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Memorandum to: Donald W. Robertson
Patent Counsel to Geodesics, Inc.
and
Synergetics, Inc.

From: R. Buckminster Fuller

Subject: Octet Truss (Octahedron Plus Tetrahedron; Octetrus*)

"Truss" - "Tres" - "Threes"

Three Phase
Triangular

Dear Don:

Enclosed is a letter from one of my most able students, with a copy of a letter telling about him so that you can know of the circumstances of his statements regarding the Octet Truss.

My Octahedron-Tetrahedron Truss was quite widely published in March, April, May and June, 1953, as you know, when I used it in the Ford Motor Company's Dearborn, Michigan, Rotunda Geodesic Dome, - which I designed as part of the Ford Motor Company's Fiftieth Anniversary celebration. Its first general publication, however, as a coordinate system for engineering use goes back to a picture of myself with energetic and synergetic geometry and Geodesic structures in Fortune for March, 1946. In this picture there is visible a large "Octet" complex. At the same time Fortune used another view of the same picture in full-page Sunday advertisements in newspapers throughout the country, identifying Fortune with my "New Industry" and its new way of thinking of: "Houses by the Pound."

I began the search for what I called energetic geometry in 1917 and the Octet Truss, or vector equilibrium, was first assumed as probable and then glimpse-discovered as possible some time in the twenties and proven in the thirties. I demonstrated it to Life staff members in 1940. My Dymaxion World Map which was published in full color on fifteen pages of Life magazine in March 1943 was on the "Vector Equilibrium-Nucleus" of the Octet Truss Matrix, - 6 square faces of the 1/2 octa and 8 triangular faces of the 8 tetra of the vector-equilibrium-nucleus.

I first published the Octet Truss privately in the printed and illustrated disclosures of my Energetic and Synergetic Geometry, distributed to approximately two hundred scientists in Washington, D. C., and elsewhere in 1944, and copyrighted this document at the

* My invented name which you might be able to copyright or trademark.

Library of Congress. The Navy Department photographed and recirculated this publication. The November 1948 issue of Science Illustrated published my Octet Truss and Geodesic structures with excellent photographing of them. Many school publications and the Architectural Forum of August 1951, have published my Truss. The Museum of Modern Art, New York, included it in my exhibit there in August-September, 1952. Octahedron-Tetrahedron Truss is now, therefore, widely disseminated in the atmosphere of technology.

At every school I visit I find student models of the Truss. I see it employed by architect after architect in their public proposals for new structures. Some architects now disassociate it from my work by calling it a "Space Frame", and by orienting its square aspect into outward prominence. However, I am sure that, considered solely as geometry of structure, its final identification by the chemists and physicists as "Closest Packing", puts it into the universal domain of availability as pure principle.

My own discovery of the "Octet" Truss was syngergetic, intuitively avoiding special case tactics. "Synergy" is defined as follows: behavior of wholes unpredicted by behavior of parts. I was seeking in the whole of experience and knowledge for a comprehensive mathematical scheme of patterning. The "Octet Truss" was incidental to larger discovery.

Energetic and synergetic geometry prove Octet Truss to be a coordinate and comprehensive vectorial system rational to all chemical, biological and electro-physical behaviors of Nature. Ergo: Energetic and synergetic geometry's isotropic vector matrix is Nature's comprehensive coordinate system.

Any invention within this major coordination of principles must center on demonstration of unique means of gaining advantage through employment of this geometry. The behavior of wholes unpredicted by the behavior of parts is inherently surprising. Such surprise advantage can only accrue to some treatment of the following minimum and irreducible system aspects of Euler's topological formula which follows.

Faces Plus Vertexes Equal Edges Plus Two: F + V = E + 2

1. Vertexes
2. Edges
3. Faces
4. Some Combination of the Above (Two-Ness)

My Ford Dome solution was through emphasis of edges, and economical employment of surprise advantages to be derived by use of low-cost aluminum roll sheet and high-speed stampings of same, and surprise (approximately double) strength accruing to micro tolerance of end fixity riveting specifications, practically obtained by pre-punching

of rivet holes, through machine guidance, at tolerances of hole diameters and relative positioning, infra-visible and ergo impossible to previous on-the-job, craftsman layout techniques.

I have a large portfolio of photographs of true models demonstrating surprise techniques in joint, edge and face solutions, and combinations thereof, developed throughout recent years. All of these were inventions in that I then knew, and still know of no precedent for them. Most of these solutions I reduced to practice in full-scale components employable in man-usable structures.

As the technical world now accelerates to awareness of important new degrees of structural advantages accruing to the Octet Truss, I see published or emerging in the school shops replicas or re-outcroppings of those technical inventions of component morphation which I had developed at an earlier date. The successive inventions' original disclosures tend inherently to excite a whole new synergetic wave of evolutionary inventions. Some individuals become so stimulated and engrossed by it as to become convinced that it was always obvious in their own a priori environment and that they are now inventing its existence stimulating evolution rather than running along its already technically blazed trails.

I had the envelope of photographs of these earlier inventions with me when last I called on you, but our time was so filled that I was never able to open it. I will bring it to our January meeting.

Most important general information concerning Octahedron-Tetrahedron Truss is that despite the $3,000 I put into testing the Truss in the University of Michigan Aeronautical Engineering Department, no engineers, as yet, know how and why the Truss provides greater strength than conventional engineering analysis is able to ascribe to it.

This is because conventional engineering analysis long ago discovered that a two-way vertically sectioned beam-crossing, at ninety degrees supported from four walls, provided no more strength at the mid-crossing point than could be found in the stronger of the two beams, for they were redundantly acting as hinges, and only one axis of hinging could be articulated at one time.

When a Yale professor of architecture, employed my Octet Truss in a design for the floor structuring throughout the new Fine Arts Building at Yale University, - recently opened, - that Truss, in economic compliance with the building code, had to be fabricated in reinforced concrete. But the Yale Engineering Department and its consulting engineers refused to credit my three-way beam for the task on the grounds of the invalidity of two crisscross beams, "because", they said, "three were even more redundant." Yale, therefore, built the floors on the basis that only one axis of the Truss could carry the load. They called it

a slanting beam construction. Result: the Octet Truss was reduced to a role of aesthetic nonsense - a fantastically expensive set of lampshades.

Fallacy here was that the architect should have employed a system which he could not defend structurally before the ignorance of the engineers. Result: relegation of an important new development to submergence in ignorance.

As a synergist, my explanation of the Octet Truss must start with the Universe. My definition of "Universe" follows:

> Universe is the sum total of all men's sensed and teleologically translated experience. Whole Universe may not be simultaneously tuned into treatable thought pattern.

My definition of "System" follows:

> A System is a primary definable thought tune-inable subdivision of Universe. As such a definable set it separates and dismisses inwardly and outwardly of its tuned finite pattern all that is microcosmically and macrocosmically irrelevant. Systems have, therefore, inwardness and outwardness limits and electable view induced polarities, thus always specifically identifying the two-ness of Euler's formula.

First division of Universe into omni-directional radially defined zone between maxima and minima withinness and withoutness sense and experience tunability, affects not only the local tuned-in system, but the balance of Universe within and without, even as does the little and big spherical triangle subdivide the system zoneness circumferentially, so also do the basic maxima and minima radial and circumferential dichotomies, which are the basically differentiated 90° acceleration functions and inherent reciprocal self precessors.

Essence of my own explanation of the effectiveness of the three-way beam follows:

> Each vertical sectioned beam has a two-way tendency to rock or torque or hinge over from its most favorable aspect of maximum dimension in opposition to gravity into its least favorable aspect, - that of least dimension in opposition to gravity. As each beam could hinge from vertical in two ways, each may be split theoretically in two vertical parts and thus hinge both ways, and is countered by the simultaneous and symmetrical both-ways split rocking of all three vertical split beam hinges, - as three sets of parallel planes until their edges meet in ridge poles to provide a matrix of tetrahedra, with common lean-to stability, and

with maximum energy repose economy. Synergetically between a fourth,-or horizontal set of planes.

While the three Beams' sets of uniquely split plus and minus vertical planes rotated into three positive and negative parallel sets of planes at 35° 16' off vertical, each of the tilted beam's tops and bottoms were in two parallel and horizontal planes respectively, making a total of four unique and symmetrically oriented planes within the system. Where the four unique sets of planes intercept each other there are established a system of interconnected lines, which lines may then be substituted for by struts which contain all the stress patternings and the planar webs may then be eliminated. When struts alone are used for horizontal decking they are designed to receive loads at their vertexial ends and to send their loads through their neutral axis whereas beams inefficiently take loads anywhere at 90° to their neutral axii.

Best picture of what happens locally is the following: The three sides of a tepee-tripod, composed first of three vertical triangles rising from a fourth ground triangle and subsequently rocking toward one another until their respective apexes and edges are congruent and the three triangles plus the one on the ground together constitute a minimum system, for it has minimum "withinness." Any one edge of our tepee, acting along, as a pole with an universal joint base, would fall over into horizontal position, two edges of the tepee acting alone form a triangle with the ground and act as a hinge with no way to oppose rotation toward horizontal position, except when prevented from falling by interference with a third edge pole, falling toward and into congruence with the two other poles' common vertex.

In the Octahedron-Tetrahedron Truss, three planes of beams and their triangularly binding edge patterns rotate tepee-wise positively and negatively to non-redundant ridge-pole fixity, and with such symmetry as to result in radial distribution of all loads from any one loaded vertex through the neutral axii of all the edges of the system precessionally differentiated as either pure compression or pure tension stresses, metered at even rates, because edge vectors are identical in length, precessing further into positive and negative radial and circumferential waves, excentric to the loaded vertex and the stress distributed positively and negatively throughout those adjacent vertexes surrounding any one loading center, and which wave distribution in all directions precesses into tensile action the concentric series of rings around the originally loaded vertex. The increasing succession of concentric rings which continually redistribute the received loads

act in themselves as unitary systems with an increasing number of excentrically distributive vectors, after full dispersion loads come to symmetric reconcentration at supporting area in direct pattern reversal.

The Octet Truss is synergetic because the four planes comprise a system and what were previously individual beams, and therefore free systems in themselves, are now fixed components of a larger tetrahedronal system which latter is inherently nonredundant because it is the minimum fixed system. Ergo, all of those previous individual free system beams are now converted into one nonredundant complex of basic systems and all the previous beams' component biological and sub-chemical structures are systematically refocused in such a manner that all subcomponents are nonredundantly interactive in the second power rates of effectiveness accruing to systems circumferential finiteness in respect to their radial modulii.

This unitary systematic nonredundant complex provides a total floor system with higher structure performance abilities than engineers could possibly ascribe to it through any conventional structural analysis means when predicated only upon the behavior of its several parts, in which it is axiomatic to conventional engineering, that if "horizontal" those parts are beams, - for the total floorability by such conventional engineering could be no stronger than the single strongest beam in the plural group and their prediction falls short of the true behavior of the octetruss by many magnitudes, for in true mathematical fact no "beams" are left in the complex; that is, there are in it no members loaded at other than polar terminals, - down to the minutest atomic components, and the octetruss is therefore proved to be synergetic and its discovery as structure, - in contra-distinction to its aesthetic or superficial-appearance-discovery, - being synergetic in ability, - that is, it has behavior as a whole unpredicted by its parts, - makes its discovery as structure a true surprise and therefore a true invention. What is the surprise? It is because we had used three planes of the beams oriented to most favorable ability aspect in respect to gravity, and inadvertently gained a fourth interacting favorable aspect plane of symmetry not consciously introduced as a previously acquired component of the whole, and thereby made the beams "vanish" into abstract limbo. The fourth plane is strictly the fourth plane of the tetra-hedron inadvertently accruing, as does hinging on of one equilateral triangle to two previously hinged equilateral triangles provide inadvertently a fourth triangle -- 1 + 2 = 4.

Second derivative surprise is that the nonredundance of the larger associated complex of tetrahedra is occasioned by its precessionally induced self differentiation of functions, when loaded at any one vertex, in such a manner that every member acts in axially focused pure tension or pure compression, and with the subsequent loading of any next adjacent vertex inherently induces comprehensive reversal of all the system's pure tension into pure compression functions and vice versa, - that is to say, it is dynamically nonredundant.

Only in this way could one understand the behavior of one of my Ford Dome Octet Truss units which had a five frequency 32-inch favorably surprising modular edge unit, whose 13-foot over-all edged triangular assemblies were 30 inches deep between top and bottom planes, and whose individually stamped aluminum sheet member strut angles were approximately 33 inches each, in over-all length, and weighed only one-third of a pound each. Approximately one hundred seventy of these struts made up the whole truss with an over-all weight of only sixty-five pounds when riveted and gusseted together. Despite its delicate components and over-all weight of only sixty-five pounds, it could, when supported at its three corners, in turn support upon one central vertex of its top surface a 12,000-pound load. That is, it could carry a six ton net weight truck or a small army tank. This strength weight ratio was entirely unpredicted by conventional engineering and is, therefore, synergetically surprising.

As I have already reported, the Octet Truss was well documented as uncomprehended in fundamental working significance as late as 1952 by the Yale Engineering Department. Its successful empirical employment, such as by the Italian Firm of Gino Valle in covering an open court in Venice, Italy, in 1954, is only a practical application for its aesthetic effect as permitted by its inherent and essentially unchallenged and unknown strength rather than by their organized calculations of its ability, as is documented in Taylor's letters.

This has made me feel right along that despite the Octet Truss' metaphysical and unscientific identification, - as conformingly coincident only with generalized principles as earlier mentioned, my comprehension of its intimate, logical working principles, understood by its occurrence within the total complementarity of energetic and synergetic geometry's permitted displacement accommodation of all transformative aspect phenomena, and my reduction of it to first practice, and my underwriting of its expensive development and testing (E.G., $3,000 at University of Michigan, and now $10,000 at Geodesics, Inc., Raleigh, North Carolina, an expense not yet assumed by the Navy), puts me in a position of inventor and prime contractor because I can predict my results and have shown surprise economy in the unique employment of component assembly techniques.

The tests may eventually disclose in full workable formula the rates of distributive changes in integrating variables, and quantitate the synergetically induced wave behavior, and thus bring the new advantage into broad economic usefulness. Wherefore, whatever I have been able to discover and invent as a unique means of the employment of the principle should be doubly fortified by responsibility and risk in the eyes of jurisprudence in regard to my present attempt to obtain original patents covering the techniques and to defend the same in subsequent court actions.

I am sorry that my whole family of inventions tends, by rational acceleration, to sneak up on you and press you for attention. But isn't this the nature of invention and surprise, with which you deal so expertly?

Faithfully yours,

R. Buckminster Fuller