THE POTENTIAL OF NONPERIODIC TRUSS STRUCTURES FOR SPACE APPLICATIONS

K. C. Park, Staff Scientist
Applied Mechanics Laboratory
Lockheed Palo Alto Research Laboratory
3251 Hanover Street
Palo Alto, California 94304

and

J. M. Winget, Graduate Student
Division of Engineering
California Institute of Technology
Pasadena, California 91125

Large Space Systems Technology - 1981
Third Annual Technical Review
November 16-19, 1981

DYNAMIC CONSIDERATIONS FOR SPACE STRUCTURES

The design and analysis of large space structures for dynamic loads require the considerations of: wave propagation, transient response and steady-state vibration problems. The desirable intrinsic structural characteristics to these problems are good dispersive properties, rapid decay of the transients and an optimum distribution of frequency spectrum, respectively. The truss lattices proposed so far for constructing large space platforms are based on either tetrahedrons or octetruss elements. Although they are easy to construct and their equivalent continuum models can be developed as periodic structures, the space platforms made of such periodic lattices can have two major drawbacks of the three dynamics considerations. First, periodic structures can be considered to be well tuned. Therefore, they do not possess good wave dispersion characteristics. Second, if the dimensions of the platform are fixed then the frequency spectrum of the structure is also fixed, thus leaving no room for frequency modifications other than through redesign and/or effective vibration control devices.

OBJECTIVE OF PRESENT STUDY

- TAILOR LATTICE-TRUSS STRUCTURES TO IMPROVE CONTROLLABILITY OF DYNAMIC RESPONSES
- INVESTIGATE WHAT CAN BE DONE TO IMPROVE DYNAMIC PERFORMANCE OF STRUCTURES

DYNAMIC CONSIDERATIONS FOR SPACE STRUCTURES

- GOOD WAVE DISPERSION
- RAPID DECAY OF THE TRANSIENTS
- DESIRED FREQUENCY SPECTRUM & MODE SHAPES
- ADAPTABILITY TO PASSIVE & ACTIVE CONTROL

PERIODIC LATTICE-TRUSS STUCTURES

• ADVANTAGE	• DISADVANTAGE
• EASY TO CONTRUCT & ASSEMBLE	• TUNED STRUCTURE: POOR WAVE DISPERSION
• EQUIVALENT CONTINUUM MODEL	• FIXED FREQUENCY SPECTRUM WITHOUT RE-DESIGN

NONPERIODIC LATTICES FOR IMPROVED DYNAMIC PERFORMANCE

The observations from the preceding section motivate us to seek means for improving wave dispersion properties and for introducing detuning provisions within the structures. This calls for the adoption of nonperiodic lattice structures. In addition, one would like to have room for rearrangements of internal lattice members so that the desired frequency spectrum can be realized to a maximum extent. This paper explores an alternative approach for the construction of large space platforms by adopting nonperiodic lattice configurations. This is in the hope of improving the two aforementioned dynamic characteristics, viz., wave dispersion and controllable frequency spectrum, by the internal rearrangements of the nonperiodic lattices without changes in material properties and dimensions of the lattice members.

TWO TECHNIQUES FOR ALTERING DYNAMIC CHARACTERISTICS OF A GIVEN STRUCTURE

- FIXED-MATERIAL/VARYING LATTICE ARRANGEMENTS (TECHNIQUE ADOPTED HERE)
- FIXED-LATTICE ARRANGEMENT/VARYING MEMBER PROPERTIES

WHY IRREGULAR LATTICE TRUSSES FOR SPACE STRUCTURES

- DETUNE THE STRUCTURES TO IMPROVE WAVE DISPERSIVE PROPERTIES
- TAILOR THE LATTICE GEOMETRY (OR MEMBER PROPERTIES) TO IMPROVE FREQUENCY SPECTRUM AND MODE SHAPES FOR EASIER VIBRATION CONTROL
- FROM CONTINUUM POINT OF VIEW, WE WISH TO EXPLOIT ANISOTROPY TO IMPROVE DYNAMIC PERFORMANCE OF LARGE SPACE STRUCTURES

It is noted that stable lattices consist basically of triangles and/or quadrangles. In the search of stable nonperiodic lattice truss platforms it is highly desirable to make the top and bottom surfaces of irregular tri- and/or quadrangular patterns while all the vertical connecting members are identical. The simplest possible nonperiodic lattice configurations that meet these requirements turn out to be the ones shown in Figures 1 and 2. In this paper they will be called dipenta-dodecahedron(or DPD-hedron) and pentatriangular-octahedron (or PTO-hedron), respectively. The DPD-hedron and PTO-hedron are the two building-block lattices used to form nonperiodic lattice truss platforms. Figure 3 shows five different internal arrangements of the DPD-hedron by utilizing four stabilizing members on the two pentagonal top and bottom surfaces. Similarly, three distinct internal arrangements are possible for the PTO-hedron. A platform segment made of the two lattices is shown in Figure 4. Note that in order to emphasize the freedom to arrange the stabilizing members as desired they have been omitted from Fig. 4. Incidently, the two lattices can, if properly reshaped, be used to construct spherical, cylindrical and parabolic surfaces.

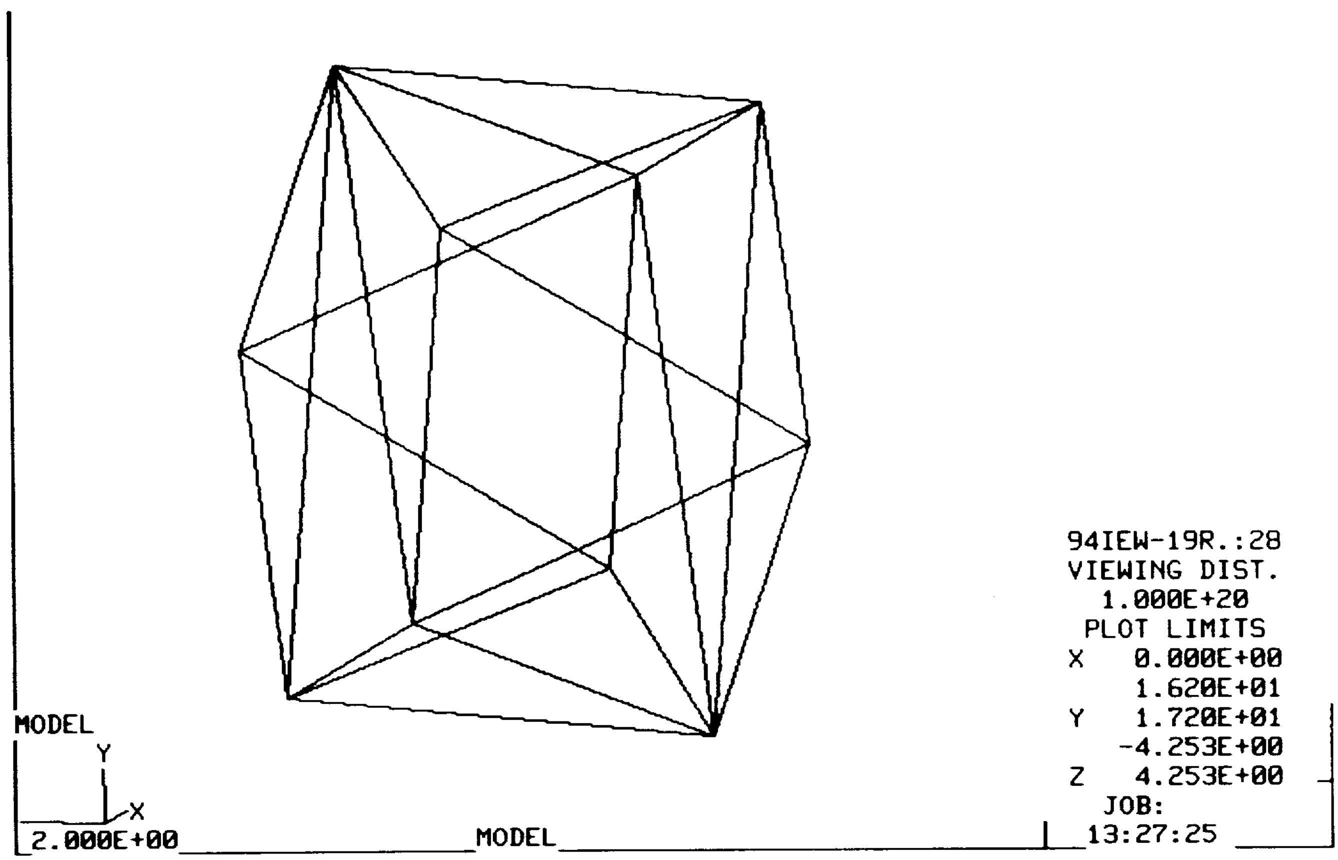

FIG. 1 DPD-HEDRON

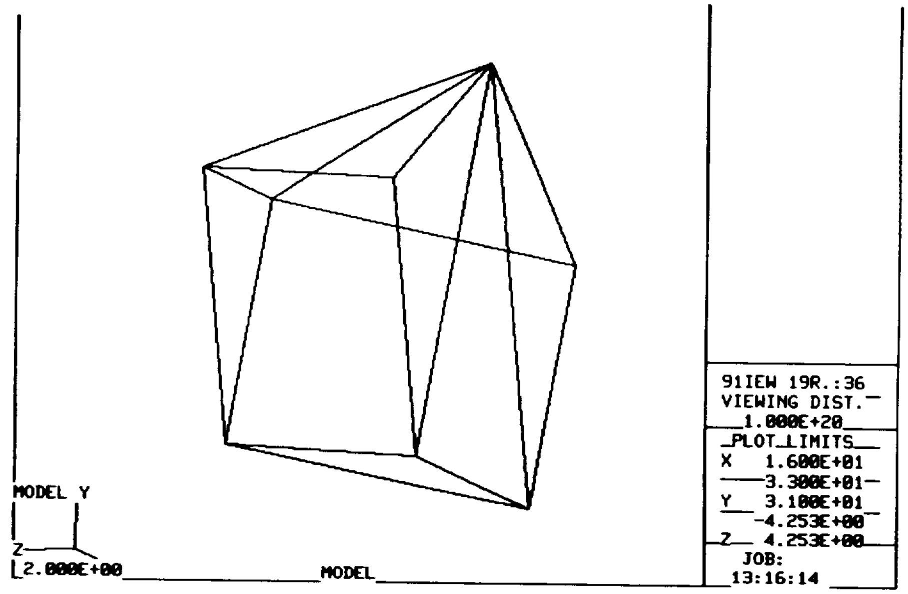

FIG. 2 PTO-HEDRON

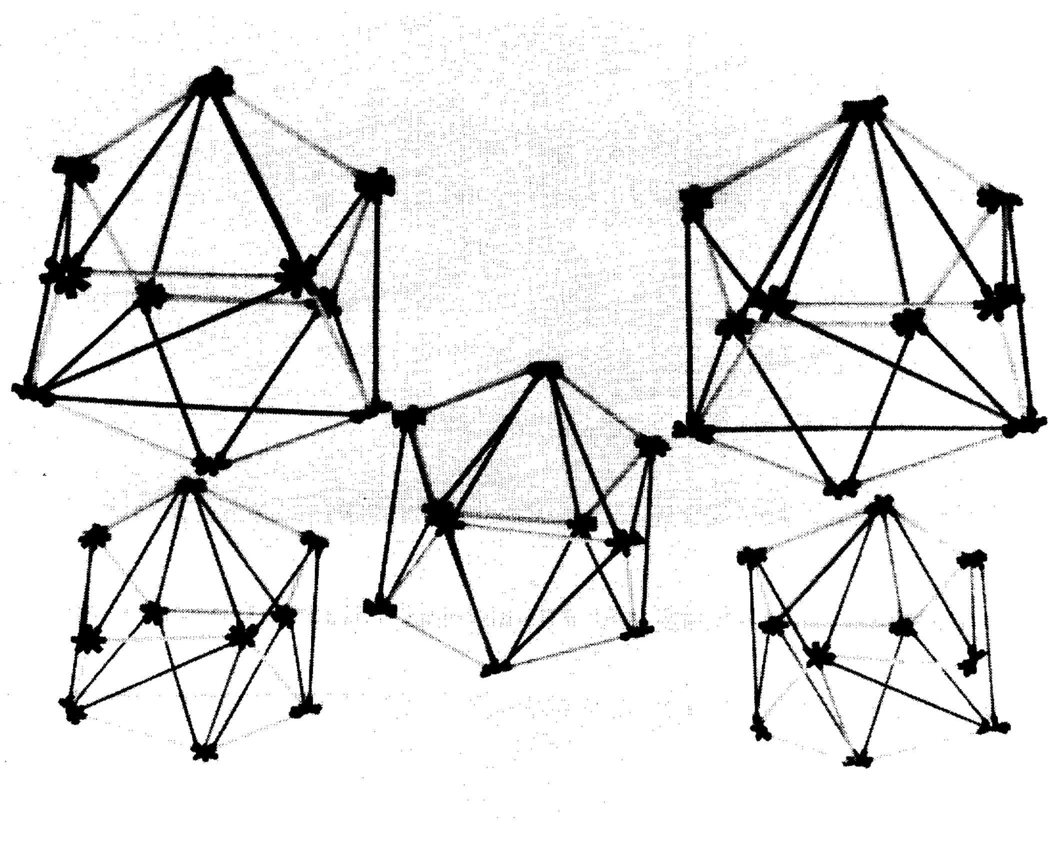

Fig. 3 Five different internal arrangements of DPD-hedron

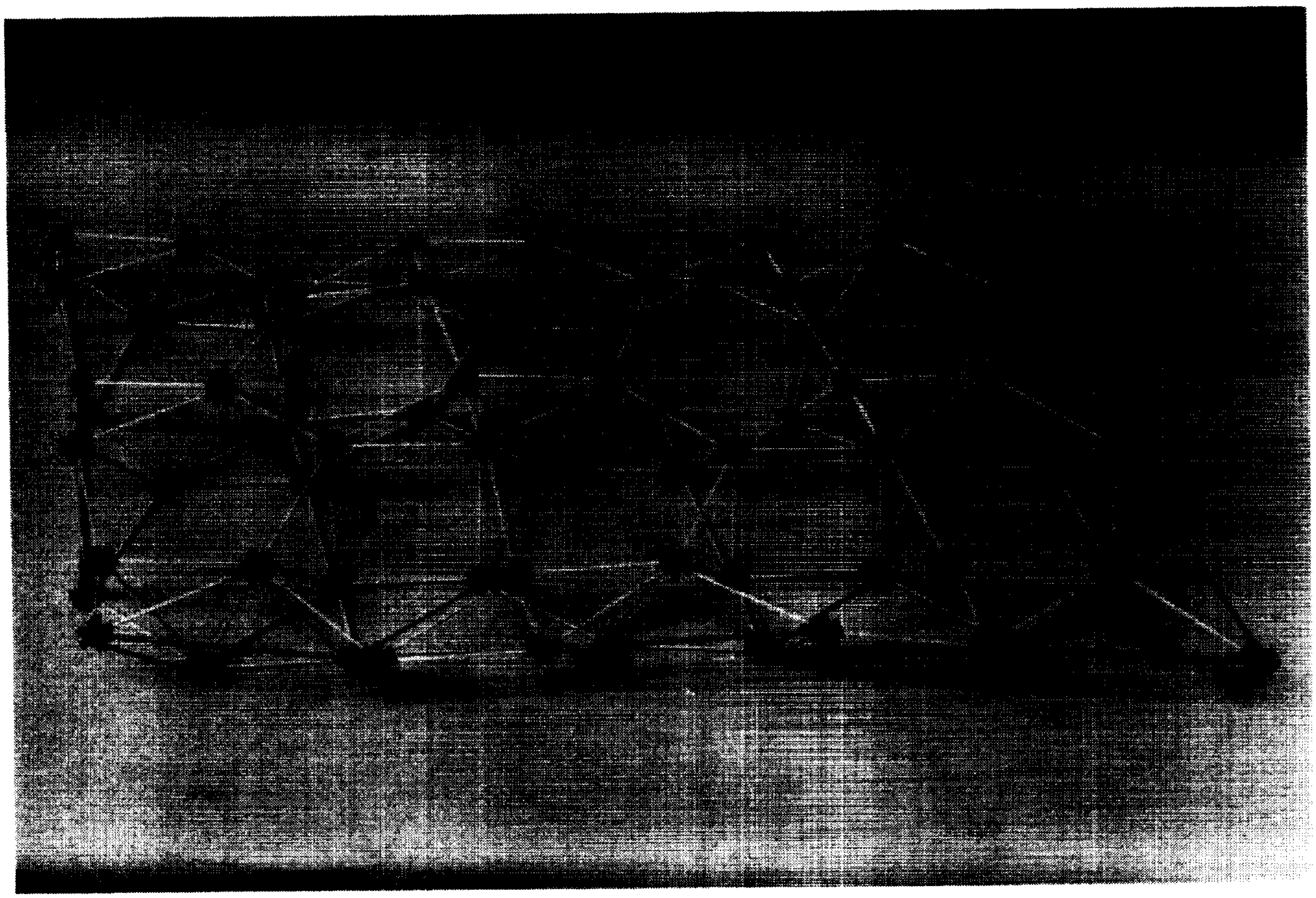

Fig. 4 Flat platform made of DPD and PTO-hedrons (diagonal members are absent)

DYNAMICS OF NONPERIODIC TRUSS BEAMS

In order to assess the dynamic characteristics of truss structures made of the nonperiodic lattices, a cantilever truss beam as shown in Figure 5 was analyzed for vibrations. In addition, three additional lattice configurations were also constructed along with two beams made of tetrahedrons (Fig. 6). Figure 7 shows the relative frequency variations of the six cantilever truss beams for their first mode. To make the comparison meaningful, the beam length, the number of lattice joints and the total weight were chosen to be identical within 2 percent differences. Note from Figure 7 that the frequencies of the four nonperiodic truss beams vary over 60 percent while those of the two beams of tetrahedron lattices vary only about 13 percent. Such wide frequency variations of the proposed nonperiodic truss beams indicate that the introduction of nonperiodic lattices could be effectively used to improve the controllability of steady-state vibration as well as improved wave dispersion characteristics.

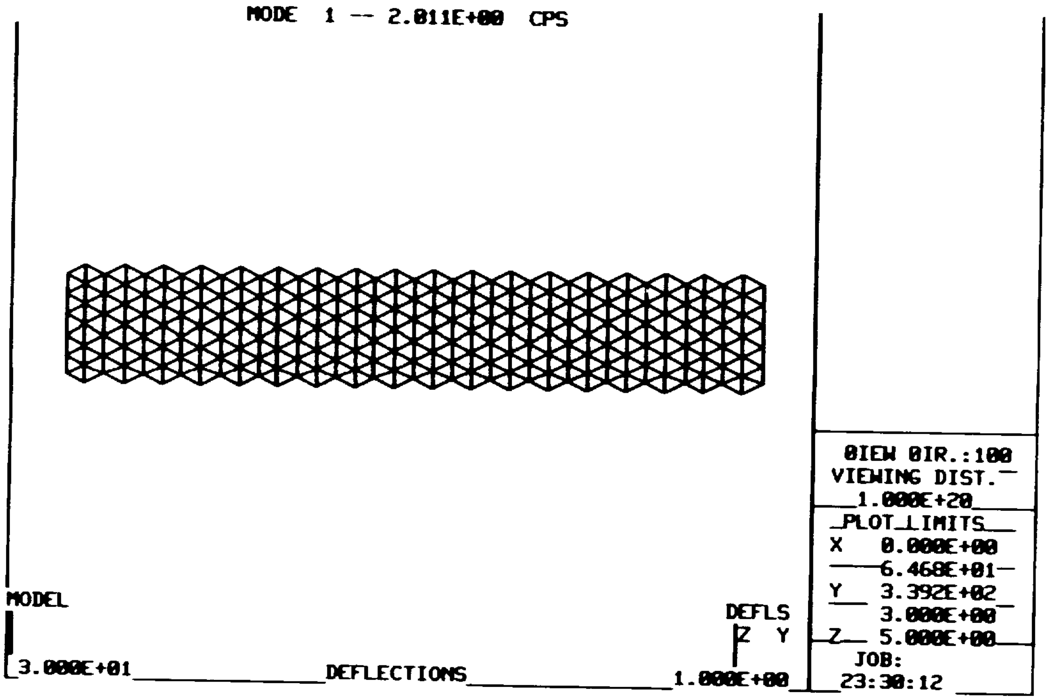

FIG. 5 TOP SURFACE OF VERTICALLY ARRANGED TETRAHEDRON TRUSS BEAM

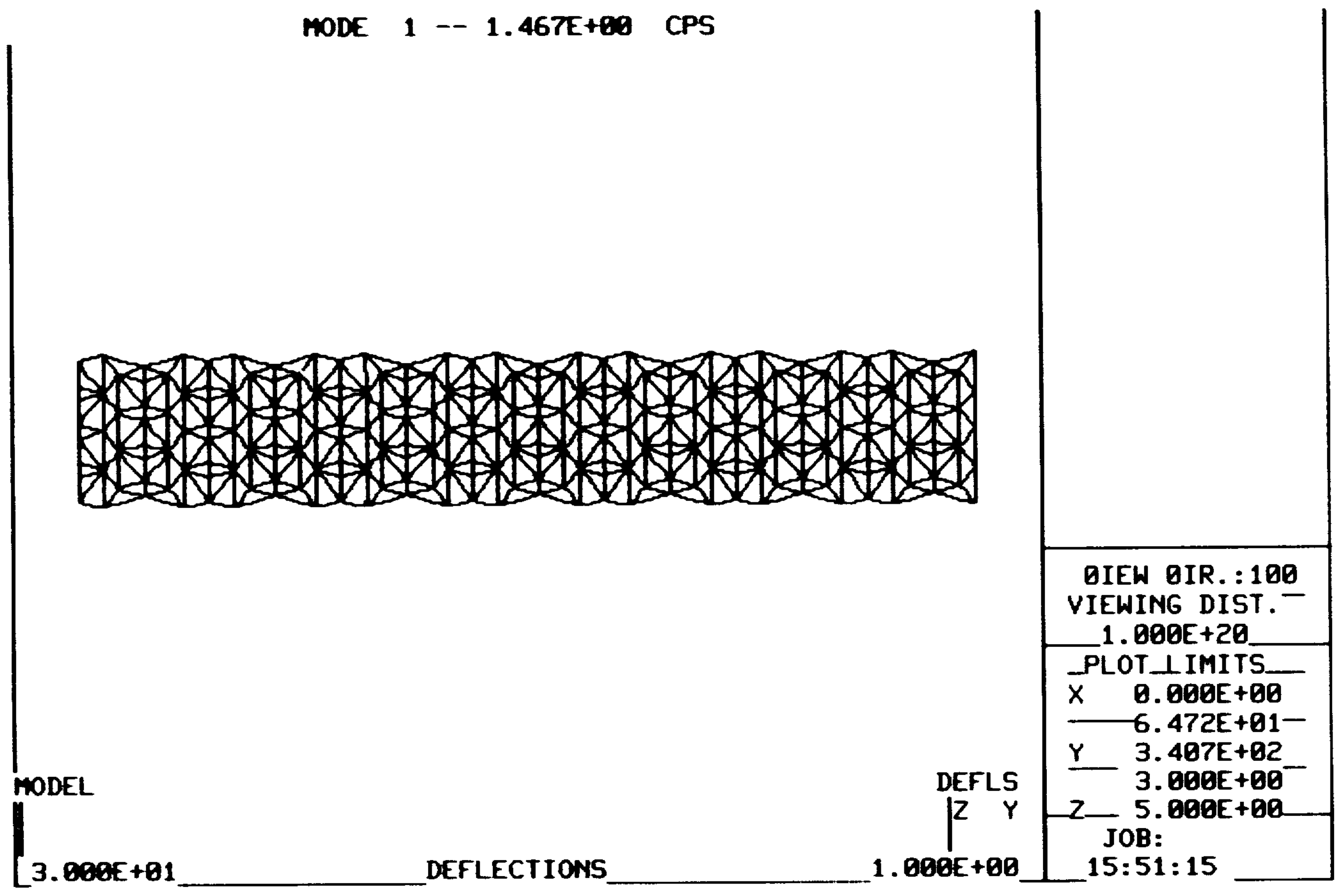

Fig. 6 Top surface of nonperiodic lattice; type 2 truss beams

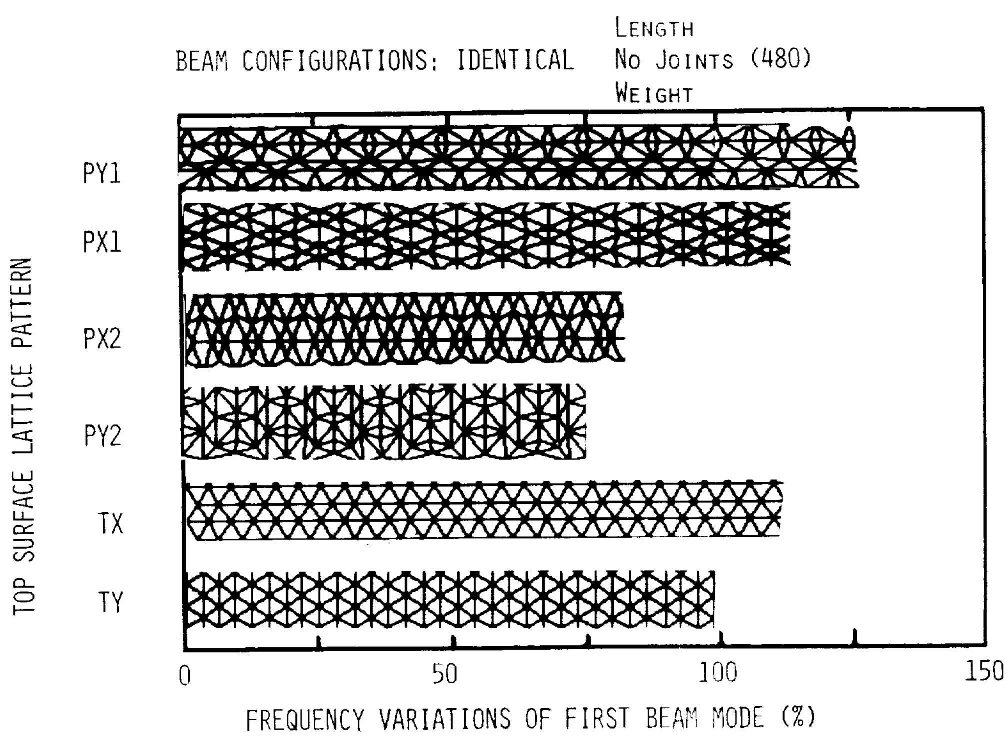

FIG. 7 RELATIVE FREQUENCY OF SIX LATTICE TRUSS BEAMS

VIBRATION OF FREE-FREE TRUSS PLATES

Free-free vibration analysis of an octetruss plate as shown in Fig. 8 was performed as a benchmark problem and the vibration nodal lines for the first five modes are determined as indicated in Fig. 8. In order to examine the effect of different lattice patterns, several arrangements were constructed. Two of the present lattice arrangements are shown in Figs. 9 and 10 along with their vibration nodal lines. Note the significant changes in the vibration nodal patterns. As for frequency magnitudes, the present lattice arrangements give about 15 ~ 25 % frequency variations.

FREE-FREE VIBRATION OF TRUSS PLATES

	TETRAHEDRON	PRESENT LATTICES
• ASPECT RATIO	1.0002	1.0723
• WEIGHT RATIO	1.000	1.03
• MEMBER LENGTH	1.078	1.000
• NO. OF JOINTS	628	631
• NO. OF ELEMENTS	2646	2463
• NO. OF EQUATIONS	3762	3780
• AREA RATIO	1.000	1.0106

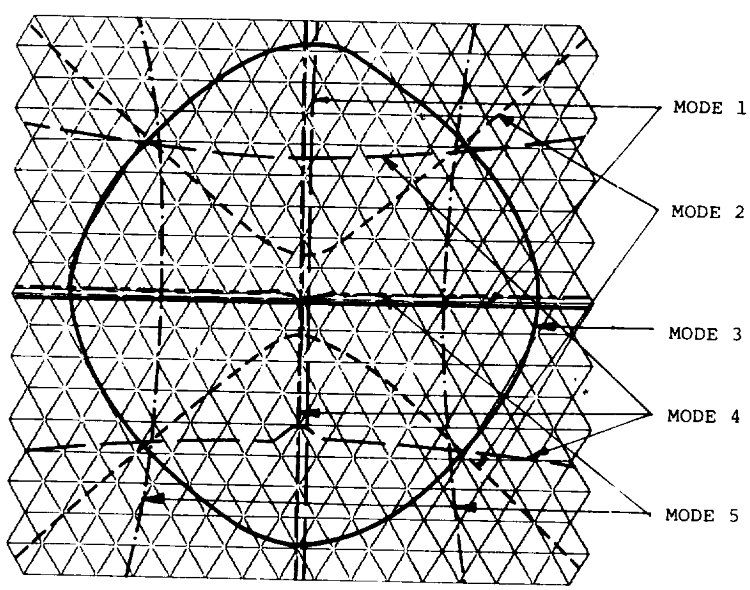

Fig. 8 Vibration Nodal Lines of Free-Free Octetruss Plate

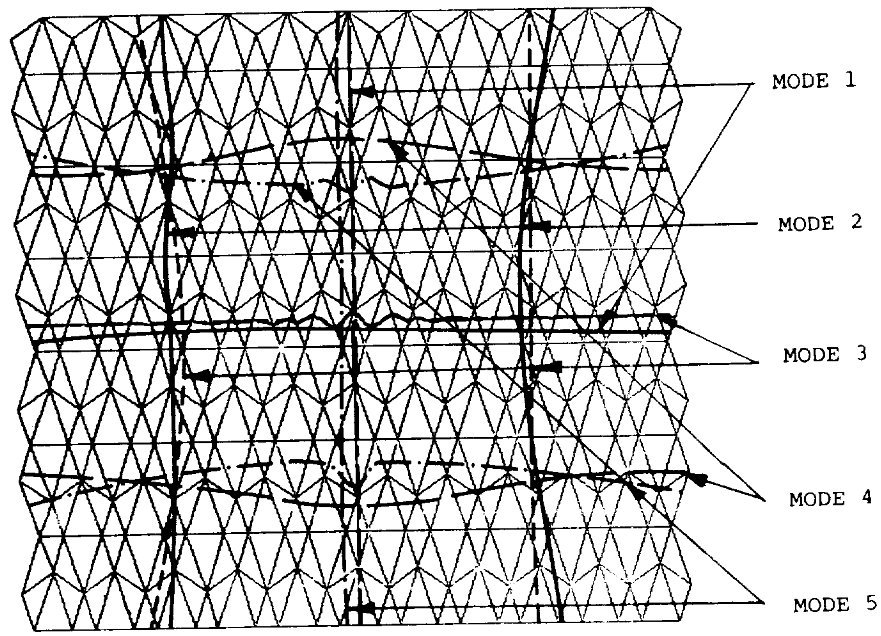

Fig. 9 Vibration Nodal Lines of Free-Free Irregular Truss Plate

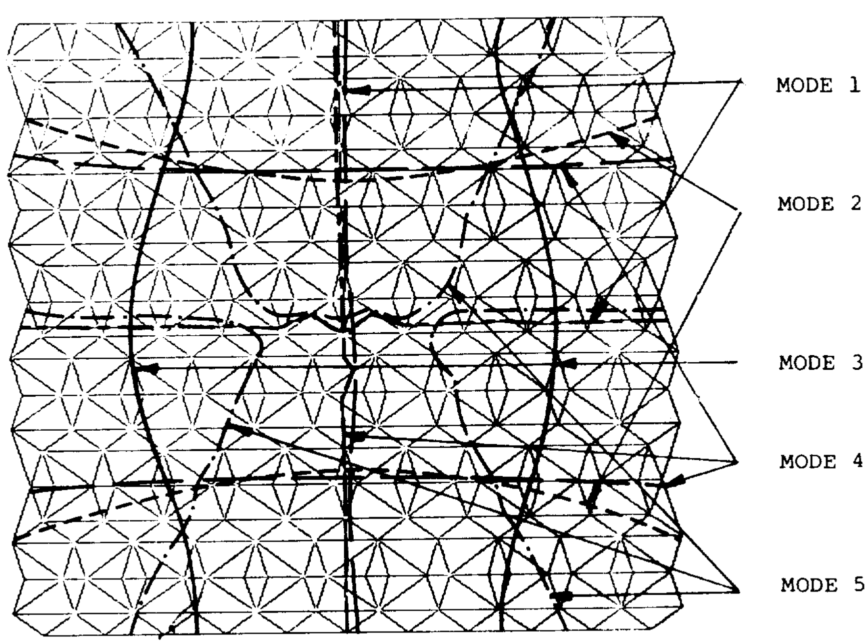

Fig. 10 Vibration Nodal Lines of Free-Free Irregular Truss Plate

SUMMARY

- NONPERIODIC (OR IRREGULAR) LATTICE-TRUSS STRUCTURES CAN IMPROVE WAVE DISPERSION PROPERTIES
- FOR BEAM BENDING, NONPERIODIC (PRESENT) LATTICES CAN VARY ABOUT 65% OF THE FUNDAMENTAL FREQUENCY
- FOR FREE-FREE PLATE, NONPERIODIC LATTICES CAN ALTER THE MODE SHAPES AS DESIRED. IN PARTICULAR MAY BE ABLE TO COME UP WITH AN OPTIMUM MODE SHAPES FOR PASSIVE AND ACTIVE CONTROL-POINT LOCATIONS
- FOR FREE-FREE PLATE, A SELECTED FREQUENCY RANGE CAN BE VARIED ABOUT 15 - 25%

FUTURE STUDY

- CONDUCT TRANSIENT ANALYSIS TO ASSESS THE EFFECTIVENESS OF INTRODUCING IRREGULAR (OR ANISOTROPIC) PATTERNS TO LARGE SPACE PLATFORMS
- DEVELOP DESIGN (PRELIMINARY) TECHNIQUES FOR ALTERING DYNAMIC CHARACTERISTICS FOR GIVEN DESIGN REQUIREMENTS
- INVESTIGATE THE FEASIBILITY OF INTRODUCING DEN-HARTOG TYPE VIBRATION CONTROLLER EITHER BY UTILIZING VERTICAL STIFFENERS OR PLACING ADDITIONAL UNLINKED STRUCTURAL MEMBERS