propagation characteristics of a 5-bay aluminum planar lattice were studied experimentally. Wave propagation speeds and frequency spectra were obtained, and wave propagation reciprocity was observed. Wave propagation attenuation was quantitatively measured and an attenuation parameter expressed on a per-bay basis was defined. Similar results for a 22-bay structure are reported as follows:

   - J.H. Williams, Jr. and J.J. Zhang, "Wave Propagation Measurements on 22-Bay Lattice", AFOSR/WEA Technical Report, June 1987.

5. One of the most distinctive uses of wave propagation versus modal analysis lies in the description of nonlinear behavior. Our work on dynamic failure and techniques for arresting such failure has provided a fascinating application of wave propagation analyses in LSS. This work is reported as follows:

   - J.H. Williams, Jr. and R.J. Nagem, "Dynamic Failure of a Periodic Lattice Structure", AFOSR/WEA Technical Report, October 1985.

   - J.H. Williams, Jr. and S.S. Lee, "Failure Propagation in Continuum Models of LSS, Part I", AFOSR/WEA Technical Report, November 1986.

   - J.H. Williams, Jr. and R.J. Nagem, "Dynamic Failure Arrest in Lattice Structures Via Wave Deflectors", AFOSR/WEA Technical Report, December 1985.

   - J.H. Williams, Jr. and S.S. Lee, "Failure Propagation in Continuum

Models of LSS, Part II", AFOSR/WEA Technical Report, February 1986.

- J.H. Williams, Jr. and R.J. Nagem, "Dynamic Failure Arrest in LSS Via Active Control", AFOSR/WEA Technical Report, July 1986.

6. When the wavelength is long compared with the length of lattice elements, continuum models may be used to provide computationally efficient analyses. Wave propagation in a tetrahedral lattice, which was modeled as a transversely isotropic continuum, was conducted to provide some insight into the nonintuitive behavior of long wavelength dynamics of LSS. This work is reported as follows:

   - J.H. Williams, Jr., R.J. Nagem and K.G. Salamé, "Wave Propagation in Transversely Isotropic Continuum Models of LSS", AFOSR/WEA Technical Report, January 1987.

SUMMARY

While there continue to be misconceptions and misrepresentations of the wave propagation perspective of dynamics of LSS, the value of wave propagation analyses of dynamic phenomena in LSS is no longer an anomalous curiosity. In an attempt to assist in the enlightenment of the technical community regarding wave propagation in LSS, an overview entitled "Wave Propagation in Large Space Structures" was presented at the Fifth AFOSR Forum on Space Structures in Monterey in August 1987.

MED

8